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Short Papers, Symposia, and Selected Abstracts

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VOLUME 2 - SHORT PAPERS, SYMPOSIA, AND SELECTED ABSTRACTS

9TH INTERNATIONAL CONFERENCE OF THE LEARNING SCIENCES

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Kimberly Gomez, Leilah Lyons, and Joshua Radinsky

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KEYNOTES

Keynote 1: The Learning Sciences and learning in the sciences - The perspective from post-secondary science education

Carl Wieman
University of Colorado and University of British Columbia

Chair: James Pellegrino, University of Illinois at Chicago
Reactor: Richard Duschl, Pennsylvania State University

Sponsored by the Spencer Foundation

Abstract: As a physicist who has been working closely with university science departments in many disciplines to improve learning in all of their undergraduate courses, often by implementing the insights from the Learning Sciences, I confront the four guiding questions of this conference on a daily basis. The disciplinary practices and understandings can inform research in the Learning Sciences, both in guidance as to important learning questions and in producing results that will be relevant and effective for improving educational practices. The broad characteristics of expertise, or expert-like thinking, in the science disciplines are a useful framework for studying science learning. There are general knowledge structures, representations, modeling, and problem solving methods that have a large amount of overlap across different science disciplines, although the details can vary between disciplines in significant way. The learning processes across the science disciplines reflect these large similarities and small differences.

However, it is important to recognize that while the general nature of the science disciplines and learning within them have a high degree of overlap, science faculty typically see learning in their own discipline as unique. There are many opportunities for collaborative research and perspectives between the Learning Sciences and the science disciplines. Such collaborations are essential both for obtaining a deeper understanding of learning in the disciplines, and for framing Learning Science results in such a way that they can be effective at guiding educational practice. However, I see curious idiosyncratic belief systems (a diplomatic way of saying "pervasive superstitions") about learning, education, and learning research that have grown up in each of the science (and math) disciplines. Recognizing and dealing with these belief systems is important for developing effective collaboration between the sciences and the Learning Sciences, and for allowing the work of the Learning Sciences to be widely understood and appreciated by post-secondary science educators.

Keynote 2: Instructional design, theory and practice in mathematics education

Koeno Gravemeijer
Eindhoven University of Technology

Chair: Alison Castro-Superfine, University of Illinois at Chicago
Reactor: Danny B. Martin, University of Illinois Chicago

Sponsored by the Spencer Foundation

Abstract: Since the 1960's and 70's we have seen a shift in the relation between educational research and instructional design. While the so-called first-generation instructional design theories aimed at founding design decisions on empirically-grounded theories, design research is nowadays seen as a method for developing empirically-grounded theories. In mathematics education, this shift in perspective cohered with changes in ways of thinking about learning and learning goals. First-generation instructional design theories were tailored to situations where the learning goals are clear and much scientific knowledge is available about how to shape instruction. Design research, in contrast, is tailored to more innovative instructional design, where little scientific knowledge is available. Another difference concerns the specificity of the theories involved; the theories of the 1960's and 70's were meant as general theories, while design research primarily aims for domain-, or topic-specific theories. The acceptance of design research as a legitimate research method did not go without struggle. The design part, however, got less attention. In this presentation I want to react to this imbalance by elaborating on practices, theories and heuristics in instructional design, while focussing on mathematics education. In doing so, I will not limit myself to design research, but also include professional instructional design as an informed practice. A central point of reference will be the so-called domain-specific instruction theory for realistic mathematics education, RME, which may be characterized by its compatibility with socio-constructivism, and can be seen as fitting under the broader heading of 'reform mathematics'. In addition, I want to dwell on the need to reconsider the goals of mathematics education in light of emerging demands of the information society.

Keynote 3: Learning to Ponder – The Puzzle and Pleasure of Literary Text

Pamela Grossman
Stanford University

Chair: Susan Goldman, University of Illinois at Chicago
Reactor: Carol D. Lee, Northwestern University

Sponsored by the Spencer Foundation

Abstract: If endangered status could be granted to curricular topics as well as to spotted owls, poetry might well make the short list. Regarded by students and teachers alike as esoteric, if not downright impenetrable, poetry faces an uncertain future in schools. Yet learning to read poetry represents the kind of generative activity that is central to disciplinary learning in English. Reading poetry demands that we engage with demanding text, that we unpack highly compressed language by filling in the gaps of what is not said. Learning to read poetry requires that we move beyond the literal world into a symbolic one, and that we respond both analytically and aesthetically to the meaning and music of language. Yet students resist poetry. From the early work of I.A. Richards (1929/1954) on, studies show that students prefer poetic texts that are easily understood, that say plainly what they mean. Perhaps students' preference for poetry "that says what it means" is not surprising. We all like what we understand, from literature to modern art. One of the goals of teaching literature, however, is to help students respect complexity and engage with texts that on first blush seem to resist understanding. Much work in both literary theory and English education has depicted the end point of literary studies--the transactions with texts that demonstrate expertise in literary understanding (Iser, 1978; Scholes, 1985; 1989; Wolf, 1988). In order to build a curriculum that helps high school students acquire more sophisticated ways of reading and responding to literature, we must first explore what makes such texts difficult. In this talk, I will unpack some of the challenges of puzzling through highly compressed literary forms and explore what students might be learning as they engage in literature. I will also explore how student readers may resist literary texts, leading to affective, as well as cognitive, challenges. Through explorations of student readings, we will ponder together what makes such disciplinary readings difficult, as well as pleasurable.

INVITED SESSIONS

Invited Session 1:
ISLS Advances and Future Opportunities

Chair: Marcia Linn, University of California Berkeley
Respondents: Iris Tabak, Ben Gurion University of the Negev
Paul Kirschner, Open University of the Netherlands
An Emerging Society - Christopher Hoadley
Internationalization of Research - Pierre Dillenbourg
Leveraging New Technologies - Roy Pea
International Challenges - Claire O'Malley
Highlighting Junior Researchers - Yasmin Kafai
Collaborative Challenges - Naomi Miyake
Capitalizing on Social Networking - Marcia Linn

Abstract: Current and past ISLS presidents reflect on where the Society has been and where it is poised to go. Past presidents participating in the panel are Chris Hoadley (2002), Pierre Dillenbourg (2003), Roy Pea (2004), Claire O'Malley (2005), Yasmin Kafai (2006), and Naomi Miyake (2007). Iris Tabak (2009) and Paul Kirschner (2010) will respond to the panelists and suggest directions for the future.

Invited Session 2: Challenges in Professional Disciplinary Preparation

Barbara Olds, Colorado School of Mines
Sherri Sheppard, Stanford University
Donald Wink, University of Illinois Chicago
Louis Gomez, University of Pittsburgh
Discussant: James Pellegrino, University of Illinois Chicago

Abstract: How do we prepare practitioners in the disciplines? How do we apprentice new members to our respective disciplinary communities professional vision (Goodwin, 1994)? How can we establish productive dialog about professional preparation that can be informative across disciplines? What constructs are most useful for developing this dialog? In this session we ask members of three disciplinary communities to reflect on the problems and practices of professional preparation in each community. We have identified presenters representing the following areas: Learning Sciences (Louis Gomez), Chemistry (Don Wink), and Engineering (Barbara Olds & Sheri Sheppard).

Invited Session 3: Representational Practices and Modeling in the Disciplines

Jay Lemke, University of Michigan
Rogers Hall, Vanderbilt University
Mary Nakleh, Purdue University
Discussant: Andrea DiSessa, University of California Berkeley

Abstract: Increasingly learning sciences research has explored ways knowledge, learning, and practice are distributed across people and artifacts, including material and cultural tools? Practices by which disciplinary communities differently represent, re-represent, model, or otherwise symbolize the world can provide a valuable lens for understanding learning in the disciplines? In this session representational practices are examined across multiple modalities of meaning-making, including visual/graphic inscriptions, gestural and linguistic semiotics, and embodied and spatial ways of representing and seeing the world.

Invited Session 4:
Identity as a Lens on Learning in the Disciplines

Chair: Josh Radinsky, University of Illinois Chicago
Na'ilah Suad Nasir, University of California Berkeley
Reed Stevens, Northwestern University
Avi Kaplan, Temple University
Discussant: Stanton Wortham, University of Pennsylvania

Abstract: Learning Sciences research has increasingly explored the construct of identity as central to the study of learning. This has included examining the relationships among culture, identity, and instructional design; conceiving of learning as the development of identities of mastery in communities of practice; attending to race, gender, language, class, or other identity categories as contexts of disciplinary learning; and focusing on the ways individuals negotiate their own role and identity development among multiple and often conflicting lifeworlds and affiliations. Beyond traditional constructs of conceptual, strategic, or dispositional learning, conceptions of disciplinary identity have emerged as valuable constructs for understanding how learners become central participants in disciplinary communities. In this session speakers provide perspectives on how a focus on identity can inform the study of learning in the disciplines.

Invited Session 5: Geography Education Reform: A Cinderella Story in the Making?

Chair: Daniel Edelson, National Geographic Society
David Uttal, Northwestern University
Josh Radinsky, University of Illinois Chicago
David Rutherford, University of Mississippi
Discussant: Clare Brooks, University of London

Abstract: The history of geographic education in the U.S. can be read as a cautionary tale for educators in other disciplines and other countries. For a variety of reasons, it fell from a place of prominence and priority in the curriculum prior to World War II, to a place of neglect in the three decades following the war. Since the mid 1980's a community of committed geographers and educators have made the most of very limited resources in an effort to both restore geography to a place in the curriculum that reflects its importance to society and to improve the quality of geography teaching. This uphill battle has been complicated by the fact that the American public and its leaders have a poor understanding of what geography is and that it cuts across the rigid boundaries in our educational system between social studies and science. In this session, we will present these educational reform efforts as a Cinderella story in the making, in which the overlooked discipline achieves its deserved standing through the intervention of an enlightened intermediary. In this story, the part of the fairy godmother could be played by learning scientists. Presentations will cover current efforts to define geographic literacy (Edelson), the history of geography education reform efforts since 1986 (Rutherford), the role of spatial thinking in geographic literacy (Uttal), and research on geospatial technologies (Radinsky). These will be followed by a reflection from a non-U.S. perspective (Brooks).

Invited Session 6: Disciplinary Foundations of the Computational Sciences

Chair: Tom Moher, University of Illinois Chicago
Mark Guzdial, Georgia Insitute of Technology
Ulrich Hoppe, University of Duisburg-Essen
Yasmin Kafai, University of Pennsylvania
Discussant: Sally Fincher, University of Kent at Canterbury

Abstract: The discipline of computer sciences has grown and matured over the last three decades but it is not clear that individuals outside the field understand the nature of the discipline. The panelists will be asked to consider the disciplinary foundations of computer science and address issues such as: How should the nature of knowledge in this field be framed? What should people learn? How should environments for learning be designed?

SYMPOSIA

Symposium: Fostering the Acquisition and Application of Domain-Specific Knowledge through Concept Mapping

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Abstract: This symposium centers on the concern about the acquisition and application of conceptual knowledge in the domain of business and economics, both important and yet demanding educational goals. The contributions are aimed at studying whether concept mapping can be helpful in reaching these goals. Moreover, we intend to provide preliminary guidelines for using concept maps (CMs) as a learning tool in this specific field. For this purpose, we adopt an instructional design perspective that focuses on the issues as (1) what kinds of learning tasks can be successfully promoted by using CMs, (2) what kinds of learning activities need to be stimulated in order to accomplish these learning tasks, (3) how concept mapping supports students in performing the required learning activities, and (4) which additional instructional means can be helpful to increase its effectiveness.

Symposium Overview

Overall focus and potential significance: Issues in the field of business and economics dramatically affect peoples' lives in an increasingly globalized world. Thus, the ability to acquire knowledge in this specific domain and to apply this knowledge to public and private concerns is not only essential with respect to professional business and economics training but may be deemed as an overarching educational goal. However, due to the diversity in (1) concepts, (2) possibilities of relating these concepts, and (3) representing the domain (i.e., causally, mathematically), knowledge in business and economics may be regarded as highly complex (e.g., Miller & VanFossen, 2008). As a consequence, acquiring a well-developed knowledge base and/or applying this knowledge to business and economics problems are anything but easy ventures. Empirical studies (e.g., Marangos & Alleys, 2007) suggest that even major business and economics students at an university level still encounter difficulties when trying to reach these educational goals. It is in the context of this unsatisfactory situation that concept maps (CMs) attract the interest of researchers and educators in the field. However, while most of the research done here uses CMs as a teacher-provided text adjunct or as an assessment device (e.g., Lawless, Smee, & O'Shea, 1998), scholars in business and economics education have more recently begun to study concept mapping as a learning tool for supporting the processes of acquiring and/or applying domain-specific knowledge. Against this background, the main purpose of the symposium is to scrutinize this latter application of concept mapping in the field of business and economics education, which includes pinpointing potential benefits and pitfalls. Based on the results of the research studies presented, we also provide preliminary guidelines for using CMs as a learning tool in this particular field. In spite of being derived from domain-specific research, we suppose these guidelines to be adaptable to other complex knowledge domains. Thus, the symposium may be of interest to all researchers and educators who wish to understand and effectively cope with the challenges and predicaments of learning about complex knowledge domains.

Major issues addressed: In order to obtain the goals mentioned above, we adopt an instructional design perspective (e.g., Van Merriënboer & Kirschner, 2007), that integrates the views of CMs (1) as a mean of supporting certain kinds of learning activities (i.e., as a process), and (2) as a learning goal (i.e., as a product) in itself. Within this frame of reference, we particularly focus on the following issues:

(1) What kinds of *learning tasks* in the field of business and economics education can be successfully promoted by using concept mapping as a learning tool?

(2) What kinds of *learning activities* need to be stimulated in order to accomplish these learning tasks?
(3) How does *concept mapping* support students in performing the required learning activities?
(4) Which additional *instructional means* might be helpful to increase the effectiveness of concept mapping as a learning tool?

Summaries of the contributions:

Paper 1 focuses on concept mapping and summary writing as learning tools for fostering students' understanding of the knowledge domain after playing a management game. The findings indicate that both construction tasks lead to more learning gains in comparison to a control condition. However, in contrast to the expectation, the summary writing task was superior to the concept mapping task.

Paper 2 suggests that collaborative problem-solving in the field of business economics is facilitated when the different part-tasks are made explicit, are properly sequenced, and foreseen with ontologically part-task congruent support in the representational tools. Collaboratively constructing different representations (i.e., concept maps) of the knowledge domain with the aid of representational tools increases students' understanding which beneficially affects their problem-solving performance.

Paper 3 addresses the issue of students' difficulties with concept mapping and how these may be overcome by directly (i.e., training) and indirectly (i.e., collaboration) scaffolding the construction of concept maps. The results indicate that collaboratively constructing concept maps fosters students' understanding of the domain, but the effects of scaffolding should be carefully matched to students' characteristics (e.g., prior knowledge) and the intended learning outcome (i.e., factual or conceptual knowledge).

Paper 1: Concept Mapping versus Summary Writing as Instructional Devices for Understanding Complex Business Problems

Baerbel Fuerstenau, Jeannine Ryssel, & Janet Kunath

Background and Aim

Preparing students to work with complex cases and procedures is one of the central goals of business and economics education. Traditional instruction is meeting this goal with only limited success. Thus, researchers as well as educational politicians recommend solving the problems mentioned by relating instruction more closely to workplace assignments and business processes. Using management games has been advocated to meet this educational goal by supporting students in understanding complex interrelationships and applying knowledge in new situations and to new tasks. However, 20 years of research indicates that management games alone are not sufficient and additional instruction aimed at stimulating students to actively rethink the management game contents is required. For that purpose – among other forms – concept mapping or summary writing can be applied. In a meta-analysis Nesbit and Adesope (2006) showed a slight advantage of concept mapping over alternative construction tasks like summary writing. This may be explained by the diagram format which corresponds with the notion of knowledge as a semantic network. Thus, the similarity of knowledge and concept maps (as learning media) may support students in externalizing their cognitive structure and in using concept maps as learning aids. In addition, a concept map represents every concept only once, and by that directly shows the interaction of one concept with other concepts, i.e. the structure. In contrast, a text is linear and constructed according to a specific grammar (Larkin & Simon, 1987). Similar or same concepts can be used several times, and it is difficult to directly articulate a structure or macrostructure. However, since there are diverse findings, more research is needed with respect to the effectiveness of concept mapping in contrast to summary writing. In addition, many research studies have been carried out with the aim of investigating concept maps as learning aids in science education (Nesbit & Adesope, 2006; O'Donnell, Dansereau, & Hall, 2002), whereas research in the domain of business and economics has rarely been taken into account.

In light of these considerations, the aim of our study is to investigate the effects of concept-mapping and summary writing on promoting students' learning processes in the field of business sciences. Both techniques are used as a complement to the management game "Easy Business™" and should support students in understanding complex business interrelationships.

Method

Research Question: Is concept mapping more effective than summary writing for promoting students' learning processes in the field of business?

Participants and intervention: Forty-four ninth grade students at a public high school took part in our study during the school year 2008/2009. On average they were 14.5 years old. All students played the management game "Easy Business™" in groups. It was designed as a board game that provides the opportunity to learn the supply chain of a company and the decisions involved by visualizing the departments of a company. Moreover, students have the opportunity to experience the effects of their decisions in the annual accounting. After finishing the management game, the students were randomly assigned to one of two experimental groups (either concept mapping or summary writing) or to a control group. The students of the experimental groups were asked to construct a concept map of the most important interrelationships of the management game. As an aid they received a list of concepts and relations. We trained the respective technique with the students about one month before starting the study. The text group was requested to write a summary on the most important interrelationships of the management game. They received a list of concepts as an aid. Both techniques aimed at supporting the students in consolidating the newly acquired knowledge. The students of the control group just played the management game and did neither additional concept mapping nor additional summary writing.

Hypotheses: 1. Concept mapping and summary writing are superior to the control condition; 2. Concept mapping is superior to summary writing.

Data gathering: Before and after the treatment a knowledge test consisting of 9 open-ended questions was administered. The test is constructed in parallel forms A and B, so that the results can be accounted for by the intervention and not by learning from the pre-test. Following the taxonomy of Anderson and Krathwohl (2001), the cognitive process categories "remember" and "understand" in particular were combined with the knowledge dimensions "factual knowledge" and "conceptual knowledge". In addition, we included a question aiming at the cognitive process category "applying" and the knowledge dimension "procedural knowledge". The tests were designed in a constructed response format including short answer and essay tasks.

Data analysis: The students' answers were analyzed using a qualitative content analysis. This is a systematic, replicable technique for assigning words or phrases of a text to content categories based on explicit rules of coding. The intercoder reliability measured 93% (Holsti coefficient) underscoring the reliability of the category system. On the basis of the qualitative content analysis a test score was calculated for each student. To determine whether differences in knowledge increase between the pre-test and the post-test could be explained by concept mapping or summary writing, a two-way mixed analysis of variance was carried out with "group" as between-subjects factor and "time" as within-subjects factor. Since neither the Kolmogorov-Smirnov-Tests of goodness and fit nor the Levene-Tests showed significant results, the prerequisites for conducting the ANOVA were given. In addition, effect sizes (measure d_{int}) were determined. In case of pretest-posttest designs the effect size can be determined by: $d_{int\ (=\ interaction)} = d_{posttest} - d_{pretest}$. The pooled standard deviation from the respective groups was used as standard deviation.

Results

The two-way mixed ANOVA showed a main effect for the factor time ($F(1,41)=128.244$; p=.000), indicating a significant increase in knowledge over time for all groups. The main effect for the factor group showed that the groups significantly differ in their level of knowledge in the post-test, but not in the pre-test ($F(2,41)=4.289$, p=.02). In the post-test the summary group exceeded the two other groups. The concept mapping group was second best, and the control group reached the lowest level of knowledge in the post-test. In addition, a significant interaction effect (time x group) could be identified ($F(2,41)=6.131$; p=.005). In other words, the groups differ significantly in their knowledge increase from pre-test to post-test. The effect sizes with regard to both experimental groups versus control group (d=0.867) and summary group versus concept mapping group (d=0.841) are remarkable. The data indicate that the summary group outperformed both the concept mapping group and the control group, whereas the concept mapping group and the control group did not differ significantly in knowledge increase.

Conclusions

As assumed in hypothesis 1, the summary writing group and the concept mapping group are superior to the control group that did not work on a construction task after the management game. This is especially indicated by the effect size which contrasted both experimental groups vs. control group, though the concept mapping group is not significantly but only by trend better than the control group. This result is consistent with other studies according to which active involvement in knowledge construction (e.g., by concept mapping or summary writing) is fostering learning. Though the management game in this case supports the learning process significantly (significant main effect time ANOVA), the additional construction activity is significantly better. This seems to be true across domains. Contrary to our second hypothesis, the summary group outperformed the concept mapping group. The following reasons might explain this result: 1. Concept mapping is a comparatively new format for knowledge explication and the students are not familiar enough with the technique so that they cannot apply it confidently. Instead, the students are much more used to summary writing. Continuous training in concept mapping previous to the study might lead to other results. 2. The format of active knowledge explication does not matter that much compared to the active involvement itself. Thus, summary writing is as effective as concept mapping or some other alternative. This is in line with many studies that report only marginal differences between concept mapping and alternative construction techniques. More research is needed here. 3. A closer look at the test shows that the difference between concept map group and summary group mainly results from items concerning procedural knowledge. By excluding these items from data analysis, the difference between the experimental groups is no longer significant. Therefore, it still has to be proven whether summary writing better supports students in the development of procedural knowledge than concept mapping or whether this is only true for remembering and understanding.

In a replication study planned for the school year 2009/2010 we will use exactly the same design except that we will train the students in constructing concept maps a number of times before starting the management game. Thus we will be able to determine whether results can be explained by familiarity with a special technique. Furthermore, we will apply the design to another topic in the field of business in order to exclude the possibility of the results depend on a specific business topic. Finally, we are going to examine whether concept mapping can foster the development of procedural knowledge and higher cognitive process dimensions, e.g., applying or analyzing.

Paper 2: Matching Representational Tools' Ontology to Part-task Demands to Foster Problem-solving in Business Economics

Bert Slof, Gijsbert Erkens, & Paul A. Kirschner

Background and Aim

Collaborative problem-solving is often regarded as an effective pedagogical method beneficial for both group and individual learning. The premise underlying this approach is that through a dynamic process of eliciting one's own knowledge, discussing this with peers, and establishing and refining the group's shared understanding of the knowledge domain, students acquire new knowledge and skills and process them more deeply (e.g., O'Donnell, Hmelo-Silver, & Erkens, 2006). However, due to its complexity (i.e., diversity in concepts, principles and procedures, see Miller & VanFossen, 2008) students in business economics encounter difficulties with acquiring a well-developed understanding of the knowledge domain (e.g., Marangos & Alleys, 2007). When solving problems, students, therefore, rely primarily on surface features such as using objects referred to in the problem instead of the underlying principles of the knowledge domain, and employ weak problem-solving strategies such as working via a means-ends strategy towards a solution (e.g., Jonassen & Ionas, 2008). This hinders students in effectively and efficiently coping with their problem-solving task because the ease with which a problem can be solved often depends on the quality of the available problem representations (e.g., Ploetzner, Fehse, Kneser, & Spada, 1999). To this end, it would be beneficial if students are supported in acquiring and applying suitable representations (e.g., Ainsworth, 2006). Research on concept mapping (Nesbit & Adesope, 2006; Roth & Roychoudhury, 1993) has shown that the collaborative construction of external representations (i.e., concept maps) can guide students' collaborative cognitive activities and beneficially affect learning. Due to its ontology (i.e., objects, relations, and rules for combining them, see Van Bruggen, Boshuizen, & Kirschner, 2003) a representational tool enables students to co-construct a domain-specific content scheme fostering students' understanding of the knowledge domain in question. Problem-solving tasks, however, are usually composed of fundamentally different part-tasks (i.e., problem orientation, problem solution, solution evaluation), that each requires a different perspective on the knowledge domain and, thus, another representational tool with a different ontology. To be supportive for problem-solving, the ontology provided in a representational tool must be matched to the part-task demands and activities of a specific problem phase. Otherwise, effective problem-solving may be hindered (e.g., Van Bruggen et al.).

The goal of the study presented in this paper is to determine whether an instructional design aimed at providing ontologically part-task congruent support in the representational tools leads to more successful problem-solving performance in the field of business economics.

Method

Participants and intervention: Students from six business-economics classes in from two secondary education schools in the Netherlands participated in this study. The total sample consisted of 93 students (60 male, 33 female). The mean age of the students was 16.74 years (*SD*=.77, Min=15, Max=18). Working in a Computer Supported Collaborative Leaning (CSCL) environment, all groups had to solve a case-based problem in business-economics in which they had to advise an entrepreneur about changing the business strategy to increase profits (i.e., company result). To come up with a suitable advice, students had to carry out three different part-tasks in a predefined order, namely (1) finding out the main factors that affects the company's results and relate them to the problem (problem orientation), (2) evaluate how certain interventions such as changing the business strategy affect company results (problem solution), and (3) calculate and compare the financial effects of these interventions and formulate a final advice based on this comparison (solution evaluation). To study the effects on problem-solving performance, the ontology in the representational tool was either matched or mismatched to the part-tasks (see Table 1). The students were randomly assigned to 31 triads divided between the four experimental conditions; seven triads in the match condition and eight triads in each of the mismatch conditions (i.e., conceptual, causal, and simulation condition).

Table 1: Overview of the Experimental Conditions

Condition	Part-tasks and provided ontology			Match / mismatch
	Problem orientation	Problem solution	Solution evaluation	
Conceptual	Conceptual	Conceptual	Conceptual	Match for the orientation phase
Causal	Causal	Causal	Causal	Match for the solution phase
Simulation	Simulation	Simulation	Simulation	Match for the evaluation phase
Match	Conceptual	Causal	Simulation	Complete match

Hypothesis: It was hypothesized an instruction design aimed at providing ontologically part-task congruent support in the representational tools leads to more successful problem-solving performance in the field of business economics than not receiving it.

Data gathering: All student groups spent six 45-minute lessons solving the problem during which each student worked on a separate computer connected by a network to enable synchronous communication (i.e., chat-tool and the sharing of the representational tool(s). Before the first lesson, students received an instruction about the CSCL-environment, the group composition, and the problem-solving task. Students worked on the problem in the computer classroom where all chat-discussions and answers to the part-tasks were logged.

Data analysis: To measure the effect of condition on problem-solving performance, an assessment rubric for all criteria of the problem-solving task was developed (see Table 2). The problem-solving task consisted of three part-tasks in which the groups each had to answer three questions. All nine answers were evaluated based on their *'suitability'*, *'elaboration', 'justification'*, and *'correctness'*, resulting in 36 items (9 answers * 4 criteria). It was also evaluated whether groups used answers from a subsequent phase and altered their way of reasoning when they had to answer the questions asked in a following phase (i.e., *'continuity'*). There were two phase transitions (i.e., transition from problem orientation to problem solution and transition from problem solution to solution evaluation) and therefore two items (2 items). Finally, the *'quality of the final advice'* was evaluated by three items; number of concepts incorporated in the advice, financial consequence of the advice, and whether the final answer was in line with the guidelines provided in the original task description. All 41 items were coded as 0, 1 or 2; a '2' was coded when the answer given was of high quality. Groups could, thus, achieve a maximum score of 82 points (41 * 2 points). One-way MANOVA with Bonferroni post hoc analyses was used to analyze the effect of condition. Since there were specific directions of the results expected (see hypothesis) all analyses are one sided.

Table 2: Items and reliability for problem-solving performance (N = 31).

Criteria	Description	Items	α
Suitability	Whether the groups' answers were suited to the different part-tasks.	9	.81
Elaboration	Number of different business-economics concepts or financial consequences incorporated in the answers to the different part-tasks.	9	.56
Justification	Whether the groups justified their answers to the different part-tasks.	9	.71
Correctness	Whether the groups used the business-economics concepts and their interrelationships correctly in their answers to the different part-tasks.	9	.68
Continuity	Whether the groups made proper use of the answers from a prior problem phase.	2	.67
Quality advice	Whether the groups gave a proper final advice. - Number of business-economics concepts incorporated in the advice. - Number of financial consequences incorporated in the advice. - Whether the final answer conformed to the guidelines provided.	3	.76
Total	Overall score on the collaborative problem performance.	41	.92

Results and Conclusions

One-way MANOVA on the total score of the problem solving performance showed a significant difference for condition (F(3,27)=4.38, p=.01). Bonferroni post hoc analyses revealed that groups in the match condition scored significantly higher than groups in both the conceptual (p=.01; d =1.46) and the simulation condition (p=.01; d=1.48). When the results for the dependent variables were considered separately, using one-way ANOVAs with Bonferroni post hoc analyses, condition effects were found for 'justification' (F(3,27)=4.85, p=.01) and 'correctness' (F(3,27)=3.97, p=.01). The mean scores indicate that there were two significant differences between conditions. First, groups in the match condition scored significantly higher on 'justification' than groups in both the conceptual condition (p=.01; d=1.56) and the simulation condition (p=.01; d=1.56). Second, groups in the match condition scored significantly higher on 'correctness' than groups in both the conceptual condition (p=.01; d=3.97) and the simulation condition (p=.03; d=2.52). Although expected, no significant differences were found between the match and the causal condition. Students in both conditions received the causal ontology (relevant concepts, solutions and their causal interrelationships), providing students the means to co-construct multiple qualitative perspectives on the knowledge domain. It seems, therefore, important to recognize that causal reasoning is beneficial for collaborative problem-solving (e.g., Jonassen & Ionas, 2008).

Collaborative problem-solving in business economics is facilitated by an instructional design aimed at making the different part-tasks explicit, sequencing them properly, and foreseeing them with ontologically part-task congruent support in the representational tools. The complementary function of those different perspectives can gradually increase students understanding and, therefore, support them in solving a complex problem (see Ainsworth, 2006). That is, groups receiving ontologically congruent support for each part-task (i.e., match condition) gave more correct and justified answers to the part-tasks and a came up with better final solutions to the problem than groups in the non-matched conditions. Future work is aimed at analyzing the chat-discussions and the constructed representations (i.e., concept maps) to gain more insight in the learning process itself and the lack of difference between the match condition and the causal condition. During the conference insight into students' discussions about the knowledge domain (i.e., concepts, principles, and procedures) will be presented.

Paper 3: Direct and Indirect Means of Scaffolding the Effective Use of Student-generated CMs in Economics Education

Carmela Aprea, & Hermann G. Ebner

Background and Aim

Not only does the adjunctive presentation of diagrams, drawings, pictures and other forms of visualizations play a prominent role in everyday classroom practice, it is also a long-running issue in educational research (e.g., Ainsworth, 2006). With the growing popularity of cognitive and constructivist learning approaches, many scholars in the learning sciences have begun to suggest that the benefits of these adjuncts can be further intensified if students are prompted to generate their own graphical representations (e.g., concept maps). This conjecture seems to be corroborated by empirical findings in various content domains (e.g., science learning, teacher education, foreign language acquisition) and with different types of students such as primary school children and high school students (e.g., Nesbit & Adesope, 2006). However, besides the fact that only few studies address the question whether the benefits of student-constructed concept maps are transferable to the domain of economics education, the research literature is not conclusive, and in some studies even severe difficulties in using concept mapping as a learning tool are reported (e.g., Reader & Hammond, 1994). As the results of these studies suggest, one reason that might have caused these difficulties is students' (and teachers') lack of familiarity with these learning tools. Thus, beginners are easily overwhelmed by the demands of the concept mapping task. Against the background of these findings, it can be concluded that there is no such thing as a 'concept mapping finger-tip effect', but that some form of scaffolding might be required to ensure adequate tool use. One way of addressing this need is to provide students with a mapping training. Yet, the results of training studies (e.g., Chang, Sung, & Cheng, 2002) suggest that the success of this direct scaffolding method seems to be limited. At least in short time interventions, it proved helpful only for students with sufficient domain and strategic knowledge. However, students lacking such a level of prior knowledge seem to need additional support. Given the current debate on the social construction of cognition and learning (e.g., O'Donnell, Hmelo-Silver, & Erkens, 2006), a promising candidate for such an additional support is to embed the concept mapping task within a collaborative learning environment. For example, Roth and Roychoudhury (1993) assume that collaboratively constructed maps may provide an ideal context for overt negotiation of meaning and construction of knowledge, because they require individuals to externalize their propositional frameworks. Others (e.g., Jones & Issroff, 2005) have highlighted the motivational and affective support of collaborative learning. Congruently with De Simone, Schmid, and McEwan (2001), this adaptation of the learning environment is classified as an indirect form of scaffolding.

Given these suggestions, the aim of the research study to be presented in this paper was twofold, namely exploring (1) the impact of student-generated maps as tools for fostering conceptual knowledge acquisition and application in the domain of economics education, and (2) whether effective tool use can be facilitated by direct means (i.e., training) and/or indirect means (i.e., collaboration) of scaffolding.

Method

Participants and intervention: 169 students from two urban secondary level business schools participated in this study. Fifty percent of the students in the sample were female, and the mean age was 20 years. In order to address the research issues mentioned above, students were randomly assigned to one of three treatment groups: (1) Subjects of the first group (*text plus experimenter-provided graphic group*; n = 52) received a text passage in combination with an already elaborated expert map. The text passage deals with the topic of environmental economics and contains about 1000 words. This treatment group was included to control for the general dual-coding effect of verbal and visual information provision. (2) Subjects of the second group (*individually mapping group*; n = 59) firstly received a mapping training unit. This training unit was inspired by a cognitive apprenticeship approach and consisted of three components: (a) a list of steps how to construct a concept map; (b) a short text passage to model map development; (c) a training text passage for coaching purposes. The content of these text passages was unrelated to the experimental text on environmental economics. After the training, the experimental text passage was handed out and students were asked to individually read the text, to identify the main ideas of the text and then to re-construct its content in a diagram. (3) As in the individually mapping group, subjects in the third group (*collaboratively mapping group*; n = 58) received the mapping training and the environmental economics text passage without any visual adjunct. They were then asked to first read the text alone and make a preliminary sketch. After that, they were requested to discuss their sketches with a learning partner and to subsequently draw up a shared concept map.

Hypotheses: We hypothesized that the collaborative mapping treatment might lead to the best results in terms of cognitive learning outcomes, followed by the results of the individually mapping group and the results of the text plus experimenter-provided diagram group. Moreover, we supposed that collaborative mappers outperform the individual mapping group with respect to concept map quality.

Data gathering: An achievement test and a free recall test were used for assessing the cognitive learning outcomes. The achievement test (*Knowledge Acquisition Test*; KAT) included six mixed-format questions (multiple choice and open-ended). These questions mainly addressed detailed understanding and transfer of conceptual knowledge and encompassed content from the whole text passage. The KAT was administered twice, namely immediately after the instructional treatments (subsequently referred to as KAT1) and approximately three weeks later (subsequently referred to as KAT2). Likewise, about three weeks later, students were asked to write down all they could remember about the text. This *free recall test* (FRT) was intended to assess whether and to what extent students were able to remember the overall conceptual structure of the text. To account for map quality (MQ), we moreover evaluated accuracy, elaboration and organization of students' representations. In addition, we included students' general economic knowledge as a covariate by using several items from the Test of Economic Literacy (TEL) (Soper & Walstad, 1987).

Data analysis: All dependant measures (i.e. KAT1; KAT2; FRT, MQ) were submitted to one-way ANOVAs and post-hoc tests. These statistical procedures were conducted for (1) the whole sample as well as (2) for students with extremely high or low general economic knowledge as indicated by the TEL items.

Results and Conclusions

Analyses of the *whole sample* showed that subjects from the collaborative mapping group significantly outperformed the text plus provided graphic group with respect to the FRT ($F(2,142)=3.545$, $p<.05$). Moreover, these subjects constructed more accurate and elaborated concept maps than their individual mapping counterparts. On the other hand, individual mappers demonstrated a significantly better knowledge organization. None of the other outcome measures proved to be significant at the $\alpha=.05$ level. Students with *low general economic knowledge* mirror the whole sample results with respect to the FRT and the MQ measures. Furthermore, collaborative mappers within this subgroup showed significantly better results on the KAT 1 than individual mappers ($F(2,78)=3.841$, $p<.05$). With respect to this latter learning outcome measure the reverse holds for the subgroup of students with *high general economic knowledge* ($F(2,25)= 3.231$, $p<.05$).

Since the data only partly reflect the expected effects, it cannot be concluded that concept mapping generally enhances students' knowledge acquisition and application in the domain of economics education. However, the results seem to reveal an important relationship between the means of scaffolding the mapping task on the one hand and learning outcomes as well as prior knowledge on the other. Thus, a more refined perspective on the operating conditions of concept mapping within our field of application might be needed. On the basis of the data, at least three directions for such refinements seem to be evident:

(a) Firstly, the results give rise to the assumption that students who can be considered as high-achievers in terms of general economic knowledge seem to profit most from an individually concept mapping task in combination with a training. In contrast, collaboration seems to be particularly helpful with regard to supporting students with low economic knowledge scores. However, since the current design did not entail a non-trained control condition, a cautious interpretation of the findings is of course imperative. With this admonition in mind, it can be tentatively recommended to differentiate the means of scaffolding with respect to the prevailing learner characteristics.

(b) Secondly, the results indicate that concept mapping in economics education seems to be of specific use for promoting long-term retention of overall conceptual knowledge structures, whereas no such long-term effect for the retention of text details could be found. In accordance with researchers of learner-generated graphical representations in other domains (e.g., Van Meter et al. 2006), we therefore deem it necessary to differentiate the effectiveness of concept mapping tasks with respect to intended learning outcomes.

(c) Finally, along with De Simone, Schmid and McEwen (2001), we feel that in order to gain a deeper understanding of the specific benefits of concept mapping and the respective means of scaffolding we need to study in more depth the learning processes that are associated with the various treatment conditions as well as the interactions of students in the collaborative mapping group.

Conclusions and further work

The contributions indicate that a learning tool as concept mapping enables students to represent their conceptual understanding of the knowledge domain and to discuss it with their peers. Actively engaging in such learning activities can foster the acquisition/retention and the application of domain knowledge (i.e., during problem-solving). Its effect are, however, not straightforward, what students can represent in the concept map should be carefully match with (1) the intended/desired learning process and learning outcome, (2) and students' prior knowledge. Future research is, therefore, required to gain more insight in how specific learning activities, leading to intended learning outcome, can be evoked and what role instruction exactly plays in supporting those kinds of learning activities.

References

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction*, 16(3), 183–198.

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.

Chang, K.-E., Sung, Y.-T., & Chen, I.-D. (2002). The effect of concept mapping to enhance text comprehension and summarization. *The Journal of Experimental Education*, 71(1), 5–23.

Collins, A. M., & Quillian, M. R. (1969). Retrieval time from semantic memory. *Journal of Verbal Learning and Verbal Behavior*, 8(2), 240–247.

De Simone, C., Schmid, R. F., & McEwan, L. A. (2001). Supporting the learning process with collaborative concept mapping using computer-based communication tools and processes. *Educational Research and Evaluation*, 7(2-3), 263–283.

Jonassen, D. H., & Ionas, I. G. (2008). Designing effective support for causal reasoning. *Educational Technology Research and Development, 56,* 287–308.

Jones, A., & Issroff, E. (2005). Learning technologies: Affective and social issues in computer supported collaborative learning. *Computers & Education,* 11(4), 395–408.

Larkin, J. H. & Simon, H. A. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science*, 11, 65-99

Lawless, C., Smee, P., & O'Shea, T. (1998). Using concept sorting and concept mapping in business and public administration, and in education: an overview. *Educational Research*, 40(2), 219–235.

Marangos, J., & Alley, S. (2007). Effectiveness of concept maps in economics: Evidence from Australia and USA. *Learning and Individual Differences,* 17, 193–199.

Miller, S. L., & VanFossen, P. J. (2008). Recent research on the teaching and learning of pre-collegiate economics. In L. S. Levstik & C. A. Tyson (Eds.), *Handbook of Research in Social Studies Education*, pp. 284-304.

Nesbit, J. C., & Adesope, O. O. (2006). Learning with concept and knowledge maps: A meta-analysis. *Review of Educational Research*, 76(3), 413–448.

O'Donnell, A. M., Hmelo-Silver, C., & Erkens, G. (2006). *Collaborative learning, reasoning, and technology.* Mahwah, NJ: Lawrence Erlbaum

O'Donnell, A., Dansereau, D. F., & Hall, H. (2002). Knowledge maps as scaffolds for cognitive processing. *Educational Psychology Review*, 14(1), 71–86.

Ploetzner, R., Fehse, E., Kneser, C., & Spada, H. (1999). Learning to relate qualitative and quantitative problem representations in a model-based setting for collaborative problem solving. *Journal of the Learning Sciences, 8,* 177–214.

Reader, W., & Hammond, N. (1994). Computer-based tools to support learning from hypertext: Concept mapping and beyond. *Computers Education*, 22, 99–106.

Roth, W. M., & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. *Journal of Research in Science Teaching*, 30(2), 127-152.

Soper, J. C., & Walstad, W. B. (1987). *Test of Economic Literacy*. 2nd Edition. New York: Joint Council on Economic Education.

Van Bruggen, J. M., Boshuizen, H. P. A., & Kirschner, P. A. (2003). A cognitive framework for cooperative problem solving with argument visualization. In P. A. Kirschner, S. J. Buckingham-Shum, & C. S. Carr (Eds.), *Visualizing Argumentation: Software tools for collaborative and educational sense-making.* (pp. 25-47). London: Springer.

Van Merriënboer, J.J.G., & Kirschner, P.A. (2007). *Ten steps to complex learning*. Mahwah, NJ: Lawrence Erlbaum.

Van Meter, P., Aleksic, M., Schwartz, A., & Garner, J. (2006). Learner-generated drawing as a strategy for learning from content area text. *Contemporary Educational Psychology*, 31, 142–166.

Developing Students' Disciplinary Historical Thinking: The Role of Textual and Instructional Resources

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Abstract: Recent reports on adolescent literacy state that students must develop domain-specific reading skills in order to comprehend the complex texts that pervade secondary and tertiary education. It has been argued that disciplinary historical thinking, in particular, because of its emphasis on evaluating and reconciling conflicting accounts, translates into the skills required for informed citizenship. However, the research on historical thinking is marked by a pronounced absence of (1) prolonged curricular interventions in real classrooms and that attempt to develop students' historical thinking; (2) transfer studies that examine the application of students' historical thinking to digital resources and other texts with which students feel personally invested; (3) the use of multimodal texts in fostering students' historical thinking. The four papers presented in this symposium address these gaps by examining the development of students' historical thinking across instructional contexts with various textual resources.

History education has been justified for over a century on the grounds that no subject is better suited to develop in students the capacity for judgment that is essential for democratic citizenship (Bradley Commission, 1988; Committee of Seven, 1899; National Council for the Social Studies, 2007). However, data from the National Assessment of Educational Progress (NAEP) raise the question of how well we are carrying out this important task. Only 32% of 12th graders scored proficient or advanced in school civics in the 2006 NAEP administration (Lutkus & Weiss, 2007), and only 14% scored at the proficient or advanced level in history on the NAEP (Lee & Weiss, 2007). In the wake of No Child Left Behind, the problem has been exacerbated as school districts have cut social studies classes in an effort to raise literacy and math scores (Center on Education Policy, 2007). This unfortunate curricular reshuffling flies in the face of a recent spate of national reports that insist reading instruction be tied to content and involve domain-specific reading skills (Biancarosa & Snow, 2006; Heller & Greenleaf, 2007; National Institute for Literacy, 2007; Shanahan & Shanahan, 2008). Moreover, the digital age demands that students possess the skills to evaluate the reliability of information sources and reconcile conflicting claims.

Research on disciplinary historical reading practices has identified certain domain-specific reading skills practiced by expert historians. This same body of research has suggested that novices—both high school and undergraduate students—do not spontaneously practice the same reading strategies that expert historians practice automatically and unconsciously (Holt, 1995; Rout et al. 1997; VanSledright & Kelly, 1998; Wineburg, 1991a, 1991b). Historians wend their way through the documentary record, scrutinizing the reliability of sources, corroborating information, and imagining the personal, social, political, and economic contexts of their historical actors. Novices struggle in their attempt to interpret historical texts and have difficulty evaluating the reliability of sources (Wineburg, 1991a). Far from the closed presentation of facts that students encounter in their textbooks, the discipline of history as historians practice it presents knowledge as open and dynamic and sees the past as ultimately elusive and irretrievable. Many students not only view history textbooks as an authoritative historical account, but they also find the texts themselves disconnected from their lives (Bain, 2006).

Having established the difference between experts and novices, the research on historical thinking has largely focused on prompting students to recognize the interpretive, constructed nature of history and to read multiple documents intertextually (Britt & Aglinskas, 2002; Paxton, 2002; Rouet, Britt, Mason, & Perfetti, 1996; Stahl, Hynd, Britton, McNish, & Bosquet, 1996; Wiley & Voss, 1999; Wolfe & Goldman, 2005). The findings from these studies suggest that students will respond to certain instructional manipulations that make apparent and scaffold the epistemological structure and constructed nature of the discipline. For example, researchers found effects for writing prompts that ask for an argument (Wiley & Voss, 1999), for the insertion of an author's voice in an otherwise passive textbook (Paxton, 2002), for the explicit request for sourcing information (Britt & Aglinskas, 2002), and for the juxtaposition of two contrasting arguments about an historical event (Wolfe & Goldman, 2005).

Yet, we believe this body of research has considered historical thinking on relatively narrow terms. With two classroom interventions standing as exceptions (Nokes et al., 2007; De La Paz, 2005), each approximately two weeks long, the research on historical thinking lacks the ecological validity of the classroom. In most cases, researchers designed laboratory conditions and students individually worked their way through computer-based prompts or document packets. Second, most of the studies were conducted with undergraduate students or high school students who were already proficient readers, not with struggling readers who represent many of the students in our nation's schools. Third, given researchers' claims that historical thinking should be widely transferable to online resources, the materials used in the research on historical thinking have been surprisingly limited to primary or secondary historical sources. Similarly, because this body of research has largely grown out of the findings of expert reading of written texts, the field has by and large ignored the other textual resources and multimodal forms through which the discipline is represented in the classroom.

The four papers in this symposium seek to broaden the foundation upon which historical thinking research has developed to date. In particular, the papers in this symposium address on or more of the following questions:

1. What does an extensive historical thinking curriculum look like in real classrooms, with many students reading below grade-level? What are the effects of such a curriculum intervention?
2. What does historical thinking look like when students work with digital resources and other texts with which they feel personally connected?
3. In what instances can we broaden our definitions of historical texts to include multimodal forms of disciplinary representation?

We believe the four studies we will present make a significant contribution to the field by broadening the resources and contexts that have typically been considered in research on historical thinking. Our panel includes a mixed-methods, experimental study comparing five treatment classrooms and five control classrooms involving over 200 11^{th} grade students. This study looks at the effects of a documents-based curriculum, featuring modified historical documents, on student reading comprehension and historical thinking. The second study asks how students use processes of historical thinking in their engagement with online texts, using verbal reading protocol data, recorded reader-computer interactions, and content analysis of students' graphic representations. We will also present a design study looking to integrate disciplinary practices from history into a community action project after school in an urban community. This effort explores the application of historical thinking, research, and reading to the engagement of youth in developing solutions to issues of concern in their community, using an iterative process of design study to test and develop the model. Finally, the panel includes a case study of three middle school teachers' conceptualizations and uses of historical texts and representations in their classrooms. This study asks how teachers represent historical ideas and texts in their classrooms and relies upon qualitative data and constant comparative analysis as well as video data analyzed through semiotic and multimodal analyses.

This symposium will examine different applications of disciplinary practices in and around schools—from middle school classrooms to high school classrooms to digital environments to after-school programs. We combined our diverse research settings and methodologies to demonstrate the wide range of practices that can inform our thinking and pedagogy in this area. By drawing from these studies of disciplinary practices across multiple settings, we hope not only to expand the conversation around what it means to learn history, but we also hope to add to conversations about collaborating across methodologies to study this important topic in education.

Individual Presentations

The Teen Empowerment through Reading, Research, and Action (TERRA) Project

Darin Stockdill, University of Michigan

The Teen Empowerment through Reading, Research, and Action (TERRA) Project involved a design study on the implementation of an after-school historical reading and action research program for students in an urban school. As a design study, the project was carried out with the goal of studying the initial effectiveness of the model and refining its design as an intervention model for future research. Twelve students were initially recruited to meet once a week during the school year to take part in this effort in an urban school located in a primarily Latino community.

The instructional approach used was based upon disciplinary practices in history which entail the identification of an historical problem, the selection and analysis of historical evidence, and the production of new historical accounts based upon this process (Bain, 2000). Students engaged in group brainstorming and discussion and chose to focus their study on environmental and infrastructure problems in their community. With the researcher as instructor and co-participant, the group then began the ongoing process of using disciplinary practices and reading heuristics from history to explore the roots of particular manifestations of these problems. In particular, as they learned about the history and economics of the physical deterioration of their community, the participants were provided disciplinary reading instruction as they analyzed historical evidence through the processes of sourcing, contextualizing, and corroborating evidence (Wineburg, 2001). Through this type of critical reflection, students engaged in the production of their own historical accounts of environmental decay in their community and used this to initiate a process of participant action research in which their historical study is guiding informed action (Cammarota, 2007; Morrell, 2006). In this context, students began to see that historical reading and research can be tools for community development and can take on important uses beyond their school classrooms.

Data collection and analysis for this research focused on the process of developing and implementing this instructional intervention. Decisions made by the researcher, who was also the instructor, were carefully recorded and analyzed. Data was also collected in order to describe how students thinking and reading about historical topics developed over the course of the program, with a focus on how the immediate context of the problem of study played a role in setting purpose for their reading and learning. In addition, the study also looked at the role played by their prior knowledge of the community in this process.

Initial analyses of field notes, discussion transcripts, and interview data demonstrated that students were very excited about the project and wanted to learn about the problem. For example, when asked what was different about learning in this fashion, one young man stated that it seemed more important because, "It's about me, it's about my city." Nevertheless, as in many after-school programs, consistent attendance of participants became a concern in some cases despite student expressions of interest. Also, some participants initially resisted the focus on reading when it appeared too much like typical schooling. However, when program adjustments were made to include more discussion and active research such as surveying classmates and documenting the environment with photography, students showed more motivation to engage in readings which they viewed as connected to these experiences. Over the course of the program, four participants in particular committed themselves to this learning process and began to take on the role of researchers. Their prior knowledge of the community helped to set the purpose for their reading and research, but it was actually quite limited in an historical sense. Nevertheless, after being in the program for several months, they began to incorporate evidence from their research into their evolving accounts of urban decay in their community. As the program ended, they used their accounts to develop an educational presentation on solving the problem for other students and community members.

This preliminary evidence suggests that after-school learning may be more effective when it incorporates disciplinary approaches to learning with learning experiences less typical to conventional classrooms. In addition, the initial evidence suggests that disciplinary approaches to historical learning can be effectively linked to the solution of real world problems and thus engage young people in meaningful, active learning.

Historical reasoning on the Internet: How do students read and learn about socially controversial issues in new literacy environments?

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This study describes reading strategies that students used to identify, comprehend, and evaluate Internet texts, and explores promises and challenges in applying heuristics for historical reading into a conceptualization of reading for learning with Internet texts. Twelve 11th-grade participants with established reading abilities individually located and read websites deemed useful to learn about a self-selected socially controversial issue that required historical reasoning. Data collection and analysis used multi-methods aimed at triangulating participants' verbal reports, recorded reader-computer interactions, and graphic representations of their understanding in order to infer their Internet reading strategy use (Afflerbach, 2000)

A preliminary data analysis indicates that historical reasoning strategies may play an important role in critical reading on the Internet while students often have difficulties using these strategies. Internet reading requires readers' constructive strategy use (e.g., constructing potential texts to read, learning text content, monitoring one's reading processes, and evaluating different aspects of reading) in which historical thinking processes are broadly involved (Afflerbach & Cho, 2009). Internet reading demands intertextual modeling of text content, interrogation of hidden meanings, and critical source evaluation (Rouet, Favart, Britt, & Perfetti, 1997; VanSledright & Kelly, 1998; Wineburg, 1991b) through which active readers learn about the world by responding to the new literacy environments (Bruce, 2000; Kress, 2003; Kuiper, Volman, & Terwel, 2005; Landow, 1992; Leu, Kinzer, Coiro, & Cammack, 2004). The analysis of students' strategy data will eventually inform a role of historical reasoning strategies in reading multiple, digital texts and what knowledge, epistemology, and skills and strategies should count in history instruction that fosters both students' domain expertise and literacy development.

Reading Like a Historian: A Document-Based History Curriculum Intervention with Adolescent Struggling Readers

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In this mixed-methods study, five history teachers' urban classrooms implemented a seven-month documents-based history curriculum with eleventh-grade struggling readers. The study asks whether the findings on expert historical reading can be brought to bear in urban public school classrooms, where students read well below grade level. With five treatment and five control classrooms, and over 200 eleventh grade students, this study was the first of its kind in any major U.S. school district.

The curriculum features modified historical documents, vetted reading instruction methods, and innovative activity structures that provide the necessary supports for disciplined historical inquiry. The curriculum rests on three theoretical assumptions. First, the approach views historical reading as fundamentally intertextual. The intervention shifts the grammar of the history classroom, from one where a single document—the textbook—embodies all historical knowledge, to one where historical knowledge results from the interpretation and evaluation of multiple documents. The second theoretical assumption is that students must *see* cognitive strategies explicitly modeled before they understand how to use and practice them. Third, the curriculum radically modifies documents, both lexically and syntactically. Though originals were available to all students, these adaptations were the only way struggling readers could be exposed to the voices of historical figures.

This study uses mixed methods to capture the effects of the proposed curriculum on student historical reading and general reading comprehension. Four measures were administered to students before and after the intervention: 1) A 30-question multiple choice and constructed-response test of historical thinking that was developed, piloted and validated by the researcher; 2) A nationally-normed reading comprehension test (Gates-MacGinitie); 3) A content test comprised of released multiple-choice items from California's state history assessment; 4) A 20-question transfer test that asked students to apply historical thinking skills to contemporary issues and problems. Because students were not randomly assigned to condition, pretests were used as covariates. A MANCOVA analysis found statistically significant gains for treatment students on all four measures.

Though the quasi-experimental nature of the study precludes causal conclusions, the fact that results were consistent for the treatment condition across a wide range of school and teacher contexts, suggests that the curriculum may have contributed to student gains in reading comprehension and historical thinking. This paper will discuss the features of the curriculum and contrast them with the textual resources and instruction in traditional history classrooms.

Constructing History in Middle Schools: A Social Semiotic Analysis of Texts Used in Three History Classrooms

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This ten-month multicase study (Stake, 2006) documents the forms of representation used by three middle school history teachers as part of their daily instruction. This study is framed in theories of social semiotics (Halliday, 1978; Hodge & Kress, 1988; van Leeuwen, 2005), which posit that texts *realize* any given social system by "not merely expressing it, but actively creating and maintaining it" (Halliday, 1978, p. 172). A semiotic conceptualization of texts includes communication in any mode or combination of modes, including spoken words, gestures, written words, music, images, and more (Kress, 2003). According to this theoretical framework, multimodal texts used within history classrooms *realize* the discipline of history by instantiating common disciplinary practices, norms, problems, and epistemologies (cf. Brophy, 1996; McDiarmid, Ball, & Anderson, 1989).

To study how the discipline of history was realized in three middle school classrooms, this study undertook a close analysis of the types of texts that three middle school teachers used, the ways in which they combined them, and the goals toward which they employed them. Four types of data were collected over the course of ten months: field notes from three to five hours of classroom observations per week; artifacts and photographs collected during these observations (e.g., photographs of PowerPoint presentations); monthly interviews with the teachers regarding their evaluation of the instructional materials they used; and three videotaped lessons from each teacher, which enabled a fine-tuned analysis of how different modes were integrated.

The written data are currently being coded in accordance with a modified constant comparative method (Smagorinsky, 2008), whose codes are designed to indicate discipline-specific patterns in the types of representation that are used and the ways in which they are combined, while the video data are being transcribed and coded in the form of a multimodal concordance chart (Baldry & Thibeault, 2006), which records how different modes (images, gestures, written words, spoken words) are integrated and used for different purposes within any given stretch of communication. Preliminary data analysis indicates that teachers often used photographs, maps, video, and other iconic images to refer to observable events or phenomena, but they used written or spoken words to emphasize intangible themes, such as power, governance, changes, or people's thoughts on events.

For example, one eighth-grade history teacher (T1) showed video footage of fire fighters approaching the Twin Towers and clips from the Disney movie *Johnny Tremain* to teach about tangible events that preceded a war: the destruction of the Twin Towers and the Boston Tea Party. However, to raise questions of ethics surrounding when it is appropriate to go to war, he held a classroom discussion that culminated in the students writing an essay addressing when soldiers should be honored as heroes, drawing evidence from multiple instances when America had been at war. As another example, a sixth-grade teacher (T2) showed photographs of the effects of air pollution and acid rain in Mexico City, including statues whose faces had been eroded, along with pointing to maps including the geographical features of Mexico City that trapped the pollution. In talking about intangible themes such as governance and power, however, T2's students held discussions comparing governmental structures across South and Central America and the Caribbean. A third example, drawn from the final teacher who participated in this study (T3), included using drawings of Cortez's landing in the New World to introduce the event of the landing; students later wrote paragraphs evaluating whether or not the Colombian Exchange was ultimately beneficial or harmful.

The three history teachers also drew heavily from embodied representations, or representations in which the students' or teachers' bodies represented a historical figure or object. For example, T3 asked one student to wear a blindfold and walk to the edge of a table to demonstrate what Columbus may have felt like in venturing into relatively unchartered territory, whileT1's class involved students who dressed up as Civil War soldiers and explained what life was like during their time period. In T2's classroom, students studied the histories of sports in different Latin American countries and dressed in jerseys to indicate those countries' affinity for soccer. T3, in teaching an enrichment lesson on reading maps, dressed as a pirate and asked her students to search historical maps to begin a "treasure hunt," while T1 and his students acted in plays that required them to take the place of immigrants to America in the 1800s. Because one goal of history is to encourage students to read both empathetically and critically (Levesque, 2008), while recognizing that all texts convey a perspective shaped by the author's context and group affiliations, these representations enabled teachers and students to embody history as though they were actually living in that time and thinking from that perspective.

In all, however, the teachers valued written words as being the primary source of information in history, regardless of whether those written words were from primary source documents, textbooks, or self-created power point presentations. Though the teachers viewed other representations as vital to their disciplinary goals, they emphasized that history was characterized by a heavy reliance on written and spoken words as key mediators of students' historical understandings and as primary purveyors of content. Written and spoken words enabled them to discuss intangible themes, such as power or justifications for war, in ways that could not be conveyed through iconic representations (or representations such as photographs that bear a physical resemblance to the item they represent). These themes and ideas were more important to the teachers than the actual tangible and observable historical events themselves.

Implications

Taken together, these four papers broaden the resources and contexts that have heretofore been considered in the study of historical thinking. We see two direct implications for the development of historical thinking in students. The first emerges from the scholarship on adolescent literacy that argues that reading instruction must be embedded in the content areas and integrate domain-specific ways for reading if students are to be prepared to comprehend the complex texts they encounter in their upper-level classrooms. According to Massey & Heafner (2004), many teachers "do not know how to help students develop the skills and strategies necessary for reading comprehension in history classes" (p. 26). Several of the papers on this panel suggest new instructional approaches and alternative resources that could be used to teach disciplinary reading in history classes. The second implication emerges from the earliest arguments for the inclusion of history education in high schools that emerged at the end of the 19th century: the study of history has the potential to develop the capacity for reason and judgment. All the more so in 2009, as the deluge of data in the information age demands an unprecedented degree of discernment and judgment. In the face of increasingly sophisticated marketing of products and ideas towards our youth, it is more important than ever that young people think and learn critically from and about multiple forms of texts, that they can consider opposing points of view and conflicting accounts, and make informed judgments about the world. In the words of Wineburg and Martin (2004), "in our age of new technologies, every crackpot has become a publisher. The ability to judge the quality of information can no longer be considered 'extra credit'" (p. 42). We believe that the papers in this symposium, by broadening both the resources and contexts associated with historical thinking, increase the likelihood that youth will encounter opportunities to 'judge the quality of information' and use their analyses in productive ways.

References

Afflerbach, P. (2000). Verbal reports and protocol analysis. In M. J. Kamil, P. B. Mosenthal, P. D. Pearson & R. Barr (Eds.), *Handbook of reading research* (Vol. 3, pp. 163-179). Mahwah, NJ: Lawrence Erlbaum Associates.

Afflerbach, P., & Cho, B.-Y. (2009). Identifying and describing constructively responsive comprehension strategies in new and traditional forms of reading. In S. E. Israel & G. G. Duffy (Eds.), *Handbook of research on reading comprehension* (pp. 69-90). New York: Routledge.

Bain, R. B. (2000). Into the breach: Using research and theory to shape history instruction. In P. Stearns, P. Seixas, and S. Wineburg (Eds.), *Knowing, teaching and learning history: National and international perspectives* (331-353). New York: New York University Press.

Bain, R. B. (2006). Rounding up unusual suspects: Facing the authority hidden in the history classroom. *Teachers College Record, 108*, 2080-2114.

Baldry, A., & Thibault, P. J. (2006). *Multimodal transcription and analysis: A multimedia toolkit and coursebook with associated on-line course.* London: Equinox.

Biancarosa, C., & Snow, C. E. (2006). *Reading next—A vision for action and research in middle and high school literacy: A report to Carnegie Corporation of New York* (2nd ed.). Washington, DC: Alliance for Excellent Education.

Bradley Commission on History in Schools. (1988). Building a history curriculum: Guidelines for teaching history in schools. In P. Gagnon (Ed.), *Historical literacy: The case for history in American education* (pp. 16-47). New York: Macmillan Publishing Company.

Britt, M. A., & Aglinskas, C. (2002). Improving students' ability to identify and use source information. *Cognition and Instruction, 20,* 485–522. *Cognition and Instruction, 15*(4)*,* 85–106.

Brophy, J. (1996). Introduction. In J. Brophy (Ed.), *Advances in research on teaching: Teaching and learning history* (pp. 1-18). Greenwich, CT: JAI Press.

Bruce, B. C. (2000). Credibility of the Web: Why we need dialectical reading. *Journal of Philosophy of Education, 34*(1), 97-109.

Cammarota, J. (2007). A social justice approach to achievement: Guiding Latina/o students towards educational attainment with a challenging, socially relevant curriculum. *Equity & Excellence in Education* 40: 87-96.

Committee of Seven. (1899). The study of history in schools: Report to the American Historical Association. New York: MacMillan Company.

De La Paz, S. (2005). Effects of historical reasoning instruction and writing strategy mastery in culturally and academically diverse middle school classrooms. *Journal of Educational Psychology, 97*(2), 139-156.

Halliday, M. A. K. (1978). *Language as social semiotic: The social interpretation of language and meaning.* London: Arnold.

Heller, R., & Greenleaf, C. (2007). *Literacy instruction in the content areas: Getting to the core of middle and high school improvement.* Washington, DC: Alliance for Excellent Education.

Hodge, R., & Kress, G. (1988). *Social semiotics.* Ithaca, NY: Cornell University Press.

Holt, T. (1995). *Thinking Historically: Narrative, Imagination, and Understanding.* New York: College Entrance Examination Board.

Kress, G. (2003). *Literacy in the new media age*. New York: Routledge.
Kuiper, E., Volman, M., & Terwel, J. (2005). The Web as an information resource in K-12 education: Strategies for supporting students in searching and processing information. *Review of Educational Research, 75*, 285-328.
Landow, G. P. (1992). *Hypertext: The convergence of contemporary critical theory and technology*. Baltimore: The Johns Hopkins University Press.
Lee, J., and Weiss, A. (2007). *The Nation's report card: U.S. history 2006* (NCES 2007-474). U.S. Department of Education, National Center for Education Statistics. Washington, D.C.: U.S. Government Printing Office.
Leu, D. J., Kinzer, C. K., Coiro, J. L., & Cammack, D. W. (2004). Toward a theory of new literacies emerging from the Internet and other information and communication technologies. In R. B. Ruddell & N. J. Unrau (Eds.), *Theoretical models and processes of reading* (5th ed., pp. 1570-1613). Newark, DE: International Reading Association.
Levesque, S. (2008). *Thinking historically: Educating students for the 21st century*. Toronto: University of Toronto Press.
Lutkus, A., & Weiss, A. (2007). *The Nation's report card: Civics 2006* (NCES 2007-476). U.S. Department of Education, National Center for Education Statistics. Washington, D.C.: U.S. Government Printing Office.
Massey, D.D., & Heafner, T.L. (2004). Promoting reading comprehension in social studies. *Journal of Adolescent and Adult Literacy* 48(1): 26-40.
McDiarmid, G. W., Ball, D. L., & Anderson C. W. (1989). Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. In M. C. Reynolds (Ed.), *Knowledge base for the beginning teacher* (pp. 193-205). New York: Pergamon.
Moje, E. B. (2006). Motivating texts, motivating contexts, motivating adolescents: examination of the role of motivation in adolescent literacy practices and development. *Perspectives*: 10-14.
Moje, E. B. (2007). Developing socially just subject-matter instruction: A review of the literature on disciplinary literacy teaching. *Review of Research in Education* 31: 1-44.
Morrell, E. (2006). Critical participatory action research and the literacy achievement of ethnic minority youth. In J. V. Hoffman, D. L. Schallert, C. M. Fairbanks, J. Worthy, and B. Maloch (Eds.), *55th Annual Yearbook of the National Reading Conference* (pp. 1-18). Oak Creek, WI: National Reading Conference.
National Institute for Literacy. (2007). *What content-area teachers should know about adolescent literacy*. Washington, D.C.
National Council for the Social Studies. (2007). NCSS calls for change as the nation's report card predicts trouble ahead for the next generation and of citizens and a healthy democracy. Retrieved May 21, 2007 from http:/./www.ncss.org/newsItems/viewFullItem$1168.
Nokes, J.D., Dole, J. & Hacker, D.J. (2007). Teaching high school students to use heuristics while reading historical texts. *Journal of Educational Psychology, 99*(3), 492-504.
Paxton, R. J. (2002). The influence of author visibility on high school students solving a historical problem. Cognition and Instruction, 20(2), 197-248.
Rouet, J., Favart, M., Britt, M. A., & Perfetti, C. A. (1997). Studying and using multiple documents in history: Effects of discipline expertise. *Cognition and Instruction, 15*, 85-106.
Rouet, J., Britt, A. M., Mason, R.A., & Perfetti, C. (1996). Using Multiple Sources of Evidence to Reason about History. *Journal of Educational Psychology, 88*(3), 478-493.
Shanahan, T. & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content-area literacy. *Harvard Educational Review*, *78*, 40-61.
Smagorinsky, P. (2008). The method section as conceptual epicenter in constructing social science research reports. *Written Communication, 25,* 198-226.
Stahl, S., Hynd, C., Britton, B., McNish, M., & Bosquet, D. (1996). What happens when students read multiple source documents in history? *Reading Research Quarterly, 31*(4)*,* 430 – 456.
Stake, R. E. (2006). *Multiple case study analysis*. New York: Guilford.
van Leeuwen, T. (2005). *Introducing social semiotics*. London: Routledge.
VanSledright, B. A., & Kelly, C. (1998). Reading American history: The influence of multiple sources on six fifth grades. *The Elementary School Journal, 98*, 239-265.
Wiley, J. & Voss, J. (1999). Constructing arguments from multiple sources: Tasks that promote understanding and not just memory for text. *Journal of Educational Psychology*, *91*(2), 301-311.
Wineburg, S. S. (1991a). On the reading of historical texts: Notes on the breach between school and the academy. *American Educational Research Journal, 28*, 495-519.

Wineburg, S. S. (1991b). Historical problem solving: A study of the cognitive processes used in the evaluation of documentary and pictorial evidence. *Journal of Educational Psychology, 83*, 73-87.

Wineburg, S. S. (2001). *Historical thinking and other unnatural acts: Charting the future of teaching the past.* Philadelphia: Temple University Press.

Wineburg, S. (2004, March). Crazy for history. *The Journal of American History*, vol. 90, no. 4. Retrieved October 30, 2006 from http://www.historycooperative.org/journals/jah/90.4/wineburg.html.

Wineburg, S. & Martin, D. (2004, September). Reading and rewriting history. *Educational Leadership* 62 (1): 42-45.

Wolfe, M. & Goldman, S. (2005). Relations between adolescents' text processing and reasoning. *Cognition and Instruction, 23*(4), 467-502.

Social construction of mathematical meaning through collaboration and argumentation

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Symposium overview

The mathematics education research community has considerably evolved during the two last decades towards and within a socio-cultural approach (e.g., Cobb & Bauersfeld, 1995). This approach has first led to fine-grained descriptions in which they could identify specific entities that are central to learning processes in classroom contexts. For example, they identified *socio-mathematical norms* (Yackel & Cobb, 1996) and important practices such as *collective argumentation* (Krummheuer, 1995) or *collective reflection* (Cobb & Yackel, 1996) that are central for understanding learning in classroom contexts. These theoretical tools have helped in describing learning processes in specific social settings (Hershkowitz & Schwarz, 1999). Also, anthropologists have elaborated methodological tools for describing mathematical activities in a succession of activities (see for example, Saxe et al., 2009 for a methodology for describing the 'travel of ideas' through observation of the transformation of form and function of artifacts).

Finally, researchers in mathematics education have adopted a design research approach to elaborate successions of activities in which they used the methodological tools developed to envisage desirable outcomes and values (Cobb, Sophian, et al., 2001; Hershkowitz et al., 2002). Among the central desirable practices, talk practices (e.g., Sfard, 2008) and collaborative practices (e.g., Hoyles & Healey, 1995). In another tradition, scientists from the Computer Supported Collaborative Learning (CSCL) community also shares talk and collaboration practices as settings that promote learning. CSCL scientists have recognized that these practices are not easy to trigger and have subsequently elaborated computerized tools that afford desirable practices (Stahl, Koschman & Suthers, 2006). For example, Suthers (2003) has shown that computerized tools provide *representational guidance* that deeply affects collaborative practices. The CSCL community has developed an impressive number of environments for triggering collaborative and argumentative practices.

This symposium is intended to present perspectives from the two communities in order to understand in depth some key issues in mathematics education. The three contributions of the symposium focus on successive activities that include collaborative and argumentative practices. This kind of focus invites in-depth analyses of learning processes that involve meaningful changes. The following themes emerge from the three contributions:

1. The transformational character of argumentation/collaboration in successive activities
2. Novel ways to mediate the social production of meaning: In Stahl's contribution, these are the multiples channels and mathematical representations that enable the synchronous coordination of actions among dyads; For Rasmussen, Zandieh and Wawro, these are the brokering moves of the teacher; For Hershkowitz, Schwarz & Azmon, these are distinctive talk patterns that propagate in individual and unguided activities.
3. The central role of the design of the learning unit towards productive interactions.

Each of the contributions provides a methodology for a fine-grained follow-up of the unfolding of production of mathematical meaning. Stahl extends discourse analysis methods to synchronous multi-channel communication; Rasmussen, Zandieh and Wawro adopt a cultural-historical activity theory approach to study the transformations of boundary objects between activity systems; Hershkowitz, Schwarz and Atzmon integrate between interactional analyses with inferential statistics to study the effects of kinds of structuring adopted by teachers during their interactions with students on the ways students engage in these interactions and on their argumentative ability in the collective discourse and individual tasks.

References

Cobb, P., & Bauersfeld, H. (1995). *The emergence of mathematical meaning*. Hillsdale, NJ: Erlbaum.

Cobb, P., Stephan, M., McClain, K., & Gravemeijer, K. (2001). Participating in classroom mathematical practices. *The Journal of the Learning Sciences, 10*(1&2), 113–163.
Cobb, P., & Yackel, E. (1996). Constructivist, emergent, and sociocultural perspectives in the context of developmental research. *Educational Psychologist, 31*, 175–190.
Hershkowitz, R. & Schwarz, B. B. (1999). The emergent perspective in rich environments: Some roles of tools and activities in the construction of sociomathematical norms. *Educational Studies in Mathematics, 39*, 149-166.
Krummheuer, G. (1995). The ethnography of argumentation. In P. Cobb & H. Bauersfeld (Eds.) *The Emergence of mathematical meaning: Interaction in classroom cultures*. Hillsdale, NJ: Erlbaum.
Saxe, G. B., Gearhart, M., Shaughnessy, M., Earnest, D., Cremer, S., Sitabkhan, Y., Platas, L. & Young, A. (2009). A Methodological Framework and Empirical Techniques for Studying the Travel of Ideas in Classroom Communities, In B. B. Schwarz, T. Dreyfus & R. Hershkowitz (Eds.), *Transformation of Knowledge through Classroom Interaction*, (pp. 203-222). London, UK: Routledge.
Schwarz, B. B., Hershkowitz, R. & Prusak, N. (2009). Argumentation and Mathematics. In C. Howe & K. Littleton (Eds.), *Educational Dialogues: Understanding and Promoting Productive Interaction* (pp. 115-141). Routledge.
Sfard, A. (2008). Thinking as communicating: Human development, the growth of discourses and mathematizing. Cambridge, UK: Cambridge University Press.
Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In R. K. Sawyer (Ed.), Cambridge handbook of the learning sciences (pp. 409-426). Cambridge, UK: Cambridge University Press.
Suthers, D. D. (2003). Representational guidance for collaborative inquiry. In: J. Andriessen, M. Baker, and D. Suthers (Eds.), *Arguing to Learn: Confronting Cognitions in Computer-Supported Collaborative Learning environments* (pp. 27-46). Kluwer Academic Publishers.
Yackel, E., & Cobb, P. (1996). Sociomathematical norms, argumentation, and autonomy in mathematics. Journal for Research in Mathematics Education, 27, 458–477.

Computer Mediation of Collaborative Mathematical Exploration

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Two central principles of contemporary learning science theory (Stahl, Koschmann & Suthers, 2006) are:

- Student learning involves *construction* of meaning by the learners (constructivism).
- Learning often takes place originally *inter-subjectively* (socio-cultural theory).

For learning in the discipline of mathematics, these principles imply:

- Student *exploration* of mathematical issues should play a significant role in math education.
- Collaborative approaches should be incorporated, in which *small groups* of students build mathematical understanding together.

The field of computer-supported collaborative learning (CSCL) proposes that these aims could be furthered through the use of networked computers. Online collaboration environments can mediate activities designed to promote math learning in multiple ways. They can provide a workspace, representations of math objects and tools for manipulating the representations, to provide stimulating experiences of math exploration, discovery and meaning making. They can also provide communication media to support productive collaboration and the sharing of knowledge by individuals, small groups and larger communities, such as classrooms and communities of people interested in math.

The Virtual Math Teams (VMT) Project (Stahl, 2009d) is developing an online environment for small groups of students to explore mathematics together. As a result of a design-based research effort at Drexel University since 2003, our software system has evolved to integrate synchronous text chat, shared whiteboard, asynchronous portal and community wiki. Analysis of student interactions in this environment have documented processes of group cognition (Stahl, 2006), which move between graphical, narrative and symbolic modes of collaborative mathematical meaning making (Çakır, Zemel & Stahl, 2009).

We have found that mathematics can be accomplished collaboratively, even by small groups of novice math students helping each other, building sequentially on each other's moves and exploring together, even across sessions (Sarmiento & Stahl, 2008). Virtual math teams can engage in graphical constructions, verbal accounts and symbolic derivation, using conventional methods of interaction adapted to online media, such as methods of social acknowledgment, proposal offerings, deictic references, questioning and agreement. Issues of presence, orientation and embodiment—so important in face-to-face mathematical discourse—remain critical in virtual media, although in transformed ways.

Our approach to computer-supported collaborative mathematics learning is based on the theory that math cognition is at base a matter of math exploration (Livingston, 1999; Lockhart, 2009) and math discourse (Sfard, 2008; Stahl, 2008). Of course, math discourse involves drawings and symbolic expressions as well as terms, propositions and arguments in natural language. According to (Netz, 1999), the origin of mathematical deduction in ancient Greece was a function of the development of labeled diagrams and a specialized math dialect used for asynchronous collaboration. Consider the flowering of Western mathematics through the exchange of text and diagrams on clay tablets and papyrus documents among Euclid's colleagues around the Mediterranean; now imagine analogous digital versions of this within online global communities equipped with specialized computer media and tools.

Based on theories of embodied cognition, distributed cognition, discursive cognition and mediated cognition, we are currently extending the VMT virtual learning environment to support dynamic mathematics. We are integrating the first multi-user dynamic geometry system into VMT. This is a port of the single-user GeoGebra system, which provides coordinated symbolic, graphical and spreadsheet representations of geometric constructions. This will allow online teams of math students to propose, explore and solve problems from algebra, geometry, matrices, trigonometry, conics and elementary calculus. The VMT system is instrumented to capture the entire interaction of these groups for replay and analysis by students, teachers and researchers—allowing the students themselves, their teachers and educational researchers to observe and reflect on actual collaborative math processes.

The design of the VMT software supports scripting of educational activities integrating individual, small-group and community meaning making (Stahl, 2009a). The synchronous textual chat and graphical workspaces are associated with asynchronous wiki pages and web browsers. Curriculum units (Powell, Lai & O'Hara, 2009)—which can be tuned by teachers to classroom circumstances—guide students to explore sequences of open-ended mathematical topics, to pose their own questions, to reflect on multiple problem-solving paths, to bring in mathematical terminology and principles, to summarize their argumentation and to post accounts of their work for other student groups.

As learning-science researchers, we are interested in the details of how math learners make meaning within various learning environments. The VMT system, with its logging and replay facilities, makes visible and persistent the details of the interactions by means of which small online groups co-construct their understandings of mathematical problems and situations. In this symposium presentation, we will take a more detailed and comprehensive look at the interaction data that we began to analyze in CSCL 2007, CSCL 2009 and ICCE 2009 (Koschmann, Stahl & Zemel, 2009; Stahl, 2007; 2009b; Stahl, Zemel & Koschmann, 2009). This is data from Team B during VMT Spring Fest 2006. Three students spent four hours online together discussing, exploring and reflecting upon a number of related pattern problems. We approach this data with a form of interaction analysis based on conversation analysis (Stahl, 2009e). Our new look at the data will extend sequential analysis to consider longer sequences than adjacency pairs—including group-cognitive moves and larger-scale thematic work. It will also look at a more detailed scale to identify different kinds of references—indexical, temporal, semantic and deictic, for instance—that link a given utterance to multiple past postings, drawings, events, resources and future potentialities.

Although chat postings often appear to be chaotic and inscrutable (Stahl, 2009c), it is possible to reconstruct their implicit response structure and to recreate the indexical relations that underlie their ubiquitous deictic references. We can then build up an explicit analysis of the semantic and linguistic structure that was implicit in the student collaboration. (This corresponds to the tacit understanding that participants maintain of the on-going interaction.) From the detailed relationships among lexical elements of the chat postings, we can identify pairs of initiating proposals and responses to them. These can be seen as communicative methods by which the students achieve group-cognitive moves that advance their larger discussion themes. In this way, among others, we analyze the mediation (within computer-based media) of collaborative mathematical exploration. By observing at this unprecedented level of detail the methods by which students actually coordinate their mathematical work and their shared understandings, we can see how collaborative mathematics can take place in a setting like VMT.

We observe and analyze how: students co-construct, communicate, negotiate and make shared sense of math representations (graphical, narrative and symbolic); decide as a group what to do next; inquire about things they do not understand; agree on their joint findings. An understanding of student methods for doing such things deepens our sense of how to design technology to support collaborative math exploration and how to guide, script or scaffold it pedagogically. It also advances our understanding of collaboration as sequential interaction, math exploration as discourse and learning as a social process.

References

Çakır, M. P., Zemel, A., & Stahl, G. (2009). The joint organization of interaction within a multimodal CSCL medium. *International Journal of Computer-Supported Collaborative Learning, 4*(2), 115-149. Web: http://GerryStahl.net/pub/ijCSCL_4_2_1.pdf Doi: http://dx.doi.org/10.1007/s11412-009-9061-0

Koschmann, T., Stahl, G., & Zemel, A. (2009). *"you can divide the thing into two parts": Analyzing referential, mathematical and technological practice in the VMT environment.* Paper presented at the international conference on Computer Support for Collaborative Learning (CSCL 2009), Rhodes, Greece. Web: http://GerryStahl.net/pub/cscl2009tim.pdf

Livingston, E. (1999). Cultures of proving. *Social Studies of Science, 29*(6), 867-888

Lockhart, P. (2009). *A mathematician's lament: How school cheats us out of our most fascinating and imaginative art forms*. New York, NY: Belevue Literary Press.

Netz, R. (1999). *The shaping of deduction in Greek mathematics: A study in cognitive history*. Cambridge, UK: Cambridge University Press.

Powell, A. B., Lai, F. F., & O'Hara, K. (2009). *Supplemental curriculum unit for online, collaborative problem solving in VMT*. Web: http://GerryStahl.net/vmt/combinatorics.pdf

Sarmiento, J., & Stahl, G. (2008). *Extending the joint problem space: Time and sequence as essential features of knowledge building.* Paper presented at the International Conference of the Learning Sciences (ICLS 2008), Utrecht, Netherlands. Web: http://GerryStahl.net/pub/icls2008johann.pdf

Sfard, A. (2008). *Thinking as communicating: Human development, the growth of discourses and mathematizing*. Cambridge, UK: Cambridge University Press.

Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge*. Cambridge, MA: MIT Press. 510 + viii pages. Web: http://GerryStahl.net/mit/

Stahl, G. (2007). Meaning making in CSCL: Conditions and preconditions for cognitive processes by groups. *international conference on Computer-Supported Collaborative Learning (CSCL '07)*. Web: http://GerryStahl.net/pub/cscl07.pdf

Stahl, G. (2008). Book review: Exploring thinking as communicating in CSCL. *International Journal of Computer-Supported Collaborative Learning, 3*(3), 361-368. Web: http://GerryStahl.net/pub/Sfardreview.pdf Doi: http://dx.doi.org/10.1007/s11412-008-9046-4

Stahl, G. (2009a). Designing a mix of synchronous and asynchronous media for VMT. In G. Stahl (Ed.), *Studying virtual math teams* (ch. 16, pp. 295-310). New York, NY: Springer. Web: http://GerryStahl.net/vmt/book/16.pdf Doi: http://dx.doi.org/10.1007/978-1-4419-0228-3_16

Stahl, G. (2009b). *Keynote: How I view learning and thinking in CSCL groups.* Paper presented at the International Conference on Computers and Education (ICCE 2009), Hong Kong, China. Web: http://GerryStahl.net/pub/iccekeynote2009.pdf

Stahl, G. (2009c). Meaning making in VMT. In G. Stahl (Ed.), *Studying virtual math teams* (ch. 26, pp. 505-527). New York, NY: Springer. Web: http://GerryStahl.net/vmt/book/26.pdf Doi: http://dx.doi.org/10.1007/978-1-4419-0228-3_26

Stahl, G. (2009d). *Studying virtual math teams*. New York, NY: Springer. 626 +xxi pages. Web: http://GerryStahl.net/vmt/book Doi: http://dx.doi.org/10.1007/978-1-4419-0228-3

Stahl, G. (2009e). Toward a science of group cognition. In G. Stahl (Ed.), *Studying virtual math teams* (ch. 28, pp. 555-579). New York, NY: Springer. Web: http://GerryStahl.net/vmt/book/28.pdf Doi: http://dx.doi.org/10.1007/978-1-4419-0228-3_28

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 409-426). Cambridge, UK: Cambridge University Press. Web: http://GerryStahl.net/cscl/CSCL_English.pdf in English, http://GerryStahl.net/cscl/CSCL_Chinese_simplified.pdf in simplified Chinese, http://GerryStahl.net/cscl/CSCL_Chinese_traditional.pdf in traditional Chinese, http://GerryStahl.net/cscl/CSCL_Spanish.pdf in Spanish, http://GerryStahl.net/cscl/CSCL_Portuguese.pdf in Portuguese, http://GerryStahl.net/cscl/CSCL_German.pdf in German, http://GerryStahl.net/cscl/CSCL_Romanian.pdf in Romanian, http://GerryStahl.net/cscl/CSCL_Japanese.pdf in Japanese

Stahl, G., Zemel, A., & Koschmann, T. (2009). *Repairing indexicality in virtual math teams.* Paper presented at the International Conference on Computers and Education (ICCE 2009), Hong Kong, China. Web: http://GerryStahl.net/pub/icce2009.pdf

Brokering as a Mechanism for the Social Production of Meaning

Chris Rasmussen, Michelle Zandieh, Megan Wawro

A pressing concern in mathematics education is to reveal processes by which inquiry-oriented classrooms enable learners to explore and develop their own reasoning powers while simultaneously connecting them with the collected wisdom and conventions of the discipline (Cobb & Bauersfeld, 1995; Lampert, 2001). A teacher's role in this process is one that often comes with considerable tension. For example, in her work with elementary school students, Ball (1993) posed the tension in the following way: "How do I create experiences for my students that connect with what they now know and care about but that also transcend their present? How do I value their interests and also connect them to ideas and traditions growing out of centuries of mathematical exploration and invention?" (p. 375). Research in inquiry-oriented undergraduate mathematics classroom reveals similar tensions regarding the role of the teacher and other students in the social production and uptake of ideas (e.g., Wagner, Speer, & Rossa, 2007).

In this report we address the aforementioned pressing concern by identifying the brokering moves of the teacher and some students in an undergraduate mathematics class that functioned as a mechanism for the social production of meaning. From an individual cognitive point of view, there are well-established mechanisms that describe how individuals build ideas. From a social point of view, however, mechanisms that describe how ideas are interactively constituted are less developed. Such mechanisms are significant because they address the complex job of teaching and specific teacher moves that promote the social construction of meaning (Rasmussen & Marrongelle, 2008).

In his seminal work on communities of practice, Wenger (1998) highlights how brokering requires the ability to "cause learning" by introducing into one community elements of practice from a different community (Wenger, 1998, p. 109). We adapt Wenger's work to the classroom and consider three different communities: the broader mathematical community, the local classroom community, and the various small groups that make up the local classroom community. The brokers in these communities are the teacher and specific students in the class. A broker, by definition, is someone who has membership status in more than one community. For example, in our case the teacher is a member of the broader mathematics community, the classroom community, and a peripheral member of each of the small groups that make up the classroom community.

Data for the analysis is drawn from classroom videorecordings collected during a 15-week classroom teaching experiment (Cobb, 2000) conducted in an undergraduate differential equations course. Focusing on a one week sequence that led to the reinvention of a sophisticated inscription known by experts as a bifurcation diagram (Rasmussen, Zandieh, & Wawro, 2009), we identified different types of brokering moves that contributed to the social production of meaning. Each of these brokering moves highlight the view that teaching and learning mathematics is a cultural practice, one that is mediated by and coordinated with the broader mathematics community, the local classroom community, and the small groups that comprise the classroom community.

Close analysis of the function of students' and the teacher's discursive contributions resulted in the identification the following three broad categories of broker moves: creating a boundary encounter, bringing participants to the periphery, and interpreting between communities. In the first brokering move category, creating a boundary encounter, a boundary encounter refers to direct as well as indirect encounters between communities. Moreover, boundary encounters involve boundary objects that serve as an interface between different communities. A broker, by virtue of his or her membership in more than one community, is in a position to bring forth boundary objects that can facilitate encounters between communities. For example, we identified instances when the teacher functioned as a broker between the classroom community and the mathematical community by introducing and constituting tasks that engaged learners in indirectly encountering the mathematical community via their participation in mathematizing (Rasmussen, Zandieh, King, & Teppo, 2005; Schwarz, Dreyfus, & Hershkowitz, 2009). The task, as it was constituted, functioned as a boundary object. Creating a boundary encounter was not limited to the teacher, however. The presentation will detail how one small group's presentation of their work on a task resulted in their creation of an inscription that was new to other students in the class and mathematically quite sophisticated. As such, this inscription functioned as a boundary object between the small group community who created it and the classroom community.

We refer to the second brokering category as bringing participants to the periphery. We follow Wenger (1998) in distinguishing between the terms boundary and periphery. The term boundary is more closely aligned with possible discontinuities between communities, whereas the term periphery is more closely aligned with possible continuities between communities. As such, the brokering move of bringing participants to the periphery is one in which the broker helps members of one community move along a continuum toward another community. For example, brokers are able to draw specific ideas out from a small group community so that these ideas become more accessible to the classroom community. Conversely, brokers are in a position to encourage and promote engagement and reflection by the whole class community in ideas that were put forth by a particular small group community. Our analysis revealed that the teacher was more likely than students to function as broker in this capacity.

The third brokering category we identified, interpreting communities, is one in which the broker makes explicit connections between two communities with respect to how ideas are construed, notated, related, or labeled. In comparison to the first brokering category, creating boundary encounters, this third type of brokering move occurs when a broker takes specific steps to fulfill or realize the opportunities that the creating boundary encounter moves offered. Our examples of this type of brokering move involve both the teacher and specific students as brokers as they interpret between the mathematical community and the whole class community and between the whole class community and various small group communities.

The presentation will illustrate and further clarify each of these types of brokering moves. Implications of these brokering moves for teaching and professional development will also be discussed.

References

Ball, D. L. (1993). With an eye on the mathematical horizon: Dilemmas of teaching elementary school mathematics. *Elementary School Journal, 93*(4), 373-397.

Cobb, P., & Bauersfeld, H. (1995). *The emergence of mathematical meaning*. Hillsdale, NJ: Erlbaum.

Cobb, P. (2000). Conducting teaching experiments in collaboration with teachers. In A. E. Kelly & R. A. Lesh (Eds.), *Handbook of research design in mathematics and science education* (pp. 307–334). Mahwah, NJ: Erlbaum.

Lampert, M. (2001). *Teaching problems and the problems of teaching*. New Haven, CT: Yale University Press.

Rasmussen, C. L., & Marrongelle, K. A. (2006). Pedagogical content tools: Integrating student reasoning and mathematics in instruction. *Journal for Research in Mathematics Education 37*, 388-420.

Rasmussen, C., Zandieh, M., King, K. & Teppo, A. (2005). Advancing mathematical activity: A view of advanced mathematical thinking. *Mathematical Thinking and Learning, 7*, 51–73.

Rasmussen, C., Zandieh, M., & Wawro, M. (2009). How do you know which way the arrows go? The emergence and brokering of a classroom mathematics practice. In W.-M. Roth (Ed.), *Mathematical representations at the interface of the body and culture* (pp. 171-218). Charlotte, NC: Information Age Publishing.

Schwarz, B. B., Dreyfus, T., & Hershkowitz, R. (2009). The nested epistemic actions model for abstraction in context. In B. B. Schwarz, T. Dreyfus & R. Hershkowitz (Eds.), *Transformation of Knowledge through Classroom Interaction* (pp. 11-41). London, UK: Routledge.
Wagner, J., Speer, N., & Rossa, B. (2007). Beyond mathematical content knowledge: A mathematician's knowledge needed for teaching an inquiry-oriented differential equations course. *Journal of Mathematical Behavior, 26*, 247-266.
Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity.* Cambridge, UK: Cambridge University Press.

Distinctiveness of teachers' discourse patterns and their impact on students' emergent and subsequent argumentative activities

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Although many researchers have recommended guidance practices involved with intensive interactions, argumentation and collaboration as effective ways to foster learning gains in classroom (e.g., Webb, 2009), systematic research on influencing student interaction and learning gains through teacher discourse is under-represented. The goal of this research is twofold. We first aim at uncovering patterns of teacher-led talk in the course of a learning unit. We then aim at investigating whether those patterns impinge on the students' commitment to argumentation that emerged in the talk itself, as well as on characteristics of their individual arguments in a consolidation phase, at the end of the learning unit.

Four teachers, in four different schools, and their Grade 8 students participated in the study. The teachers were invited to teach a learning unit in probability carefully designed to encourage productive argumentation. The teachers were left free to choose the way to manage their lessons: we did not stipulate social settings (individual work, [un]guided small group problem-solving, teacher-led discussions, etc.) and did not provide scripts for teachers' structuring of interactions with learners. All lessons were observed, video documented and transcribed. Three episodes in three different lessons where chosen for each teacher for micro-analysis. Each episode was similar for all four teachers. This similarity between the four teachers concerned not only the problem situations involved but comparable length of time of the analyzed episode. Another criterion for the choice of the episodes was episodes that focused on content whose mastery was checked in an individual activity at the end of the learning unit.

A major finding of this study – supported by qualitative and quantitative analysis, is that *teacher-students interactions were governed by patterns*: These patterns were distinctive and relatively stable, for each teacher, beyond the different tasks and lessons that constituted the learning unit. The distinctiveness of each pattern was characterized as follows:

The kinds of challenges initiated by the teacher. For example, the first teacher generally initiated challenges through open questions that invite the expression of elaborated explanations and dialectical moves. In contrast, the second teacher did not challenge students but rather asked closed questions whose answers were clear and expectable.

The patterns identified at a micro-level conveyed socio-mathematical norms at a meso-level: For example, the first teacher adopted a dialogic-dialectical talk (similar to the exploratory talk identified by Mercer, 1987) in which the diverse claims which were raised, were supported by examples or/and explanations and at the same time, were also challenged by examples or explanations in a rich social context. The construction of knowledge emerged from this tension. In the second class, the talk is closer to a cumulative "traditional" talk governed by IRE patterns (Cazden, 2001) in which initiative is almost exclusively in the teacher's hands. This difference between the two teachers is exemplified in following data; while Teacher 1 dedicates 63% of her utterances, in all three episodes, to encourage argumentation (explanation of claims, arguing, raising dialectical dialog, etc…) and 11% to ask for claims only (short answers, declaring facts), Teacher 2 dedicates only 14% of her utterances to encourage argumentation and 49% to ask for claims. Beyond these data, we identified distinctive patterns involving teachers and students across all teacher-led discussions. These patterns and their validation will be presented in the symposium.

Delegation of responsibilities. The socio-mathematical norms that developed in each class impinged at a macro-level concerning the responsibility of students to their knowledge constructing. For example in the class of the first teacher, the challenges of the teacher led students to feel responsibility to provide elaborated explanations. 90%) of the claims expressed by the students in the three episodes were reasoned and eventually turned to full-fledged arguments. In the second class, the elaboration of explanations was not under the responsibility of the students but of the teacher. Only 18% of the students' claims, in the three episodes in class 2, were reasoned. Interactions appeared as chains of short questions and short claims as answers (70% of the students utterances in class 2, were claims and 46% in class 1) punctuated by social validation of correctness. Quite naturally, correctness was valorized rather than processes that led to the (correct) result.

The transformatory character of argumentation. The enactment of dialogic-dialectical talk (like for the first teacher) in a succession of tasks designed to encourage knowledge construction, led students to discuss mathematical principles under the orchestration of the teacher and to co-construct them with the teacher and when left alone in small groups. It turns then that there are strong bonds between teacher-led dialectic argumentative talk and subsequent co-construction of mathematical principles/concepts.

Adaptive planning as an expression of dialogic-dialectic norms. When the teacher aims at the construction of mathematical principles, it impinges on the structure of the lesson. The order of tasks, within the learning sequence, is only a suggestion that the teacher adopts or does not adopt according to her pedagogical considerations. The more confident the teacher is in her contents' knowledge and pedagogical knowledge, the more flexible she is in planning the activities of her students. In contrast, sticking in an orthodox way to a sequence of tasks and to proposed social settings (like for the second and third teachers) suggests that some teachers view educational goals in a bureaucratic way that preserves the authoritative status of the teacher in the class.

A second major finding suggests that the impact of teacher-led argumentative talk in the classroom, on subsequent individual argument elaboration is deep and subtle. We checked the quality, frequency and correctness of the explanations which were given by her students to support their claims at the end of the learning unit. In this posttest a high percent of students in all classrooms answered to the questions on a claim level, and gave explanations as required in the test. While more than half of students in the first class (in which the patterns of interaction between the teacher and the students were dialogical/dialectical) constructed right arguments (including right reasons), less than third does it in the other classes. In addition, in another test item it appeared that answers that interacted with the first teacher, arguments were richer as they contained more idea units per argument.

In the presentation we will present quantitative data and conclusions will be drawn.

The present research suggests the importance of the mediation of the teacher. This mediation seems to be more productive when the teacher acts as an agent that negotiates meanings with students (Hershkowitz & Schwarz, 1999). The argumentative patterns that characterize talk can either give birth to meaningful constructions or to senseless artifacts. Our findings suggest the importance of in-service teachers' programs focusing on the animation of classroom discussions for the sake of the promotion of mathematical reasoning and for delegating responsibility to students on their learning.

References

Cazden, C. B. (2001). *Classroom discourse*: *The language of teaching and learning*. Portsmouth, NH: Heinemann.

Hershkowitz, R., & Schwarz, B. B. (1999). Reflective processes in a technology-based mathematics classroom. *Cognition and Instruction*, *17* (1), 65 – 91.

Mercer, N. (1997). *The guided construction of knowledge- talk amongst teachers and learners.* Clevedon. Philadelphia. Adelaide.

Schwarz, B. B., Hershkowitz, R. & Prusak, N. (2009). Argumentation and Mathematics. In C. Howe & K. Littleton (Eds.), *Educational Dialogues: Understanding and Promoting Productive Interaction* (pp. 115-141). Routledge.

Integrating Philosophy into Learning Sciences Research on Epistemic Cognition

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Abstract: The purpose of this symposium is to provide a forum for exploring how contemporary developments in philosophy can enrich learning sciences research on epistemic cognition (EC). In three papers, we discuss ways in which research on epistemic cognition can profit greatly from closer attention to the philosophical literature. The first paper reviews a broad range of philosophical literature to identify philosophical topics and subtopics which are potentially relevant to research on epistemic cognition but which have not yet been much investigated by EC researchers. The second paper discusses implications of philosophical work for the assessment of epistemic cognition. The third paper discusses implications of recent philosophical work on underdetermination for both assessment and instruction in science education.

Rationale for the Symposium

There has been rapid growth in psychological and educational research on epistemic cognition (EC)—by which we refer to research on people's cognitions related very broadly to knowledge and knowing, including research on learners' personal epistemologies, epistemological beliefs, and their understanding of the nature of science. However, research on epistemic cognition has made relatively little contact with relevant scholarship in philosophy, particularly contemporary philosophy. We think that this lack of contact has had negative consequences for research on epistemic cognition, because the philosophical analyses provide many insights that can enrich EC research.

To determine the extent to which educators cite philosophical works, we examined 128 articles addressing EC in six major educational journals from 2004 through 2008 (*Journal of Educational Psychology, Contemporary Educational Psychology*, *Educational Psychologist, Science Education, Journal of Research in Science Teaching, Journal of the Learning Sciences,* and *Cognition and Instruction*). The modal number of philosophical citations was 0; the average was about 1. Even fewer of the citations referred to recent developments found in contemporary epistemology and philosophy of science. Contemporary philosophical research raises a variety of important issues and problems that are relevant for research on EC, but it appears to us that EC researchers have not yet much considered this body of philosophical work.

The purpose of this symposium is to explore how contemporary developments in philosophy can enrich learning sciences research on epistemic cognition. We present three papers that highlight a variety of ways in which EC research could be improved by drawing on insights from philosophy.

With its strong commitment to multidisciplinary and interdisciplinary research, the learning sciences are the field of educational research that should be at the forefront of bringing insights from philosophy into research on epistemic cognition. This ICLS symposium will provide a forum for presenting and discussing critical implications of contemporary philosophy (epistemology and the philosophy of science) for educational research. The symposium includes three presentations, each discussing distinct ways in which philosophical research can help learning sciences researchers expand and improve research relating to epistemic cognition. The discussant will be James Blachowicz, a philosopher, who will comment further on implications of philosophy for educational research.

We think that philosophical insights have the potential to transform EC research in at least four different ways. We describe each below.

1. Scope of Issues Addressed in Research on Epistemic Cognition

In the first paper, we argue that philosophers have discussed *many* epistemological issues that should be of interest to EC researchers but that EC researchers have seldom or never addressed. For example, philosophers ask manifold questions about social dimensions of knowledge and about reliable processes for producing knowledge (e.g., Goldman, 1986, 1999), but researchers have not addressed human cognitions related to these and many other topics. Thus, attention to philosophy can dramatically expand the scope of dimensions of issues that EC researchers address.

2. Conceptualization of Important Epistemic Constructs

On many EC topics, philosophical work provides insights into how important dimensions of epistemic cognition should be conceptualized or analyzed. For example, we argue in the second paper that philosophical work indicates that relativism should be defined differently from the way in which EC researchers have defined it, and—as a result—EC research falls short of providing adequate evidence for their claims that people in certain stages of epistemic development are relativists.

3. Formats for Assessments

Recent developments in contemporary epistemology have strong implications for the development of assessments of personal epistemology and understanding of the nature of science. Many EC researchers have employed interviews or questionnaires that ask students to reflect on fairly abstract statements (see Hofer & Pintrich, 2002). Recent philosophical work, including new trends in experimental philosophy, challenges the usefulness of such measures and argues for more contextualized approaches to assessment. These issues are a main focus of the second paper.

4. Goals for Instruction

The philosophical literature provides insights into new goals for instruction. For example, we note in the first paper that social epistemologists have discussed processes in the media that reliably produce true beliefs as well as processes that do not (e.g., Goldman, 1999). Given the importance of the media in influencing the formation of beliefs in a society, this suggests that understanding the "nature of media" is an important form of epistemological knowledge, one that has been little studied by educational researchers. As another example, the review in the third paper of the philosophical literature on underdetermination suggests new goals for science instruction that will provide science students with more powerful tools for resolving conflicts between competing knowledge claims.

Overview of Session

A central goal of the session is to provide a forum to begin discussing philosophical work relevant to the learning sciences and the implications of this work for research on epistemic cognition. Our hope is that greater contact between philosophy, psychology, and education will inspire psychological and educational research both on new topics and subtopics relevant to personal epistemologies as well as on new approaches to addressing some of the topics that have already been investigated. We believe that this symposium could help spur the initiation of productive new lines of research on epistemic cognition.

The session will begin with three presentations reviewing philosophical research with a focus on applications to educational issues. Clark Chinn will present findings from a very extensive review of the range of epistemological topics addressed in contemporary philosophical research. He shows that philosophers have discussed many topics that are highly relevant to EC research but that have so far been neglected in educational research. Luke Buckland will review the same corpus of philosophical books and journals with a focus on implications for assessments of personal epistemology and understanding of NOS. Ala Samarapungavan will review the philosophical literature on underdetermination and discuss critical implications for the design of science instruction as well as the design of instruments to measure students' understanding of the nature of science. The discussant will be James Blachowicz, a philosopher of science at the University of Loyola in Chicago. He will discuss further philosophical issues that educators may want to consider, as well as comment on the issues discussed by the three presenters. The session will conclude with a period of time for extended, in-depth discussion with the audience about these interdisciplinary issues.

Papers

Paper 1: Broadening the Scope of Research on Epistemic Cognition: Implications from Epistemology and Philosophy of Science

Presenter: Clark A. Chinn, Rutgers University

Goals

This paper presents a review of important topics addressed in philosophical literatures in epistemology and philosophy of science. An important goal is to identify important epistemological topics that have heretofore been neglected by research on epistemic cognition (EC). Currently, many researchers have focused on the following components of epistemic cognition: the nature and structure of knowledge (including theories and laws or the complexity of knowledge), the certainty of knowledge, and the sources and justification of knowledge (e.g., Hofer &

Pintrich, 1997; Lederman et al, 1992). Philosophical scholarship suggests other components that should be considered as part of epistemic cognition, and we aim to identify some of these components.

Philosophical Works Reviewed

The review of philosophical work surveys two voluminous literatures that discuss epistemological topics: analytic epistemology and the philosophy of science. To identify epistemological topics of potential interest to EC researchers, we analyzed epistemological topics and subtopics covered in 8 recent handbooks and anthologies of epistemology and 8 recent handbooks and anthologies of philosophy of science; in 5 years of each of 10 philosophy journals; and in 150 significant books in contemporary epistemology and philosophy of science. From all these sources, we compiled and structured a large list of epistemological topics addressed in the philosophical literature.

Topics Addressed in Philosophical Works and Some Implications for

The topics and subtopics identified in the review were grouped into six categories, which are summarized and discussed briefly below. Within each of these six broad categories, there are many new topics that are worthy of EC research but that have received little or no attention as yet from EC researchers. A few of these are discussed below.

1. Knowledge and other epistemic attainments and their limits. EC researchers have tended to define epistemic cognition as cognition related to the nature of knowledge and its justifications (e.g., students' beliefs about what knowledge is and how knowledge is justified). However, an examination of what epistemologists actually study reveals that their investigations encompass much more than just these topics. Epistemologists do not focus only on knowledge, but rather aim to explicate a large network of epistemic phenomena and their interrelationships, including *knowledge*, *belief*, *acceptance, understanding*, *wisdom, epistemic virtues and responsibilities, rationality, emotion, information, objectivity, meaning, explanation, model, theory, truth, "truthlikeness," consensus, memory, testimony, perception, observation, subjectivity, objectivity, justification*, *warrant*, *explanation, evidence, standards, inquiry, methods, aims*, and many others (e.g., Goldman, 1986, 1999; Kvanvig, 2003; Zagzebski, 1996). Thus, following the practice of philosophers, EC researchers can investigate students' ideas and practices related to many diverse concepts besides knowledge and justification. Philosophers treat these topics as highly interconnected. This suggests to us that epistemic cognition should be treated as a system of interconnected cognitions—or as an *epistemic network*. If we assume that different aspects of this network may be activated at different moments (Rosenberg et al., 2006), the network could be best viewed as a dynamic epistemic network.

2. Epistemic and nonepistemic aims, values, and virtues. One core topic discussed by philosophers is what kinds of epistemic *aims* there are (e.g., true beliefs, knowledge, understanding, good explanations that fit the data—whether true or not—and so on). Another topic is the extent to which people actually adopt epistemic aims. Some have argued that epistemic aims are of little interest to most people, who seek instead aims such as happiness and family welfare (e.g., Stich, 1990). Other philosophers argue that epistemic aims are important because they are highly conducive to achieving nonepistemic aims, as when accurate knowledge of how to eat healthily is conducive to family welfare (e.g., Bishop & Trout, 2005). Philosophers also investigate issues related to *epistemic virtues*, including what human traits should be regarded as epistemic *virtues* (e.g., intellectual courage) or *vices* (e.g., intellectual laziness) and what people's epistemic *obligations* are (Montmarquet, 1986; Zagzebski, 1996).

This set of topics discussed by philosophers raises many relatively unexplored issues for EC research. Few studies have examined students' epistemic aims or their epistemic cognition related to topics such as epistemic virtues, vices, and responsibilities. EC researchers could examine what epistemic aims students adopt and what kinds of epistemic virtues and vices students exhibit in their practices (e.g., whether they exhibit virtues such as intellectual courage and intellectual carefulness during inquiry experiences). EC researchers could also present students with vignettes posing dilemmas related to intellectual virtues and obligations, such as vignettes directed at finding out how well informed students think citizens are obligated to be about issues such as global warming.

3. Sources and justification of knowledge and other epistemic attainments. The third category of epistemological topics we consider include the *sources of knowledge* (and of other epistemic attainments) and *justifications* for claims of knowledge or belief. EC researchers have extensively investigated students' beliefs about the sources of knowledge, particularly authority and experience. Many philosophers frame these sources differently (e.g., they break *experience* into different kinds of experiences such as *perception*, *introspection,* and *reasoning*; and they view *authority* more broadly as *testimony*, which is often viewed as a necessary and positive source of most of human knowledge) (e.g., Lackey, 2008). This suggests new EC investigations that address sources such as these.

Philosophical research on justification addresses a wide variety of issues that go beyond the typical EC focus on whether people justify knowledge using experience, authority, evidence, and the like. Philosophical research addresses many other issues, including the foundations (if any) of belief, the role of coherence in justification, whether and how the validity of methods of inquiry can be justified, basic reasoning schemes such as induction and abduction, contextual standards that may be used for justification, and the nature and varieties of evidence. Many of these topics are likely to be fruitful topics for EC research, as well. We think that a particularly useful avenue of research will be to investigate the standards or criteria that students employ and can articulate for evaluating theories, evidence, and arguments. (Paper 3 provides examples of criteria for evaluating theories.)

4. Disagreement. The category of disagreement encompasses philosophical work on the causes of disagreement and their prospects for rational resolution. Much of this work is in philosophy of science, where a large literature has arisen in response to the arguments of philosophers such as Thomas Kuhn (1962) that proponents of rival theories have different epistemic practices and standards that cannot be resolved by any rational means. Many of the philosophical works that *are* cited by EC researchers are works that tend to deny that rational, data-driven theory choice is possible in science. However, our review highlights the work of many different post-Kuhnian philosophers who have argued against radical views, and these philosophers are cited much less frequently in the EC literature (e.g., Boghossian, 2006; Haack, 2003; Kitcher, 1993). We therefore suggest that EC researchers could find new directions for EC research in a broadened exploration of post-Kuhnian philosophy of science. This research has developed new ideas about the strategies used by scientists to make rational decisions despite the threat that theories are underdetermined by data. It would be of great psychological interest to consider students' epistemic cognition in light of these new ideas. These issues are discussed in greater depth in Paper 3 of this symposium.

5. Causal processes that produce knowledge. Reliabilism is an influential contemporary epistemological theory which analyzes knowledge in terms of the reliable causal processes that produce true beliefs (e.g., Goldman, 1986). For reliabilists, epistemology investigates all aspects of the causal processes by which true beliefs are reliably produced, including the generation of new ideas (discovery or invention), inquiry methods (methodology and epistemic practices), methods of resolving disagreement and achieving consensus, and so on (Bishop & Trout, 2005; Kornblith, 2003). It would be difficult to overemphasize the degree to which reliabilism expands the scope of epistemology (and hence the potential scope of EC research). Reliabilism suggests that people's ideas about various processes that facilitate or impede true beliefs (memory processes, perceptual processes, processes by which groups and institutions produce knowledge, etc.) should be viewed as part of epistemic cognition. In line with these ideas, EC researchers can examine students' ideas about topics such as when the processes underlying vision are and are not trustworthy, how to make observations in a reliable way, how research should be conducted in order to reduce chances of erroneous findings, when people's testimony can be trusted and when it cannot, and so on (Goldman, 1986; Haack, 2003). Research into people's ideas about such matters may illuminate much about how they endeavor to produce knowledge and how they evaluate knowledge claims.

6. Social epistemology. The final category of epistemological topics discussed by philosophers addresses the social dimensions of knowledge and other epistemic attainments (Coady, 1992; Goldman, 1999; Kusch, 2002). The subtopics in this category are too numerous to enumerate in this brief summary. One topic of particular interest concerns students' understanding of reliable social processes for producing knowledge, such as people's understanding of journalistic and media processes that tend to enhance knowledge of significant truths in a society versus those that tend to spread falsehoods. More generally, EC researchers can investigate people's epistemic cognition in relation to a wide variety of putative knowledge-producing processes, ranging from how groups can be best organized to generate knowledge to how the formal policies and sanctions of institutions affect knowledge-producing processes of their members. Despite the intense interest by educators in social and sociocultural theories of learning, it seems to us that most EC research has focused on individualistic dimensions of epistemic cognition, so that there is a great need for research into the social dimensions of epistemic cognition.

Our research suggests that epistemic cognition encompasses a broader diversity of topics than many previous researchers have considered. We propose as a working hypothesis that students' epistemic cognition be viewed as a network of interconnected cognitions clustered into these categories: (a) epistemic aims, (b) cognitions related to the nature and structure of knowledge and other epistemic achievements such as understanding, (c) the sources, and justification and certainty of knowledge; (d) epistemic virtues, vices, and responsibilities; (e) good and poor processes of achieving epistemic aims (including cognitive processes, methods of inquiry, and social processes); and (f) social as well as individual features of epistemic cognition.

Paper 2: Implications of Philosophy for Assessing Epistemic Cognition

Presenter: Luke A. Buckland, Rutgers University

Objectives & Theoretical Framework

Educational researchers in the fields of "Personal Epistemology" (PE) and the "Understanding of the Nature of Science" (UNOS) suggest that attending to learners' ideas about the nature, sources and limits of knowledge promises a better account of cognitive development and real prescriptions for improving educational practice (e.g.

King & Kitchener, 1994; Hofer and Pintrich, 2002; Lederman et al., 2002). These research efforts share at least three central aims: (1) Expose the epistemic frameworks implicit in cognition and learning; (2) Ascertain the relations between these frameworks and the activities of formal and informal learning environments; and (3) Design targeted instruction for the effective and reliable improvement of students' epistemic cognition. The assessments used to investigate epistemic dimensions of learning are clearly crucial to the achievement of each of these goals—both for accurately charting psychological attitudes and dispositions, and for measuring instruction-driven change. In paper 1, we explored ways in which the contemporary philosophical literature might represent a considerable yet under-exploited resource for research on new components of epistemic cognition. This study focuses on the design of the instruments used in this research, reviewing these in light of insights from philosophical practice.

Methods

A broad range of PE and UNOS research assessments are reviewed, with a particular focus on written and verbal questionnaire formats. Assessments are critically analyzed in terms of the scope of the philosophical issues they address, as well as in terms of the ways in which their constituent questions are formulated. New and modified assessment items are suggested for both PE and UNOS research, as informed by consideration of the psychology of survey response and the philosophy literature described in Paper 1 of this symposium. Finally, alternate methods for eliciting and measuring epistemic cognition are considered.

Results

The assessments used in UNOS research cover a very broad range of topics, many of which overlap in complex ways and resist straightforward classification. Although PE instruments do present students with a fairly diverse set of questions, there are fewer of them, and correspondingly fewer dimensions of epistemic attitudes surveyed (e.g., the role of experience and authority as sources of knowledge, the certainty of knowledge attributions, etc.). PE assessments generally do not display the scope and fine-grained coverage of UNOS assessments, and would particularly benefit from a much greater engagement with research in epistemology. Paper 1 in this symposium canvasses a very large number of topics and subtopics that epistemologists have considered important, and many of these have not yet been subject to psychological investigation.

Resources from philosophy provide for the improvement of several existing educational research constructs. For example, consider a student who hears about two sets of experts with persistent disagreement on the safety of a food additive, and who concludes that "both groups of experts are right" (King & Kitchener, 1994). This kind of response is traditionally identified as "relativist." However, variation in the semantic role of "safe" may well influence the student's pattern of responses, with any sensitivity to the interest-relative meanings of "safe" leading to the ascription of relativism. Further, assessment items are insufficiently sensitive to *ontological relativism* (i.e. that there is no objective fact, or truth, of the matter) versus *epistemological relativism* (i.e. that it is not possibly to objectively compare methods, reasons, and justifications). Finally, students may well commit to an uncontroversial *descriptive relativism* (i.e., that different communities can disagree about what is true or justified) without also committing to a fully *normative relativism* (i.e., that there are no objective facts regarding what is true or justified), yet would still be characterized by this research program as "relativist." Alternatively, students might take an approach to knowledge based on verisimilitude, or "truthlikeness" (Niiniluoto, 2002), such that the views of each of the disagreeing expert groups are considered to approximate the truth to some degree, and so to "both be right." This example of a problematic construct is of particular interest, given the popularity of epistemic developmental trajectories in which students are considered to progress from "absolutist" to "relativist" to "evaluativist" stances (e.g., Kuhn & Weinstock, 2002).

A number of items used in UNOS and EC assessments also seem likely to confound ontological, semantic, or social aspects of cognition with epistemic aspects. For example, Greene et al., 2008 correctly note that there is an ontological dimension associated with beliefs about the simplicity of knowledge. However, there is evidence from philosophical practice that beliefs about the simplicity of knowledge have a significant epistemic dimension, as well. Philosophical work provides resources for disentangling epistemological, ontological and semantic dimensions of cognition, and suggests that students' responses to survey questions might imply philosophical stances that may be quite different from what EC researchers have previously assumed.

Assessment items can also be considered in terms of three general levels at which they are presented: (1) reflection on general questions or statements about the nature of science and knowledge; (2) metacognitive reflection on epistemic practice; and (3) engagement in actual epistemic practice. Assessments in both UNOS and PE research are dominated by abstract questions from level 1 (e.g., "What is science?") and so assume that participants have a high degree of introspective access to the epistemic underpinnings of their own cognition. They also assume that students can engage in some fairly sophisticated philosophizing, and that their explicit beliefs about knowledge and science align with their actual epistemic practices. These assessments therefore neglect the role that implicit epistemic attitudes might have on natural deliberation (i.e., deliberation in authentic contexts of inquiry and belief formation) rather than in contexts of involving the rating of agreement with abstract statements about science or knowledge. While a considerable amount of research has been directed at level 3—at revealing students' actual epistemic practices—far less has been directed at level 2, for example, asking students to justify their selection of the better theory and to explain why their justification is a good one.

Perspectives on survey design are also drawn from work in experimental philosophy, a nascent field of study in which surveys are used to explore traditional philosophical problems as well as to map the philosophical attitudes and assumptions of the "folk" (i.e. non-philosophers). Weinberg, Nichols, and Stich's (2001) study is a representative example, assessing variation in epistemic norms within and across cultures. The experimentalist movement in contemporary philosophy has involved a shift from a focus on normative, a priori, and intuition-driven practices in philosophy, towards more descriptive, a posteriori and empirical practices. In particular, this research has downplayed the degree of introspective access participants have to the philosophical underpinnings of their own cognition. Experimental philosophers thus expect that people might engage effectively in an epistemic practice without being able to articulate a good understanding of it; for example, nonscientists might exhibit facility with some of the reasoning practices of science without being able to reflectively articulate what these practices are. This therefore represents a challenge to the educational research communities' reliance on questionnaires that elicit general, abstract beliefs.

Assessments from both UNOS and PE research would thus benefit from a shift in focus from what learners can articulate about their epistemic commitments, towards the study of their epistemic practices when engaged in authentic inquiry. Real benefits are likely to flow from a greater reliance on more detailed vignettes, thought experiments, case-based reasoning, rich and intensive interviews, and real inquiry tasks for both PE and UNOS research.

Conclusions

The philosophical literature represents an excellent and under-utilized resource for educational researchers, both for improving assessments of epistemic cognition and for better interpreting participants' responses. A richer and more authentic set of tasks and environments is likely to enhance assessment, revealing the influence of both implicit and explicit epistemic attitudes during real learning, reasoning and decision-making. An explicit focus on "enacted," contextualized epistemic cognition is therefore likely to enrich research in this area.

Paper 3: Underdetermination in Philosophy of Science and Science Education

Presenter: Ala Samarapungavan, Purdue University

Objectives

The goal of this paper is to provide a theoretical review of the post-positivist literature in the philosophy of science on the underdetermination of theories by evidence. The results of this analysis have implications both for the scope of issues discussed in EC research and for the goals of science instruction.

Modes of Inquiry, Sources, and Theoretical Framework

The methods comprise a theoretical analysis of underdetermination arguments in the philosophy of science and the application of these ideas in science education. A wide range of contemporary philosophical works on underdetermination including recent books and anthologies that address issue related to underdetermination are included in the review. Philosophers of science and sociologists of scientific knowledge whose works are reviewed include Achinstein, Bloor, Cartwright, Clough, Cole, Collins, Daren, Fuller, Galison, Giere, Haack, Hacking, Harding, Kitcher, Knorr Cetina, Kuhn, Latour, Laudan, Longino, Machamer, Mayo, Newton-Smith, Niiniluoto, Pickering, Popper, Solomon, Staley, Thagard, van Fraasen, Wylie, and Zammito. The paper draws especially on Nersessian's work (2002, 2008) on conceptual change in the history of science and on Laudan's (1977, 1990) arguments against the claim that scientific theories are so underdetermined by evidence that the rationality of science is in doubt (e.g., Bloor, 1981; T. Kuhn, 1962). Grounded in these works, the paper discusses postpositivist arguments against the epistemic relativism implied by strong forms of underdetermination in philosophy and identifies situations in which rational theory choice is possible. The theoretical analysis developed from the philosophy of science literature is then applied to the science education literature.

Results and Conclusions

Analyses in the philosophical literature (buttressed by historical case studies) show how disagreements among competing scientific paradigms might be rationally resolved. For instance, Laudan (1977) used historical examples (such as the disagreement between the Cartesians and the Newtonians with regard to whether the earth was a perfect sphere or an oblate spheroid which bulged at the equator and was flattened at the poles) to show that rival paradigms often resolve disagreements at the factual level on methodological grounds because they agree on the relevant methodological rules. Nersessian (2002, 2008) argued that incommensurability arguments of the kind advanced by Thomas Kuhn (1962) are mistaken in focusing excessively on a comparison of the products (i.e. end theories such as Newtonian theory) rather than the cognitive processes of generating and evaluating theoretical alternatives (see also Kitcher, 1993). Boghossian (2006) and other philosophers have argued that there are epistemic standards that can be used to adjudicate between competing theories in situations in which theories are underdetermined by data. The problem that the data themselves may be theory-laden can be ameliorated by strategies that increase the independence of data and theories (Haack, 2003). In short, the review of the philosophical literature discloses many strategies used by scientists to avoid underdetermination in actual practice.

The implications for science education are complex. On the one hand, the normative content of formal school science may be even more underdetermined for students than competing scientific theories are for practicing scientists. For example, while scientists who favor rival paradigms often share methodological norms, the typical science novices in the classroom probably do not. Moreover, students are aware of much less data that constrain theories than scientists are. Thus, available theories may often be genuinely underdetermined for science students. Although many science educators recognize the problem of underdetermination, there has been less success in developing instructional strategies that might reduce specific forms of underdetermination for science learners. There has also been little work on helping students learn epistemic practices that they can use to try to resolve disagreements between competing theories. Our review of the philosophical literature identifies learning goals and instructional strategies for science classrooms. For example, developing and applying methodological standards and epistemic values to theory evaluation and choice should be a specific focus in the design of science learning environments.

Philosophical scholarship provides analytic tools that science educators can use to identify specific forms of underdetermination faced by science learners, to design ways of reducing underdetermination in instruction, and to teach students strategies that can ameliorate problems of underdetermination. In addition, philosophical work points to existing work in cognitive development and conceptual change that successfully addresses problems of underdetermination. For example, cognitive research points to effective instructional strategies that help students understand radically new and incompatible knowledge frameworks that can contribute to problems of underdetermination. Examples of these strategies include refining student intuitions through progressive abstraction (Nersessian, 1992), using bridging analogies (Clement, 1993), and facilitating model articulation with the use of electronic visualization and simulation technologies.

As noted earlier, one way in which scientific theories may be underdetermined for students during science learning is that unlike practicing scientists, students may not share or even be aware of the existence of certain epistemic and methodological standards and practices. For example, the work of cognitive psychologists has shown that non-scientists, especially children, typically do not use methodological strategies such as the control of variables strategy (e.g., Chen & Klahr, 1999) and often focus on gathering confirming evidence in hypothesis evaluation instead of trying to systematically build and evaluate a comprehensive body of evidence that includes a search for potentially disconfirming evidence. Philosophical analyses suggest a wide range of standards for evaluating and choosing among theories in the face of uncertainty; these include evidential criteria (e.g., explaining the broadest array of data), consistency criteria (e.g., internal coherence of the theory; coherence with other accepted theories), criteria concerning the theoretical precision of terms and measures, criteria of testability, methodological standards, simplicity, relevance to practical human needs, and so on. These criteria could be explicitly discussed by students as a way of helping them develop strategies for dealing with situations in which theories are partly underdetermined by data. This is an area that is currently under-analyzed and under-researched in science education. One problem is that many science education researchers fail to pay attention to important differences in methodological and epistemic norms and practices within different areas of science (Samarapungavan, Westby & Bodner, 2006). Helping students understand the epistemic and methodological norms and practices that form the foundation of normative scientific knowledge in different areas of science is critical to reducing underdetermination for students.

References

Bishop, M. A., & Trout, J. D. (2005). *Epistemology and the psychology of human judgment*. Oxford, England: Oxford University Press.

Bloor, D. (1991). *Knowledge and social imagery* (2nd ed.). Chicago, IL: University of Chicago Press. (First edition published 1976)

Boghossian, P. A. (2006). *Fear of knowledge: Against relativism and constructivism*. Oxford, England: Oxford University Press.

Chen, Z., & Klahr, D. (1999). All other things being equal: Children's acquisition of the control of variables strategy. *Child Development, 70,* 1098–1120.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching, 30*, 1241-1257.

Coady, C. A. J. (1992). *Testimony: A philosophical study*. Oxford, England: Oxford University Press.

Goldman, A. I. (1986). *Epistemology and cognition*. Cambridge, MA: Harvard University Press.

Goldman, A. I. (1999). *Knowledge in a social world*. Oxford, England: Oxford University Press.

Haack, S. (2003). *Defending science: Between scientism and cynicism*. Amherst, NY: Prometheus Books.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67*, 88-140.

Hofer, B. K., & Pintrich, P. R. (Eds.). (2002). *Personal epistemology: The psychology of beliefs about knowledge and knowing*. Mahwah, NJ: Erlbaum.

King, P. M., & Kitchener, K. S. (1994). *Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults*. San Francisco, CA: Jossey-Bass.

Kitcher, P. (1993). *The advancement of science: Science without legend, objectivity without illusions*. New York: Oxford University Press.

Kuhn, D., & Weinstock, M. (2002). What is epistemological thinking and why does it matter? In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 121-144). Mahwah, NJ: Erlbaum.

Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago, IL: University of Chicago Press.

Kusch, M. (2002). *Knowledge by agreement: The programme of communitarian epistemology*. Oxford, England: Oxford University Press.

Kvanvig, J. L. (2003). *The value of knowledge and the pursuit of understanding*. Cambridge, England: Cambridge University Press.

Lackey, J. (2008). *Learning from words: Testimony as a source of knowledge*. Oxford: Oxford University Press.

Laudan, L. (1977). *Progress and its problems: Toward a theory of scientific growth.* Berkeley: University of California Press.

Laudan, L. (1990). Demystifying underdetermination. In C. W. Savage (Ed.), *Scientific theories* (Vol. 14, pp. 267-297). Minneapolis: University of Minnesota Press.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of Nature of Science Questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*, 497-521.

Kornblith, H. (2002). *Knowledge and its place in nature*. Oxford: Oxford University Press.

Montmarquet, J. A. (1986). Epistemic virtue. *Mind, 96*, 482-497.

Nersessian, N. J. (1992). Constructing and instructing: The role of 'abstraction techniques' in developing and teaching scientific theories. In R. Duschl & R. Hamilton, (Eds.), *Philosophy of science, cognitive science, & educational theory and practice* (pp. 48- 68). Albany, NY: SUNY Press.

Nersessian, N. J. (2002). Kuhn, conceptual change, and cognitive science. In T. Nichols (Ed.), *Contemporary philosophers in focus* series (pp. 178-211). Cambridge University Press.

Plantinga, A. (1993). *Warrant and proper function*. New York: Oxford University Press.

Stich, S. (1990). *The fragmentation of reason.* . Cambridge, MA: MIT Press.

Nersessian, N. J. (2008). *Creating scientific concepts*. Cambridge, MA: MIT Press.

Niiniluoto, I. (2002). *Critical scientific realism*. Oxford, England: Oxford University Press.

Rosenberg, S., Hammer, D., & Phelan, J. (2006). Multiple epistemological coherences in an eighth-grade discussion of the rock cycle. *Journal of the Learning Sciences, 15*, 261-292.

Samarapungavan, A., Westby, E. L., Bodner, G. M . (2006) Contextual epistemic development in science: a comparison of chemistry students and research chemists. *Science Education, 90,* 468–495.

Stich, S. (1990). *The fragmentation of reason*. Cambridge, MA: MIT Press.

Weinberg, J., Nichols, S., & Stich, S. (2001). Normativity and epistemic intuitions. *Philosophical Topics*, *29,* 429-460.

Zagzebski, L. T. (1996). *Virtues of the mind: An inquiry into the nature of virtue and the ethical foundations of knowledge*. Cambridge, England: Cambridge University Press.

Qualitative, Quantitative, and Data Mining Methods for Analyzing Log Data to Characterize Students' Learning Strategies and Behaviors

Co-Chairs: Ryan S.J.d. Baker & Janice D. Gobert , Worcester Polytechnic Institute

Discussant: Wouter van Joolingen, University of Twente

Presenters: Janice D. Gobert, Worcester Polytechnic Institute
Ryan S.J.d. Baker, Worcester Polytechnic Institute
Roger Azevedo, University of Memphis
Ido Roll, University of British Columbia

Abstract: This symposium addresses how different classes of research methods, all based upon the use of log data from educational software, can facilitate the analysis of students' learning strategies and behaviors. To this end, four multi-method programs of research are discussed, including the use of qualitative, quantitative-statistical, quantitative-modeling, and educational data mining methods. The symposium presents evidence regarding the applicability of each type of method to research questions of different grain sizes, and provides several examples of how these methods can be used in concert to facilitate our understanding of learning processes, learning strategies, and behaviors related to motivation, meta-cognition, and engagement.

Symposium Topic

Increasingly, students' educational experiences occur in the context of educational technology. A trend with importance for the Learning Sciences is that this usage is increasingly being logged in very fine-grained fashions, providing a trace of students' conceptual and strategic learning processes and behaviors. As these data become increasingly available to the broad Learning Sciences research community, in some cases through large public data repositories such as the Pittsburgh Science of Learning Center (cf. Koedinger et al, 2008), researchers are increasingly asking the questions: What can we learn from log data (in particular, what can we learn from log data, that is difficult to learn from other types of log data)? And how can we best learn from log data?

The emergence of the Educational Data Mining conference and journal (cf. Baker & Yacef, 2009) have provided one perspective about how to use log data to study education research questions. In Educational Data Mining, automated methods are used to explore and model educational data. However, researchers have also utilized analytical quantitative methods, such as cognitive modeling (Anderson, 1993) – the production of quantitative models within a cognitive architecture to represent student cognition – and human-driven statistical analysis, to explore log data. Similarly, case study and qualitative analysis methods have been used to explore log data.

In this symposium, we bring researchers experienced in the use of these methods to discuss the relative benefits of each of these categories of method for analyzing log data. We focus the discussion on the methods' use to study students' learning processes, learning strategies, and behaviors related to motivation, meta-cognition, and engagement. The progress in methods for analyzing log files has enabled more sophisticated analysis of how students choose to interact with learning software, in turn allowing fine-grained investigation of which students choose which learning strategies, in what situations these strategies manifest themselves, and how the behaviors impact learning. The set of talks demonstrates how each of these methods can help elucidate learner strategies and processes, and how these impact learning, and then discussion illuminates the relative benefits and drawbacks of each of these methods.

Structure of Symposium and Potential Significance of the Contributions

The symposium, chaired by Ryan Baker and Janice Gobert (Worcester Polytechnic Institute), has four presentations: one by Janice Gobert (using quantitative/statistical and qualitative methods to study the relationship between learner characteristics and inquiry skills), one by Ryan Baker (using educational data mining methods and quantitative/statistical methods to study why students game the system), one by Roger

Azevedo (using qualitative and quantitative/modeling methods to study self-regulated learning processes), and one by Ido Roll (using quantitative/modeling and qualitative methods to study student thinking during invention tasks). The four presentations are followed by commentary from our discussant, Wouter van Joolingen, and in turn by vigorous group discussion as to what research questions each methodology is most appropriate for, and what conditions are necessary for each research method to succeed. For example, educational data mining methods often require significant amounts of data to be utilized, whereas qualitative methods are difficult to scale to massive amounts of data. Similarly, Quantitative/modeling methods enable closer understanding of the constructs being studied, whereas educational data mining methods can support higher construct validity, in terms of supporting closer matches between models and "common sense" notions of the constructs, and can integrate model validation explicitly into the model creation process.

The discussion of the issues are brought into context by the multi-methodological experience of each of the presenters, enabling the presenters to speak with insight on the relative merits of different approaches. Given the mixed-method approaches represented, the symposium contains several examples of how these methods can be used in concert to promote valid and innovative research that is only possible through the analysis of log data.

Each of the presentations concerns work that contributes to a deeper understanding of why specific students choose specific learning strategies or behaviors, and how a student's learning strategies and behaviors impact their learning and/or the depth of their learning. These features make the presentations relevant to attendees for whom the methodological issues are of lesser import.

At the same time, the presentations provide insight as to what types of research questions each type of method can best be used to address, including which ways of using educational data mining methods are optimal, what types of research questions are better addressed through non-automated methods such as cognitive modeling, and when qualitative analysis enables richer understanding than other methods support.

Presentations

Studying the interaction between learner characteristics and inquiry skills in microworlds

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It is broadly recognized that science literacy means that learners have content knowledge, have process skills for conducting inquiry, and have an epistemological understanding of the nature of science (Perkins, 1986). Although this definition prescribes the knowledge ontologies learners need, it is not clear that these forms of knowledge are sufficient to characterize the variance observed in students' scores on conceptual post-test scores. More recently, there has been interest within the intelligent tutoring community in obtaining data on important student characteristics in order to better explain the variance observed in conceptual learning scores.

In this presentation we describe research conducted to study the relationship between learner characteristics and inquiry skills in the Science Assistments project, a free, online, intelligent tutoring system that "assists students while assessing them". The Assistments approach was previously used only in mathematical content domains. The Math Assistments project has been successful at modeling student learning and tutoring students on math skills. Some key findings are: 1) Students' responses to scaffolding are helpful in tracking students' knowledge, and 2) By taking into account the scaffolds requested by students, state scores can be more reliably predicted when compared to using correctness information only. As an extension to this system, the Science Assistments system tutors students on their inquiry skills with the goal of supporting both skill development as well as content knowledge. We have shown that the system can be successfully used to tutor students' understanding of the control for variables strategy (CVS), a key strategy under the larger skill named "design and conduct experiments" (Sao Pedro et al, 2009). In the Science Assistments project, we are also using data on learner characteristics to design individualized instruction and adaptive scaffolding.

In the talk, we discuss qualitative and quantitative-statistical analyses conducted to investigate the relationship between learner characteristics and inquiry skills. Baseline learner characteristic data were gathered from large cohorts of 5th through 8th grade students (n=1000) from three different public middle schools in central Massachusetts. Schools vary in their performance on the state standardized science test (MCAS) from 50% to

90% of students scoring in the "below proficient" category. Our measures for learner characteristics included GRIT, i.e., perseverance (Duckworth & Seligman, 2005), learning orientation, i.e., mastery/performance orientation (Midgley et al, 2000), self-efficacy (Kettelhut, 2007) for science, and epistemologies of models in science (Treagust et al. 2002). Our measures for inquiry learning included students' skills at formulating hypotheses (IV, DV, and a relationship between them), planning and conducting experiments within the learning environment, interpreting data from these trials, and linking data back to their hypotheses. Our results indicate statistically significant relationships between both conceptual post-test knowledge (time1) and conceptual post-test knowledge (time 2) with inquiry skills, adaptive learning (PALS scales 1 & 4), and self-efficacy (for science inquiry and computer use). Results are discussed with regard to the interaction between learner characteristics and inquiry skills.

Educational Data Mining Methods For Studying Student Behaviors Minute by Minute Across an Entire School Year

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In this talk, we discuss how educational data mining methods (cf. Baker & Yacef, 2009), conducted using log files of student use of Cognitive Tutor software for mathematics (Koedinger & Corbett, 2006), have significantly increased our scientific understanding of two behaviors that students engage in. The two behaviors studied are gaming the system and off-task behavior. Gaming the system is defined as attempting to succeed in an interactive learning environment by exploiting properties of the system rather than by learning the material (cf. Baker, Corbett, Koedinger, & Wagner, 2004). Examples of gaming within Cognitive Tutors include systematically guessing or abusing hints. Beyond Cognitive Tutors, gaming the system has been observed in assessment software (Walonoski & Heffernan, 2006), graded-participation newsgroups (Cheng & Vassileva, 2005), and educational games (Miller, Lehman, & Koedinger, 1999; Rodrigo et al, 2007). Off-task behavior (engaging in behavior that does not involve the system or the learning task) has been shown to occur with comparable frequency in Cognitive Tutors and traditional classrooms (cf. Baker et al, 2004). Both off-task behavior and gaming the system have been shown to be associated with poorer learning in Cognitive Tutors (Baker et al, 2004; Baker, 2007).

We discuss two analyses where educational data mining shed light on the nature, causes, and impacts of these behaviors. Each analysis can be considered an example of "discovery with models", where a model developed using educational data mining methods is then applied to a more extensive data set, and utilized to make inferences about how data from factors available in the larger set (additional measures or contextual factors) associate with the predictions from the model (cf. Baker & Yacef, 2009).

In the first analysis, log file data was obtained for 58 students using a Cognitive Tutor for Algebra in 22 topics, across the course of an entire school year. The 58 students solved 73,880 problem steps within the tutoring software, and data on the timing and semantic meaning (wrong, wrong-indicating-misconception, correct, and help; also, the relevant cognitive skill) of their actions was collected. A model validated to accurately infer off-task behavior (cf. Baker, 2007) was applied to each action in the data set. Gaming the system was assessed by "text replays", rapid hand-coding of distilled log files (cf. Baker, Corbett, & Wagner, 2006). An enumeration of the ways intelligent tutor lessons vary from each other was developed via a collaborative design process involving both researchers and practitioners, and was applied to each of the 22 tutor units. The assessments of student behavior and the information on the design of each tutor lesson were combined to discover factors in the design of Cognitive Tutors that predicted the incidence of the behaviors. The resultant models predicted over

50% of the variance in each behavior. One example finding is that problems with many seductive details (cf. Harp & Mayer, 1998) are gamed less, and problems with no cover story at all are gamed less, but problems with sparse ("hokey") cover stories are heavily gamed.

In the second analysis, log file data was obtained for 296 students using a Cognitive Tutor for middle school mathematics in three topics, Geometry, Percents, and Scatterplots. The 296 students solved 72,845 problem steps within the tutoring software, and data on the timing and semantic meaning of their actions (as described above) was collected. Models validated to accurately infer off-task behavior and gaming the system (cf. Baker, Corbett, Roll, & Koedinger, 2008; Baker, 2007) were applied to each action in the data set. Next, we developed logistic regression models to investigate two hypotheses about the mechanisms that led to reduced learning: (a) the behaviors lead to less learning within individual problem steps (immediate harmful impact) and (b) the behaviors lead to overall learning loss due to fewer opportunities to practice (aggregate harmful impact). Our findings suggest that gaming has immediate harmful impact on learning, whereas off-task behavior has aggregate harmful impact on learning.

Deciphering the complex nature of log-file data collected during self-regulated learning with MetaTutor

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MetaTutor is a multi-agent, adaptive hypermedia learning environment that trains and fosters high school and college students' use of self-regulatory processes in the context of learning about science topics such as human body systems. The purpose of the MetaTutor environment is to examine the effectiveness of pedagogical agents (PAs) as external regulatory agents used to detect, trace, model, and foster students' self-regulatory processes during science learning with multiple representations of information. The multi-agent system provides adaptive tutoring based on students' evolving conceptual understanding of the topic and their strategic use of cognitive and metacognitive processes. Each of the four agents is responsible for specific aspects of SRL, including task definition, planning, metacognitive processes, and learning strategies. Based on their specialized roles, each PA has been designed to detect a specific set of SRL processes. For example, Mary the Monitor is in charge of detecting when students deploy metacognitive processes and make metacognitive judgments such as expressing a judgment of learning (JOL; e.g., used in relation to judging one's understanding of the current content) and also in determining the valence (e.g., JOL - or JOL +) associated with the metacognitive judgment. The presupposition of an accurate detection method (by each agent) leads the agent to model the temporal dynamics associated with each SRL process, across all SRL processes, and how they relate to several learning outcomes such as declarative, procedural, and inferential knowledge and mental models of the science topic. This evolving model is then used to foster SRL and content understanding by providing several levels of scaffolding. Instructional scaffolding involves the coordination of other architectural modules of MetaTutor that coordinate and manage the dialogue system between agents and the learner. Instructional scaffolding is provided based on current research on human and computerized tutoring research (Chi et al., 2004; Graesser, D'Mello & Person, in press; VanLehn et al., 2007; Wolff, 2009) and recent studies comparing SRL with ERL (externally-regulated learning; Azevedo et al., 2007, 2008). The types of scaffolding range from having the learner vicariously watch as the agent models the SRL process to having the student use a specific SRL process while being provided with elaborate feedback regarding the effective use of the process (based on Zimmerman & Moylan, in press).

We present quantitative and qualitative analyses of log-file data from a mixed-method study with sixty (N = 60) college students using MetaTutor to learn about the circulatory system. Our analyses focus on the various data analytic techniques used to make inferences from the complex log-file data. The quantitative analyses focus on comparisons between frequency use of SRL processes, duration of SRL processes during learning, amount of time spent on each type of informational source, strategic moves made during each session, navigation patterns, and learning outcomes and their relation to specific type of scaffolding and agent moves during the learning session. We also provide descriptive and qualitative data focusing on the quality and cyclical nature of learners' deployment of SRL processes and the agents' use of ERL processes. Overall, this study stands to contribute to theoretical conceptions of SRL and ERL, examination of the cyclical nature between SRL and ERL, and the role of various scaffolding methods to foster learning. Lastly, we also derive instructional implications for the design of intelligent learning environments.

Analysis of students' actions during online invention activities - seeing the thinking through the numbers.

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Intelligent Tutoring Systems are widely used coached problem-solving environments (Koedinger, Anderson, Hadley & Mark, 1997; VanLehn, Lynch, Schulze, Shapiro & Shelby, 2005). They are successful, in part, due to their ability to give adaptive feedback (Corbett & Anderson, 2001; Koedinger & Aleven, 2007). More specifically, Intelligent Tutoring Systems adapt to students' behavior and knowledge by tracing students' learning trajectories using a cognitive model of the domain (Corbett & Anderson, 1995). A different family of educational technologies supports students during discovery and scientific inquiry tasks (de Jong & van Joolingen, 1998). However, the large solution space in these tasks, among other reasons, make the model tracing approach very hard to design and implement in these environments (van Joolingen, 1999; Veermans, de Jong & van Joolingen, 2000).

In this symposium we discuss data from the Invention Lab, an intelligent tutoring environment for invention tasks in the domain of Variability, built using the Cognitive Tutor Authoring Tools (Aleven, McLaren, Sewall & Koedinger, 2006). Invention tasks are a form of scientific inquiry activities, in which students are asked to invent solutions to novel mathematical problems without prior instruction (Roll, Aleven & Koedinger, 2009; Schwartz & Martin, 2004). In order to tailor the support students receive to their knowledge, the Invention Lab analyzes students' responses and identifies features that are apparent or missing from their solutions. To deal with the unique challenges of inquiry tasks, the lab uses two cognitive models - a metacognitive model of the inquiry process, and a domain-level model of variability. The domain-level model combines two approaches, model tracing (Corbett & Anderson, 1995) and constraint based models (Mitrovic, Koedinger & Martin, 2003), in order to extract the conceptual features of students' solutions. We present qualitative and quantitative results from an in-vivo evaluation of the Invention Lab with 92 students in a public middle school. Specifically, we focus on how the Invention Lab analyzes students' inventions, and how its log files open a window into students thinking, giving us an opportunity to identify a-ha moments at the domain and metacognitive levels as the data unfolds students' learning trajectories.

Discussant

The session discussant is Wouter van Joolingen. Wouter van Joolingen is Professor of Instructional Technology at the University of Twente, The Netherlands. His main research interest is the use of technology to support inquiry learning, which includes the design of cognitive tools to support inquiry processes and modeling with intuitive interfaces, such as freehand drawings. He studies the influence of cognitive tools and/or the interaction with learner characteristics such as motivation and or epistemological beliefs. Currently he is technical coordinator of the European SCY (Science Created by You) project in which science learning is modelled as the creation and exchange of *Emerging Learning Objects*. An important role is seen for pedagogical agents that base their behavior on the real-time analysis of learner interaction data.

References

Aleven, V., McLaren, B. M., Sewall, J., & Koedinger, K. R. (2006). The cognitive tutor authoring tools (CTAT): Preliminary evaluation of efficiency gains. *Proceedings of the International Conference on Intelligent Tutoring Systems*. Berlin: Springer Verlag.

Anderson, J.R. (1993) *Rules of the Mind.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Azevedo, R., Greene, J. A., & Moos, D. C. (2007). The effect of a human agent's external regulation upon college students' hypermedia learning. *Metacognition & Learning, 2(2/3),* 67–87.

Azevedo, R., Moos, D. C., Greene, J. A., Winters, F. I., & Cromley, J. G. (2008). Why is externally-regulated learning more effective than self-regulated learning with hypermedia? *Educational Technology Research & Development, 56(1),* 45–72.

Baker, R.S.J.d. (2007) Modeling and Understanding Students' Off-Task Behavior in Intelligent Tutoring Systems. *Proceedings of ACM CHI 2007: Computer-Human Interaction*, 1059-1068.

Baker, R.S., Corbett, A.T., Koedinger, K.R., Wagner, A.Z. (2004) Off-Task Behavior in the Cognitive Tutor Classroom: When Students "Game The System". *Proceedings of ACM CHI 2004: Computer-Human Interaction*, 383-390.

Baker, R.S.J.d., Corbett, A.T., Roll, I., Koedinger, K.R. (2008) Developing a Generalizable Detector of When Students Game the System. *User Modeling and User-Adapted Interaction*, 18, 3, 287-314.

Baker, R.S.J.d., Corbett, A.T., Wagner, A.Z. (2006) Human Classification of Low-Fidelity Replays of Student Actions. *Proceedings of the Educational Data Mining Workshop at the 8th International Conference on Intelligent Tutoring Systems*, 29-36.

Baker, R.S.J.d., Yacef, K. (2009) The State of Educational Data Mining in 2009: A Review and Future Visions. *Journal of Educational Data Mining, 1 (1),* 3-17.

Beckley, R. (2008). Practice Test for Scientific Inquiry #1 with Scientific Ways of Knowing #1 and #2. Retrieved July 2, 2009, from Robert Beckley's Science Web Page: http://www2.olentangy.k12.oh.us/~robert_beckley/Science%20Web%20Pages/practice%20Summative%20Test2.pdf

Cheng, R., Vassileva, J. (2005) Adaptive Reward Mechanism for Sustainable Online Learning Community. *Proceedings of the 12th International Conference on Artificial Intelligence in Education*, 152-159.

Chi, M. T. H., Siler, S., & Jeong, H. (2004). Can tutors monitor students' understanding accurately? *Cognition and Instruction, 22,* 363–387.

Corbett, A. T., & Anderson, J. R. (1995). Knowledge tracing: Modeling the acquisition of procedural knowledge. *User Modeling and User-Adapted Interaction, 4(4),* 253-278.

Corbett, A. T., & Anderson, J. R. (2001). Locus of feedback control in computer-based tutoring: Impact on learning rate, achievement and attitudes. In J. Jacko, A. Sears, M. Beaudouin-Lafon, & R. Jacob (Eds.), *CHI'2001 conference on human factors in computing systems*. New York: ACM Press.

de Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains . *Review of Educational Research, 68,* 179-201.

Duckworth, A. & Seligman, M. (2005). Self-Discipline Outdoes IQ in Predicting Academic Performance of Adolescents. *Psychological Science, 16(12),* 939-944.

Feng, M., Beck, J,. Heffernan, N. & Koedinger, K. (2008). Can an Intelligent Tutoring System Predict Math Proficiency as Well as a Standardized Test? In Baker & Beck (Eds.). *Proceedings of the 1st International Conference on Education Data Mining*, 107-116. Montreal, 2008.

Feng, M., Heffernan, N.T., & Koedinger, K.R. (2006a). Addressing the assessment challenge in an Online System that tutors as it assesses. To appear in *User Modeling and User-Adapted Interaction: The Journal of Personalization Research (UMUAI).*

Feng, M., Heffernan, N.T, Koedinger, K.R. (2006b). Predicting State Test Scores Better with Intelligent Tutoring Systems: Developing Metrics to Measure Assistance Required. In Ikeda, Ashley & Chan (Eds.). *Proceedings of the 8th International Conference on Intelligent Tutoring Systems*, 31-40.

Gobert, J., Heffernan, N., Ruiz, C., & Kim, R. (2007). *AMI: ASSISTments Meets Inquiry*. Proposal funded by the National Science Foundation (NSF-DRL# 0733286).

Gobert, J., Heffernan, N., Koedinger, K. & Beck, J. (2009). *ASSISTments Meets Science Learning* (AMSL; R305A090170). Proposal funded by the U.S. Dept of Education.

Graesser, A., D'Mello, S., & Person, N. Meta-Knowledge in tutoring. In D. Hacker, J. Dunlosky, & A. Graesser (Eds.), *Handbook of metacognition and education.*

Harp, S.E., Mayer, R.E. (1998) How seductive details do their damage: A theory of cognitive interest in science learning. *Journal of Educational Psychology, 90,* 414-434.

Ketelhut, D. (2007). The Impact of Student Self-efficacy on Scientific Inquiry Skills: An Exploratory Investigation in *River City*, a Multi-user Virtual Environment. *Journal of Science Education and Technology, 16*(1). DOI: 10.1007/s10956-006-9038-y

Koedinger, K. R., & Aleven, V. (2007). Exploring the assistance dilemma in experiments with cognitive tutors. *Educational Psychology Review, 19 (3),* 239-264.

Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education, 8,* 30-43.

Koedinger, K.R. & Corbett, A.T., (2006) Cognitive tutors: Technology bringing learning sciences to the classroom, in *The Cambridge handbook of the learning sciences*, R.K. Sawyer, Editor. Cambridge University Press: New York, NY, 61-77.

Koedinger, K., Cunningham, K., Skogsholm A., & Leber, B. (2008) An open repository and analysis tools for fine-grained, longitudinal learner data. *Proceedings of the 1st International Conference on Educational Data Mining,* 157-166.

Midgley, C., Maehr, M.L., Hruda, L., Anderman, E.M., Anderman, L., Freeman, K.E., Gheen, M., Kaplan, A., Kumar, R., Middleton, M.J., Nelson, J., Roeser, R., & Urdan, T. (2000). *Manual for the Patterns of Adaptive Learning Scales (PALS).* Ann Arbor, MI: University of Michigan.

Miller, C., Lehman, J., & Koedinger, K. (1999). Goals and learning in microworlds. *Cognitive Science, 23,* 305–336.

Mitrovic, A., Koedinger, K. R., & Martin, B. (2003). A comparative analysis of cognitive tutoring and constraint-based modeling. *Proceedings of User Modeling 2003*, 313-322

Pardos, *Z. A.*, Heffernan, N. T., Anderson, B. & Heffernan, C. (2007). The effect of model granularity on student performance prediction using Bayesian networks. *Proceedings of User Modeling 2007.*

Perkins, D. (1986). *Knowledge as design.* Hillsdale, NJ: Erlbaum.

Razzaq, L., Feng, M., Nuzzo-Jones, G., Heffernan, N., Koedinger, K., Junker, B., Ritter, S., Knight, A., Aniszczyk, C., Choksey, S., Livak, T., Mercado, E., Turner, T., Upalekar. R, Walonoski, J., Macasek. M., & Rasmussen, K. (2005). The Assistment Project: Blending Assessment and Assisting. In C. Looi, G. McCalla, B. Bredeweg, & J. Breuker (Eds.). *Proceedings of the 12th International Conference on Artificial Intelligence In Education.* Amsterdam: ISO Press. pp. 635-644.

Rodrigo, M.M.T., Baker, R.S.J.d., Lagud, M.C.V., Lim, S.A.L., Macapanpan, A.F., Pascua, S.A.M.S., Santillano, J.Q., Sevilla, L.R.S., Sugay, J.O., Tep, S., Viehland, N.J.B. (2007) Affect and Usage Choices in Simulation Problem Solving Environments. *Proceedings of Artificial Intelligence in Education 2007*, 145-152.

Roll, I., Aleven, V., & Koedinger, K. R. (2009). Helping students know 'further' - increasing the flexibility of students' knowledge using symbolic invention tasks. *Proceedings of the 31st annual meeting of the cognitive science society*, 1169-1174. Austin, TX: Cognitive Science Society.

São Pedro, M., Gobert, J., Heffernan, N., & Beck, J. (2009). Can an Intelligent Tutor Teach the Control of Variables Strategy for Scientific Inquiry? *Proceedings of the 31st Annual Meeting of the Cognitive Science Society*.

Schwartz, D. L., & Martin, T. (2004). Inventing to prepare for future learning: The hidden efficiency of encouraging original student production in statistics instruction. *Cognition and Instruction, 22(2),* 129-184.

Treagust, D., Chittleborough, G., & Mamiala, T. (2002). Students' understanding of the role of scientific models in learning science. *International Journal of Science Education*, *24(4),* 357-368.

van Joolingen, W. R. (1999). Cognitive tools for discovery learning. *International Journal of Artificial Intelligence in Education, 10*, 385-397.

VanLehn, K., Graesser, A. C., Jackson, G. T., Jordan, P., Olney, A., & Rose, C. P. (2007). When are tutorial dialogues more effective than reading? *Cognitive Science, 31(1),* 3–62.

VanLehn, K., Lynch, C., Schulze, K., Shapiro, J. A., & Shelby, R. (2005). The andes physics tutoring system: Five years of evaluation. *Proceedings of the international conference on artificial intelligence in education*.

Veermans, K., de Jong, T., & van Joolingen, W. R. (2000). Promoting self-directed learning in simulation-based discovery learning environments through intelligent support. *Interactive Learning Environments, 8(3),* 229-255.

Walonoski, J.A. and Heffernan, N.T. (2006). Detection and analysis of off-task gaming behavior in intelligent tutoring systems. *Proceedings of the 8th International Conference on Intelligent Tutoring Systems*, 382-391. Jhongli, Taiwan.

Woolf, B. (2009). *Building intelligent interactive tutors: Student-centered strategies for revolutionizing e-learning.* Amsterdam: Elsevier.

Zimmerman, B. & Moylan, A. (in press). Self-regulation: Where metacognition and motivation intersect. In D. Hacker, J. Dunlosky, & A. Graesser (Eds.), *Handbook of metacognition and education*.

The Learning Sciences as a Setting for Learning

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Abstract: This symposium offers a reflexive examination of the Learning Sciences. We draw upon a variety of empirical data to explore the way the Learning Sciences is a distributed phenomenon, built on assemblages of artifacts, in which cognition is distributed and constructed, and identities are constituted. Our analysis has three steps. First, we explore the learning sciences community as a space in which discourse circulates, concepts are put forward, and specific kinds of objects have become recognized. Central among these objects, of course, is 'learning.' Second, we look in detail at examples of the interactions in which learning scientists do their work. Third, we consider how a learning scientist is formed as a particular kind of person through participation in formative practices of the community.

Overall Focus of the Symposium

The Learning Sciences have been defined as an interdisciplinary approach to the study and the facilitation of learning in real-world settings (Bransford, Barron, Pea, Meltzoff, Kuhl, Bell, Stevens, Schwarts, Vye, Reeves, Roschelle, & Sabelli, 2006; Meltzoff, Kuhl, Movellan, Sejnowski, 2009). Learning Sciences programs frequently include faculty with diverse background and training, from fields that may include cognitive science, psychology, education, machine learning, neuroscience, sociocultural studies, and educational technology. But what kind of setting is the Learning Sciences itself? Through what kind of participation in real-world activities do learning scientists learn how to recognize learning, and what do they learn about it? How does someone learn to be a learning scientist?

This symposium undertakes a reflexive examination of the learning sciences. The presenters consider a range of empirical data to explore the Learning Sciences as a distributed phenomenon, an assemblage of artifacts, a space in which cognition is distributed and constructed, a community in which identity is forged. Our analysis has three steps. First, we examine the official discourse of the Learning Sciences, its texts and announcements, in order to reconstruct the space in which that discourse circulates, to articulate the concepts that are advanced, and to identify the specific kinds of objects that the Learning Sciences recognize. Central among these objects, of course, is 'learning.' Second, we look in detail at samples of everyday interactions among learning scientists in one selected program to see how they do their work. Third, we consider how, in this program at least, a learning scientist is formed as a particular kind (or kinds) of person through participation in formative practices of the discipline.

A number of learning scientists have pointed to the importance of reflexivity in learning. For example, Sawyer (2006) points out in the introduction to his Handbook of the Learning Sciences:

> "Studies of experts show they are better than novices at planning and criticizing their work - both reflective activities.… Based on these findings, and similar findings regarding other school subjects, learning scientists often conceive of the problem of learning as a problem of transforming novices into experts by developing their ability to reflect on their own thinking in these ways" (p. 7).

It is appropriate, then, for learning scientists themselves to be reflective, and work to increase our reflective activities of, and capacities for, examining our own work. One way to do is this by applying some of the techniques of objectification of the Learning Sciences to these sciences themselves.

Indeed, it has been proposed that reflexivity is an important component of all social scientific inquiry, one that is necessary to avoid the "symbolic violence" of imposing the scientists' conceptual framework on the people who are studied, or assuming an intellectual attitude when in fact people are engaged in embodied, practical activity (Bourdieu & Wacquant, 1992). This is not to ignore or deny the challenges involved in any self-reflexive activity. Blumenfeld, Kempler, and Krajcik (2006) note that teachers and students "may not respond well to the idea of reflecting on and revising their work" (p.475), and they point out the importance of finding the right motivators and forms of cognitive engagement to promote a reflexive frame of mind. We hope to demonstrate in this symposium that a reflexive investigation of the Learning Sciences has value.

Major Issues Addressed by the Collected Work

The three presenters will each report on one step of our analysis, though our work has been a collaborative division of labor. The first presenter (Evans) will describe the results of our activities of tracing and mapping the "community of practice" of the Learning Sciences as a dispersed and contested network in which concepts are mobilized to develop claims about specific objects of investigation. The second presenter (Stevens) will add a temporal dimension, reporting both on our reconstruction of this history of this network and on an interaction analysis of an episode of everyday activity in a selected Learning Sciences program. The third presenters (Packer and Maddox) will explore the "techniques of the self" in which students become learning scientists through their participation in such activity. Our intention is that these three steps will lead to a more profound understanding of the Learning Sciences as a form of life: a human activity system that produces knowledge, practices, and people that is, in turn, reproduced and transformed by these people as they apply their knowledge in action.

The Learning Sciences are frequently located in Pasteur's quadrant, that is to say as bridging the division between 'basic' and 'applied' research, as seeking fundamental understanding of scientific problems and at the same time aiming to be beneficial to society at large (Stokes, 1997; Schoenfeld, 1999). The design studies and design experiments advocated by methodologists in our field hold up this "bridging" feature as unique, distinguishing us from disciplines more focused on theoretical conjectures and clinical work, such as cognitive science, neuroscience, and educational psychology (Confrey, 2006). The reflexive examination of the Learning Sciences in this session has the same dual goals. We hope to understand how our interdisciplinary enterprise is functioning - what makes it tick. But we also hope that by identifying key characteristics of the operation of the Learning Sciences - as well as perhaps pointing out some contradictions and obstacles - our analysis can be beneficial in practical ways, and have application to the training of the next generation of learning scientists. The presentations are not intended as external criticism, but rather as an example of circumspection from within, in which practitioners pause to look around at what we are always already doing, to articulate what we see to return to our practice with increased clarity. The three presentations will now be described in more detail in the next sections, a brief overview offered below:

- Presentation 1: Mapping the Network of the Learning Sciences: traces the network of the Learning Sciences and maps its territory, primarily by focusing on the dispersion of concepts in 'official' texts such as program descriptions, course syllabi, and published papers. The various Learning Sciences programs are then located on this map.
- Presentation 2: The History and Micro-Genesis of the Learning Sciences: reconstructs the history of this network and also describes its micro-genesis, through the interaction analysis of an episode of everyday interaction obtained through fieldwork at one Learning Science program selected from the map.
- Presentation 3: The Making of a Learning Scientist: describes how a student becomes a learning scientist, based on the same interaction analysis and interviews with newcomers and old-timers.

Presentation 1: Mapping the Network of the Learning Sciences

The first presentation will explore the Learning Sciences as a form of life and a setting for learning. This presentation traces and maps the networks or assemblages that define the Learning Sciences. Rather than assume from the outset that the Learning Sciences is a coherent, consensual or clearly defined intersubjective space, we treat it first as a geographically dispersed and temporally dynamic network of participants, artifacts, and institutions, and then map this network to see where consensus lies and where there is contestation. As Nespor (1994) has written:

> "interactions and situations are… articulated moments in networks of social relations and understandings, in which our experiences and understandings are actually constructed on a far larger scale than we happen to define for that moment as the place itself, whether that be a street, a region, or even a continent" (p. 3)

Tracing the linkages of the network that is the Learning Sciences is a necessary first step, then, that should be prior to any examination of interpersonal relations or personal understandings. It is increasingly recognized that learning takes place in interactions that are mediated by designed artifacts (Stahl, 2006; Suthers, 2006), and that such artifacts are often arranged in a highly geographically dispersed manner, the extreme case being international virtual teams of academics, researchers, and collaborators (Bichelmeyer, Cagiltay, Evans, Paulas, & Soon, 2005; Evans & Schwen, 2006). There are now Learning Science programs in at least three universities outside the United States (in the Netherlands, the United Kingdom, and Australia), so the network has now grown to this scale. Given the interdisciplinary character of much research in the Learning Sciences it is quite likely that even the simplest arrangement will involve sophisticated linkages.

This first presentation will present the results of our analysis of data from at least twelve recognized Learning Sciences programs. Official program definitions, statements of program goals, syllabi of required courses, and other data provide evidence of the similarities and differences among these programs. In this way, the assemblages of the Learning Sciences can be said to define a space in which discourse circulates. In the form of published papers, oral presentations, research reports, informal messages, and so on, this discourse serves to propose claims about the specific kinds of objects recognized by the learning sciences, using concepts of various kinds. The concepts of the Learning Sciences serve as a vocabulary in which knowledge claims about these objects are proposed, contested, and accepted or abandoned. They offer ways for learning scientists to see the world. Tracing these concepts enables us to see where the Learning Sciences is dynamic and contested, and where it is unified and homogenous.

For example, one of the central concepts of the Learning Sciences is *cognition*, but it is interpreted in a variety of intersecting ways. *Cognition* can be understood as the structures and processes of knowledge, so that the principal goal of teaching and learning is the transformation of cognition. But cognition can also be understood as something situated, practical, and even 'wild' (Hutchins, 1995). On one side there are laboratory-based computer models that aim to simulate human knowledge and skills. On another side are ethnographic studies in which it is insisted that cognition should never be separated from culture. The metaphor of building knowledge is frequently used (Scardamalia & Bereiter, 1994), but individuals interpret this metaphor in different ways with different presumptions about cognition.

A second central concept is that of *social context*. The Learning Sciences tend to emphasize the dynamics of real situations of learning and teaching, in contrast to the laboratory studies of cognitive science. Attention is focused on the complexities of the real world, and on the need for ecological validity in scientific studies. But social context can be construed either as an external factor which has an influence or impact on cognition, or as an intrinsic aspect of cognition, something constitutive of thinking and learning. Social context can be a concept used to refer to specific circumstances, such as the workplace or classroom, or it can be used to refer to everyday life, to the essentially social character of all thought and action. In the latter case, even the laboratory is a social situation.

While these are concepts that surely are inherent to the Learning Sciences, so that without them it would not exist, there are others that one might say demonstrate how the network extends to other areas of the social sciences. One such concept is *mediation*. Mediation is a major tenet of Vygotsky's (1986) account of learning and especially concept development in children, since he proposed that people interact with the world "indirectly" through the use of mediators. In the Learning Sciences the concept has been applied in this way to analyses of how children acquire understandings of the world around them. From this perspective, it is as children use cultural and psychological tools (i.e. signs and symbols) that they acquire higher psychological functions such as analysis and reasoning. This original conception of mediation, though, has been challenged (Wertsch, 2007) and extended to include rules, community, and division of labor (Barab, Evans, & Baek, 2004). What might be claimed is that mediation has taken on a broader, more complex place in the learning sciences, particularly in the digital age (Shaffer & Clinton, 2006).

Vygotsky's texts on cultural-historical development also make use of the concept of *tool*. Vygotsky argued that society's tools, language, signs, and technologies were closely intertwined with their collective levels of cognition. As a result of the integration, how things are done changes, perhaps forever:

> "As soon as speech and the use of symbolic signs are included in this (tool) mediated operation, it transforms itself along entirely new lines, overcoming the former natural laws and for the first time giving birth to authentically human use of implements… speech and actions are in this case one and the same psychological function" (Vygotsky & Luria, 1930/1993, pp. 108-109)

But the concept of *tool* has another lineage in Learning Sciences, one that reflects interests in the cognitive potential and transformative power of technology. For example, Brown, Collins and Duguid (1989) recommended that knowledge be thought of as a set of tools. Tools can be learned only through their use, and in using them the user changes, in particular they come to adopt the belief system of the culture that produced the tools, because "tools and the way they are used reflect the particular accumulated insights of communities" (p. 33). In this way of talking and seeing, learning is a process of enculturation and apprenticeship, a result of being embedded in practical activity that, nonetheless, leads to abstract knowledge.

Finally, the core concept of the Learning Sciences, of course, is *learning*. Here too what we find is, understandably, not consensus but an intersection of efforts to carve out a plausible way of conceptualizing the complexity of people coming to do their work successfully together. To return to the example in the last paragraph, in Brown, Collins and Duguid's way of talking and seeing, learning is a process of enculturation and apprenticeship, a result of being embedded in practical activity that, nonetheless, leads to abstract knowledge. In Vygotsky's texts, in contrast, learning is a process of self-mastery, in which social tools are applied to self. These various positions and perspectives on learning in the Learning Sciences, at times complementary, at times in opposition, reflect to some degree its interdisciplinary character. Is learning a neurobiological phenomenon? Is it a change in internal systems of mental representation? Is it transformation in embodied practical activity? Here the dynamic tension of the Learning Sciences is most evident, and the sources of its creativity and generativity are most apparent.

By tracing these concepts of *cognition*, *social context, mediation, tools* and *learning*, this first presentation will construct a map of the territory occupied by the Learning Sciences, and identify its shifting and contested boundaries. The various Learning Sciences programs can then be located on this map, enabling us to make a principled selection of a program to study in detail in the second and third steps.

Presentation 2: The History and Micro-Genesis of the Learning Sciences

The second presentation introduces a genetic or temporal dimension into our investigation, both historical and micro-genetic. It traces the history of Learning Sciences, reconstructing the genealogy of its origins in the Artificial Intelligence and Education conferences of the 1980s, the founding of the Northwestern University Institute of the Learning Sciences and the Xerox Institute for Research on Learning, the inauguration of the Journal of the Learning Sciences, the newly-named ICLS conference in 1991 and the subsequent alternation of ICLS and CSCL conferences, and the founding of ISLS in 2002.

Roger Schank has argued that it is in stories that humans store and organize knowledge (Schank & Abelson, 1994). The stories that participants tell about the origins of their community of practice offer important insights into the character of that community. This second presentation will draw both on published retrospective accounts of Learning Sciences and on interviews with selected learning scientists or, at least, those who would claim that their work addresses problems important to the learning sciences. One way of telling the story of the Learning Sciences, for example, is as a tale of frustration with cognitive science that led to the birth of the new journal JLS, a "big ideas" journal that has focused on learning in real-world situations, that has explored new perspectives and new methodologies as well as novel uses of technology, and from which a community has grown and matured (Kolodner, 2004).

Another example is Koschmann's (1994, 1996) retelling of the history of "paradigmatic shifts" in learning theory, models of instruction, and research issues. His reconstruction of the origins of computer-supported collaborative learning describes the accumulations and dissolutions that took place as the field moved from its early roots in behaviorism, programmed instruction, and instructional efficacy to socially oriented theories of collaborative learning and instruction as enacted practice (Koschmann, 1996, p. 16).

Like any good evolutionary account, this presentation will pay attention to the fit and mutual constitution of organism and environment (in this case the various niches of the Learning Sciences and its various niches) as well as to the impact of rare but dramatic forces from outside the system. Or, to switch metaphors, like any genealogy, it will pay attention to the orderly arrangements of patrimony and birthright, as well as to the accidental encounters that bring strangers together and lead to unforeseen offspring.

At the same time, a second temporal aspect of the Learning Sciences is the moment-to-moment processes of learning scientists' interactions. Study of face-to-face interaction has become an important methodology for the Learning Sciences (Jordan & Henderson, 1995), and "Many learning scientists study the moment-to-moment processes of learning" (Sawyer, 2009, p. 13). A reflexive investigation of Learning Sciences should not neglect this important aspect of understanding the discipline. Consequently, this second presentation will also report on analysis of a selected episode of everyday interaction. This episode will be obtained through fieldwork in a selected Learning Sciences program. As Nespor (1994) has pointed out, studies of face-to-face interaction need to be informed by knowledge of the network in which they are located, and this will be one way in which the second presentation relates to and is informed by the first.

In short, the second presentation will bring an explicitly temporal dimension to the network of discourse, concepts, and objects that was described in the first presentation, to explore both the history of how it came to assume its current form and the ongoing way in which the network is reproduced.

Presentation 3: The Constitution of a Learning Scientist

The third presentation describes the final step in our analysis. Having traced the network of arrangements that define the community of the Learning Sciences, and having studied in detail both the history of this network and the interactions in which learning scientists do their daily work, we turn to the specific techniques by which people become learning scientists. Here too we are able to turn the tools of the Learning Sciences around and apply them reflexively, for this too has been a topic of interest in the Learning Sciences. Whether it is "peripheral participation," the move from "novice" to "expert," or the formation of "identity," learning scientists have been interested not only in the ways that learning involves construction of knowledge but also the ways it transforms the learner as a person.

Kolodner, for example, has written of LS as a "community of practice" in which a learning scientist is formed as a person with "deep and abiding" beliefs who can "harvest" theories in order to "design" environments. She has pointed out that although the first members of the Learning Sciences community were "immigrants" from the shores of other disciplines and endeavors, new learning scientists are now home grown: "Over the past decade, we've added a generation of young researchers educated by immigrants to the learning sciences as first-generation learning scientists" (Kolodner, 2004).

Graduate training in programs in the Learning Sciences is frequently described in terms that reflect the local theoretical framework. For example, there may be a focus on apprenticeship, as students collaborate with teams working on funded research projects. Such teams are often interdisciplinary, so students have hands-on experience of design and methodology from a variety of perspectives. Coursework may emphasize practical work on projects, closely tied to faculty members' ongoing research. Effort may be made to establish community, in part through informal meetings that are both academic and social, in part through participation in formal events such as conferences and colloquia. Both classroom and research activities may be situated in real-world settings such as workplaces and schools. Finally, students' research may be directed towards the design of learning environments and to the transformation of activity in a real setting.

Such aspects of graduate training can be considered as ways the Learning Sciences has arranged for its reproduction over time, its continued existence through the production of new practitioners who have not only the appropriate knowledge and skills but also the practical know-how and everyday common-sense needed to act as a member. Since Lave and Wenger (1991) coined the phrase "legitimate peripheral participation," if not before, learning scientists have conceived of group membership as the entry not only to new forms of knowledge but also new kinds of identity. As they put it, "one way to think of learning is as the historical production, transformation, and change of persons" (Lave & Wenger, 1991, p. 52), so that "learning thus implies becoming a different person with respect to the possibilities enabled by these systems of relations. To ignore this aspect of learning is to overlook the fact that learning involves the construction of identities" (p. 53). But *identity* is a concept that itself is used in differing ways by different branches of the Learning Sciences discourse. For example, when Greeno (1997) proposed that "students develop patterns of participation that contribute to their identities as learners," Anderson, Reder and Simon (1996) complained, "We really do not know what Greeno means by a student's 'identity as learner,' or to what extent he pictures identity as being subsumed in a 'group identity'" (p. 19). An accord was soon reached (Anderson, Greeno, Reder & Simon, 2000), but still for some, identity is equivalent to self-concept: the conception a person has of him or herself. For others, identity is an aspect of membership, how other participants in a community identify a person. It has been suggested that we conceive of learning as a process in which both people and their form of life are transformed (Packer & Goicoechea, 2000), a transformation with an embodied character, an ontological rather than merely epistemological process.

Whether the transformation is thought of as a peripheral participant becoming non-peripheral, apprentice becoming master, or novice becoming expert, what is of central importance to us is that the work of becoming a learning scientist is public and practical, and so it can be studied. A particular application of interaction analysis, then, is the investigation of participation in those professional activities in which the person is transformed. The third presentation will draw on analysis of both episodes of interaction and interviews, the latter as opportunities to explore the "ontological complicity" that a participant comes to have with their community of practice.

An example of a technique for bringing a student into the Learning Sciences is provided by a research project co-led by undergraduate students at the University of Chicago. The aim of the project was to identify children's communicative strategies when faced with the task of solving a geometric puzzle in a group setting, and so identify their potential for creating 'distributed' cognition in mathematics learning contexts. One data set included two groups of three 8-year-old children, one group of boys and the other of girls, each given a tangram puzzle to solve in two different settings: a physical set-up, using plastic pieces and a board; and a virtual set-up, using a computer and mouse to maneuver the pieces into place on the screen. By examining the children's speech, gestures, gaze and actions, the student researchers explored the points of discursive cohesion that structured the groups' collaborative reasoning throughout the process of solving the problems. Cohesive points were identified as "coreferences," understood as the repeated expression of a single referent (Evans et al., 2009). In this study, the investigators wished to expand the concept of 'coreference' to include both verbal and non-verbal deixis. The result was an expansive rubric for classifying how action, gesture, and speech related to and built upon one another during the problem-solving process. Viewed in terms of the larger goal of developing advanced technologies to facilitate collaborative problem solving in mathematics, such results may lead to new requirements for instructional strategies, technologies, and interventions.

Our point in summarizing this research project is to emphasize that participation in such projects is one important way that students become seasoned scientists. Viewed reflexively, such a project amounts to a communication and learning task *for the researchers*. They must discover how to establish points of discursive cohesion as they observe and talk together about the video-recordings of children's interaction. As they develop a system of classification of children's actions, gesture, gaze and speech, their collective vision of the events they are studying is transformed. The researchers concluded that pivotal moments of interaction occurred when the children directed the development of their collaboration by using meta-commentary about the task itself.

Our reflexive analysis of this kind of example of learning science research amounts to just such a meta-commentary.

In short, this third presentation will focus on the material practices in which learning scientists are constituted, the embodied expertise or habitus they come to have, and how this provides them with the methods (such as interactional devices) that are necessary for them to be successful members of the community.

Connections Among Presentations

In summary, these three presentations work together to describe three aspects of the Learning Sciences considered as a site and activity of learning, and becoming. The first presentation maps the terrain that is defined by the network of people, artifacts and places that constitute the Learning Sciences, the second reconstructs the history of this network and describes the ongoing collaborative work in which it is maintained, while the third explores how one becomes a participant. The search for knowledge will be considered a process of interaction among members, and a practice in which newcomers become old timers. We hope that we have shown how the parts of this symposium fit together to create something that is more than their sum.

Potential Significance of the Contributions

Where are the Learning Sciences at this moment? In what direction is the field going? Which questions have been asked and answered successfully, and which questions apparently resist solution? What questions need to be addressed in future work? What is the problematic from which these questions arise?

These are *our* questions about the Learning Sciences, and in this symposium we will begin to answer them. In a paper titled "Learning for anything everyday," Heath and McLaughlin (1994) discussed pedagogical authenticity and presented their ethnographic research on fields of informal learning. They offered two conclusions that are relevant to any focus on the inter-relationships of participation in diverse communities. The first is that authenticity cannot be artificially created. The second is that, nevertheless, it is possible to create supportive organizational or learning environments in which authentic activity is embedded, environments which may increase the likelihood of novice members moving into more sophisticated roles and communal ways of knowing.

Heath and McLaughlin concluded that pedagogical authenticity is to be found in the structure of tools and activities, both current and historical that define participation in a specific community. This suggests that authentic curricula should include access to "the social distribution of knowledge and skills through personal, interpersonal and community working together" (Heath and McLaughlin, 1994, p. 473), and that analyses of this distribution are necessary if we are to understand how people work together in a community. Taking participation seriously means thinking in spatial-temporal terms. Authentic curricula are explicit efforts to provide students entry into the experiences afforded by being part of the historical-material-social geographies of participation. Authenticity also requires relevancy; when institutions such as the Learning Sciences are certainly created, the goals, values, initiatives, and functions of the social organization must be relevant to the day-to-day needs of the participants and communities involved.

Heath and McLaughlin also indentified structural features shared by successful, authentically embedded informal learning fields (cf. Schneider & Evans, 2008), features we will look for in our analysis of Learning Sciences:

1. Organizations serve as border zones: they support active participation in the community while brokering and preparing participants to participate in other organizations. The community's participation shares values, skills, and roles with these other communities.
2. Successful organizations value novices as a resource that contributes much-needed talent, perspectives, and experience. The division of labor is non-hierarchical and there is a strong sense of belonging.
3. All participants contribute to defining problems and finding solutions or to the plan of action. There is intense collaboration, with activity organized around a relevant problem, project, or product.
4. Participants are accountable to each other and to the group.
5. There are few community rules of conduct, but these are strictly enforced.
6. Participants are continuously assessing themselves and each other, and are assessed by people outside the community that they perform for, provide products to, or interact with.

Participants (alphabetical order)

Michael A. Evans – Presentation 1: The Learning Sciences as a Community of Practice

Dr. Evans, an assistant professor in the department of learning sciences and technologies at Virginia Tech, teaches courses and conducts research focusing on the application of human learning theory to the design and development of instructional materials and systems. Graduate courses taught include games and simulations for education, instructional multimedia development, and, perhaps most relevant to the symposium, and introduction to the learning sciences for advanced masters and doctoral students. His publications include *Facilitating guided participation through mobile technologies: Designing creative learning environments for self and others* (Journal of Computing for Higher Education), *Transforming e-learning into ee-learning: The centrality of sociocultural participation* (Innovate: Journal of Online Education), and *Conceptual and practical issues related to the design for and sustainability of Communities of Practice: The case of e-portfolio use in preservice teacher training* (Technology, Pedagogy, & Education).

Jorge Larreamendy, UNIANDES – Chair
Dr. Larreamendy is associate professor and chair of the Department of Psychology at the University of the Andes in Bogotá, Colombia. He was a visiting professor at the Learning Research and Development Center, Pittsburgh. His research interests center on scientific reasoning, informal learning, and learning in communities of practice. His publications include *Going the distance with online education* (Review of Educational Research with G. Leinhardt), *Learning, identity, and instructional explanations* (to appear in Stein & Kucan (Eds.), Instructional explanations in the disciplines).

Cody Maddox - Presentation 3: The Constitution of a Learning Scientist
Cody Maddox is a graduate student in the Department of Psychology at Duquesne University in Pittsburgh.

Martin Packer – Presentation 3: The Constitution of a Learning Scientist
Dr. Packer is an associate professor in the Department of Psychology at Duquesne University in Pittsburgh, and associate professor in the Department of Psychology at the University of the Andes in Bogotá, Colombia. He teaches courses in developmental psychology and qualitative research methodology. He is one of the founding editors of the journal *Qualitative Research in Psychology*, published by Taylor & Francis. He is author of *Changing Classes: School Reform and the New Economy,* and co-editor of *Cultural and Critical Perspectives on Human Development.* His book *The Science of Qualitative: Towards a Historical Ontology* will be published this year by Cambridge University Press.

Keith Sawyer, University of Washington, St Louis – Discussant
Dr. Sawyer is an Associate Professor of Education at Washington University, with additional appointments in the Department of Psychology and the School of Business. He is author of *Group Genius: The Creative Power Of Collaboration* and editor of *The Cambridge Handbook Of The Learning Sciences*. He studies creativity, collaboration, and learning.

Reed Stevens – Presentation 2: Interaction Analysis of the Learning Sciences
Dr. Stevens is Professor of Learning Sciences at Northwestern University. His research interests include learning and activity in a wide range of places and situations; design of learning tools — curriculum, activities, and technologies. Publications include (co-authors cited in reference below) *Foundations and opportunities for an interdisciplinary science of learning* (The Cambridge Handbook of the Learning Sciences).

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References

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher*, 25(4), 5–11.

Anderson, J. R., Greeno, J. G., Reder, L. M., & Simon, H. A. (2000). Perspectives on learning, thinking, and activity. *Educational Researcher, 29*(4), 11-13.

Barab, S. A. Evans, M. A., & Baek, E. (2004). Activity Theory as a lens for characterizing the participatory unit. In D. H. Jonassen (Ed.), Handbook of research for educational communications and technology, (2nd ed, pp. 199-214). Mahwah, NJ: Lawrence Erlbaum.

Bichelmeyer, B.A., Cagiltay, K., Evans M.A., Paulas, T., & Soon, J.A. (2005). Collaboration among multicultural virtual teams: Issues, challenges, strategies. In C. Howard, J. Boettcher, L. Justice, K. Schenk, P. Rogers, & G. Berg (Vol. Eds.), *Encyclopedia of distance learning*, (Vol. 2, pp. 256-263). Hershey, PA: Idea Group.

Blumenfeld, P.K., Kempler, T.M., & Krajcik, J.S. (2006). Motivation and cognitive engagement in learning environments. In K. Sawyer (ed.), *The Cambridge Handbook of the Learning Sciences*, (pp. 475-488). New York: Cambridge University Press.

Bourdieu, P., & Wacquant, L. J. D. (1992). *An invitation to reflexive sociology*. Chicago: University of Chicago Press.

Bransford, J.D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academy Press.

Bransford, J.D., Barron,, B., Pea, R.D., Meltzoff, A., Kuhl, P. Bell, P., Stevens, R., Schwartz, D.L., Vye, N. Reeves, B., Roschelle, J., & Sabelli, N.H. (2006). Foundations and opportunities for an interdisciplinary science of learning. In K. Sawyer (ed.), *The Cambridge Handbook of the Learning Sciences*, (pp. 19-34). New York: Cambridge University Press.

Brown, J.S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Confrey, J. (2006). The evolution of design studies as methodology. In K. Sawyer (ed.), The Cambridge Handbook of the Learning Sciences, (pp. 135-151). New York: Cambridge University Press.

Evans, M.A. & Schwen, T.M. (2006). Chasing a fault across ship and shore: Explaining the context of troubleshooting in the U.S. Navy. *Performance Improvement Quarterly, 19*(2), 211-229.

Evans, M.A., Ryon, E., Feenstra, A., & McNeill, D. (2009). *Discourse coding from a multimodal approach: Distributed cognition & geometric problem solving in young children.* Paper presented at the Alpine-Rendezvous Workshop, November 30 - December 2, 2009, Garmisch-Partenkirchen, Germany.

Greeno, J. G. (1997). On claims that answer the wrong questions. *Educational Researcher*, *26*(1), 5–17.

Heath, S.B., & McLaughlin, M.W. (1994). Learning for anything everyday. *Curriculum Studies, 26*(5), 471-489.

Hutchins, E. (1995). *Cognition in the Wild*. Cambridge, MA: MIT Press.

Jordan, B. & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences, 4*(1), 39-104.

Kolodner, J. L. (2004). The Learning Sciences: Past, Present, and Future. *Educational Technology: The Magazine for Managers of Change in Education*, *44* (3), 37 - 42.

Koschmann, T. (1994). Toward a theory of computer support for collaborative learning. *The Journal of Learning Sciences, 3*(3), 219-225.

Koschmann, T. (1996). Paradigm shifts and instructional technology: An introduction. In T. Koschmann (ed.), *CSCL: Theory and practice of an emergent paradigm*, (pp. 1-23). Mahwah, NJ: LEA.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Meltzoff, A.N., Kuhl, P.K., Movellan, J., & Sejnowski, T.J. (2009). Foundations for a new science of learning. *Science,325*, 284-288.

Nespor, J. (1994). *Knowledge in Motion: space, time and curriculum in undergraduate physics and management*. Falmer Press: London.

Packer, M. J., & Goicoechea, J. (2000). Sociocultural and constructivist theories of learning: Ontology, not just epistemology. *Educational Psychologist*, 35(4), 227-241.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences, 3*(3), 265-283.

Shaffer, D.W., & Clinton, K.A. (2006). Toolforthoughts: Reexamining Thinking in the Digital Age. Mind, Culture, and Activity, 13(4), 283-300.

Schank, R.C., & Abelson, R.P. (1977). *Scripts, plans, goals and understanding: An inquiry into human knowledge structures.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Schneider, S.B., & Evans, M.A. (2008, October/November). Transforming e-learning into ee-learning: The centrality of sociocultural participation. *Innovate: Journal of Online Education, 5*(1). Retrieved October 30, 2008 from http://www.innovateonline.info/index.php?view=article&id=511.

Schoenfeld, A.H. (1999). Looking toward the 21st century: Challenges of educational theory and practice. *Educational Researcher, 28*(7), 4-14.

Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge.* Cambridge, MA: MIT Press.

Stokes, D. E. (1997). *Pasteur's Quadrant: Basic Science and Technological Innovation.* The Brookings Institution.

Suthers, D.D. (2006). Technology affordances for intersubjective meaning making: A research agenda for CSCL. *International Journal of Computer-Supported Collaborative Learning, 1*(3), 315-337.

Vygotsky, L.S. (1986). *Thought and Language - Revised Edition*. Boston, MA: The MIT Press.

Wertsch, J.W. (2007). Mediation. In H. Daniels, M. Cole, & J.W. Wertsch (eds.), *The Cambridge companion to Vygotsky* (178-192). New York: Cambridge University Press.

A Cognitive Apprenticeship for Science Literacy Based on Journalism

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Abstract: The Science Literacy through Science Journalism (SciJourn) project aims to reframe the discussion of science literacy for citizenship, and explore how science journalism practices can be used to inform a cognitive apprenticeship that increases the science literacy of participants. This symposium features four paper presentations that report on the progress of the SciJourn project. We report on the development of standards for science content literacy based on the expertise exhibited by science journalists, assessment measures for science literacy, and assessment measures for engagement with science and technology. Finally, we describe our efforts aimed at apprenticing high-school aged learners into a science journalism community of practice spanning multiple schools and a community-based organization.

General Introduction

Members of the Learning Sciences community engaged in science education almost universally agree that educated citizens in democracies should develop a strong disciplinary understanding of science. To date, such efforts have focused primarily on practicing expert scientists as the yardstick for what it means to "know science", and in the last twenty years on "coming to know science" through learning environments inspired by apprenticeship. Knowing science has typically been seen as having conceptions consonant with those of expert scientists (e.g., diSessa 2006); "talking science" (Lemke, 1990); using reasoning about models (Lehrer & Schauble, 2006) and spatial representations (Schwartz, 2006) like scientists; and knowing how to carry out the authentic inquiry practices of scientists (e.g., Edelson & Reiser, 2006; Krajcik, et al., 1998; O'Neill & Polman, 2004). Coming to know science has frequently been encouraged by creating communities of practice carrying out science inquiry (e.g., Pea, 1993; Rosebery, Warren, & Conant, 1993; Ruopp, et al., 1993). Learning environments based on a community of practice model have taken inspiration from the research on traditional apprenticeship learning (e.g., Lave & Wenger, 1991), and the related concept of cognitive apprenticeships for learning in schools (Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989).

These views of science knowing and learning have had a profoundly positive impact on education through direct reform and by being taken up and elaborated on in influential reports (e.g., Bransford, Brown, & Cocking, 2000; Michaels, Shouse, & Schweingruber, 2008) and standards for science education (e.g., National Research Council, 1996, 2000). The tendency to base science learning goals on analysis of the expertise of practicing scientists is understandable, but it has important limitations relative to a broader view of "science literacy." In the learning sciences and science education literature, "science literacy" is sometimes used synonymously with "practice-based science literacy" (O'Neill & Polman, 2004) focused on being able to carry out the first-hand inquiry practices of expert scientists. When this happens, the literacy in "science literacy" may become lost. But a "science literacy" which includes reading, making sense of, writing, and communicating about contemporary science topics as they relate to everyday life and policymaking is obviously important to life and citizenship.

The Science Literacy through Science Journalism project ("SciJourn"; Polman, Saul, Newman & Farrar, 2008) is a National Science Foundation research effort to better understand science literacy, and how science journalism practices can be used to inform a cognitive apprenticeship that increases the science literacy of participants (see http://www.scijourn.org). The project includes team members with backgrounds in the learning sciences, science education, literacy, science, and journalism; we draw on these diverse backgrounds to inform our understanding of both science literacy and learning. The project began in 2008, and we are in our second of four years of planned development and research. The 2008-09 academic year consisted of our alpha and beta tests of a journalism model for advancing science literacy in two high schools, simultaneous to the development of standards and discourse practices for science literacy, as well as transfer tasks and a survey of engagement. In summer of 2009, we conducted professional development with high school science and English teachers who are implementing various pilot instantiations of a journalism model in their classes during the 2009-2010 school year. At the same time, a group of science news reporters and editors was established at a youth development program at the Saint Louis Science Center (SLSC). The student reporters at schools and SLSC are publishing science news articles in an online and print newspaper we established called *The SciJourner* (http://www.scijourner.org). We are piloting our research instruments in 2009-2010 at school and SLSC sites. The project will conduct further teacher professional development in the summers of 2010 and 2011, and continue implementation studies.

There is an extensive and ongoing discussion in the broad field of science education over what constitutes science literacy and how it applies in schools, various other settings and life situations (e.g.; DeBoer, 2000; Eisenhart, et al., 1996; Hurd, 1998; Shamos, 1995; Turner, 2008). Nearly all definitions include aspects aimed at furthering civic, cultural and personal understanding (AAAS, 1989; Department of Education, n.d.; National Research Council, 1996; Trefil, 1996). For the purposes of the SciJourn project, we embrace the ideas embodied in terms such as "public understanding of science" (Bodmer, 1985); "public engagement with science and technology" (House of Lords, 2000); "scientific awareness" (Devlin, 1998; Shamos, 1995); "science for citizenship" (Fensham, 2004); etc. To whit, our goal is to educate students to:

- Think, talk, and write critically about what they read, hear and see in the media;
- Understand what counts as science;
- Recognize the risks and benefits of scientific discoveries and technologies;
- Become engaged with science and technology;
- Develop the confidence and skills to tackle science/technology issues independently;
- "Use" experts to answer questions and solve problems; and
- Understand the nature of science as an ongoing process of exploration with varying opinions or general consensus on theories, different stakeholders and levels of expertise, and norms for claims and evidence.

In this symposium, we feature four paper presentations that will report on the progress of the SciJourn project in developing standards and measures for science content literacy and engagement, as well as developing a set of practices and norms aimed at apprenticing high-school aged learners into science journalism as means to increase science literacy. Our discussants, who also serve as advisory board members for the project, will provide critical commentary and discuss the project's implications for the learning sciences. Bill Penuel (SRI International) will comment on the science education and measurement issues raised by the papers; Kevin Leander (Vanderbilt University) will comment on the literacy and discourse practices and issues.

Symposium Presentations

Toward an Articulation of Standards for Science Literacy Based on Journalism – Newman, Saul, Singer, Turley, Pearce, and Polman

Authors of the Alliance for Education/Carnegie Foundation (AAE) report entitled "Literacy Instruction in the Content Areas" call upon educators to rethink the ways in which we prepare students for college, work and citizenship. They—and we—are especially concerned with the ability of secondary students to read and write about academic content—specifically science content. To clarify salient features of science literacy we turned to a set of experts who work to communicate scientific content to a public audience—science journalists and editors. Drawing on qualitative data from interviews, read-alouds, and editorial comments experts provided to high school students and teachers writing science news articles, this paper begins to articulate prominent features that characterize scientifically literate individuals. Their comments, perspectives, and priorities are then used to articulate standards we seek to introduce to high school students and teachers. These standards are not an attempt to impose professional journalistic standards on novice student writers, but rather to help articulate practices of reading, writing and thinking that stand to improve students' science literacy. In the SciJourn project, we will be using these standards to inform a writing rubric as well as coding of discourse.

The five standards describe the importance of: 1) using multiple sources; 2) attending to issues of credibility and attribution of sources; 3) contextualizing science information; 4) making the reported science relevant to readers [high school students in our case]; and 5) presenting factually accurate, up-to-date information.

Just as science journalists report comments and ideas from multiple sources as they write and edit, we want students to write articles based on **multiple sources**, and recognize the importance of corroboration of sources when reading. Science journalists determine relevant and reliable sources with respect to a topic or issue and, when appropriate, consult various stakeholders. It is important for students to recognize that not all sources are equally trustworthy and even credible sources have perspectives and biases, which should be taken into account. They also need to understand and assess the limitations of scientific information.

Identifying **credible** sources and **attributing** them properly within stories is critical to building a journalist's and a scientifically literate individual's ethos. Science journalists name experts and organizations, qualifying their areas of expertise and noting any biases or potential conflicts of interest. Attribution prevents a science journalist from making blanket or false statements, especially by quoting credible sources. For students, determining whether a source is credible is crucial to science literary. When students name and evaluate their sources, they recognize that information comes from someone and some organization (that may have an agenda). Attribution provides a pathway for the reader to verify and expand on the story, develop new paths of inquiry and creates an historical record of circumstances, opinions and concepts at the moment the story is published.

Science journalists **contextualize** technical and scientific information for a broader audience by: identifying the import of the new scientific information; indicating the status (accepted or preliminary) of those findings, data, or ideas; weighing the importance of the findings; and providing sufficient details. For students, contextualization brings a greater scientific understanding to the story by helping the reader understand the significance of the scientific information, as well as the nature, limits, and risks of the discovery, technology or issue as it relates to science.

In science journalism it is imperative for the journalist to make the scientific information in the article **relevant to the readers**. Most often science journalists accomplish this by "translating" technical language and concepts in easier-to-understand words, analogies or images. We have found that linking scientific findings to local concerns or considering new applications of the discovery/technology helps the student reporter produce stories that are relevant to their reader. Students, then, ought to consider their audience and the audience's questions in writing about a scientific discovery, new technology or pertinent scientific issue.

Finally, a science journalist presents **factually accurate** information showing an understanding of the content and explaining scientific ideas and experimental processes. Precise language is employed and scientific terms are used appropriately. Students learning to think like expert journalists need to pay attention to details, ensuring the science is right and names, figures, and dates are correct. Students should draw on the latest scientific information in their reporting. This encourages students to look at publication/announcement dates as a means to determine timeliness.

Studying the literacy practices of experts in the field of science journalism provides a language and framework for how educators might use science journalism as a means engage students with scientific content. Fusing "science content" and "science journalism" places some traditional practices of science education and general journalism in the background, while foregrounding new ways of engaging students with literacy practices and science content that is current and developing.

Designing Transfer Tasks to Measure Science Literacy–Farrar, Polman, Saul, Newman

This discussion focuses on the development of tasks to measure changes in learners' scientific literacy as defined above. Unlike some other attempts at measuring science literacy, our approach is premised on the notion that science literacy is not limited to an accumulation of facts and concepts, but includes the ability to critically consume and produce science information in order to make decisions personally, socially, and politically. While there are a multitude of assessments designed to assess conceptual understandings in science, a measure that captures such a view of scientific literacy is needed.

Research on scientific literacy stems from three broad interests; social scientists and public opinion researchers, sociologists and science educators (Laugksch, 2000). Although many of these interests agree on a multidimensional nature of scientific literacy (conceptual knowledge, contextualization, and skills) rarely is scientific literacy measured in its entirety (Laugksch & Spargo, 1996). By focusing on smaller components of scientific literacy separately, an incomplete picture of student scientific literacy emerges. Few composite measures of scientific literacy have been published (Laugksch, 2000).

As part of the Science Literacy through Science Journalism project, we have strived to develop a series of tasks that will measure scientific literacy skills that enable them to be critical consumers and producers of science information. These tasks stem from the broader goals of educating students to think, talk, and write critically about what they read, hear and see in the media; understand what counts as science; recognize the risks and benefits of scientific discoveries and technologies; develop the confidence and skills to tackle science/technology issues independently; "use" experts to answer questions and solve problems; and understand the nature of science as an ongoing process of exploration with varying opinions or general consensus on theories, different stakeholders and levels of expertise, and norms for claims and evidence. Korpan, Bisanz, and

Bisanz (1997) posit that one of the hallmarks of scientific literacy is "the ability to make effective requests for information or to ask good questions about scientific research" (p. 518). We contend that in order to do this, a student must be able to do the following: evaluate expertise; identify appropriate questions for experts; select and use multiple credible sources to gain more information; determine coherence between text and image or graphic; employ effective search strategies for more information.

Research on critically evaluating articles about science is limited (Mallow, 1991). Korpan et al (1997) created a series of tasks to explore the ways in which students evaluated science information in the form of news articles, where students were presented with a science article and asked a series of questions such as "what additional pieces of information would you like to have about the researcher's report to decide whether the conclusion is correct?" (Korpan et. al., 1994). It is in this vein that we have developed the transfer tasks. These tasks were developed in the fall and spring of 2008-9. In the fall of 2009, several teachers are piloting the tasks in their classrooms. The completed tasks will be used to inform the revision process. Full implementation will begin in the fall of 2010 and continue through June of 2012.

Currently there are seven tasks, each of which provide opportunity to gain insight on multiple aspects of a student's scientific literacy. Examples of the tasks:

- Reading informational text such as a brochure on high blood pressure or the flu; followed by prompts such as "What are your risks associated with this?", "Who else would you consult about this to learn more?"; "Why would you contact that individual?", and "What questions would you want them to answer?".
- Creating interview questions from a news article in conjunction with identifying search terms and additional sources.
- Evaluating text and graphics for factual accuracy; suggesting other experts or sources that could help determine if it is accurate.

At this point in development (Fall 2009), our team is creating the coding scheme based on the standards and frameworks for science literacy described above. In the symposium, we will present our coding scheme, results of our pilot implementation in 2009-2010, and describe any revisions to the instruments and coding intended in our research during the 2011-2012 academic year.

In order to comprehensively assess scientific literacy in students, a measure must assess conceptual knowledge, contextualization of information, and the skills necessary to consume and produce scientific information. With the development of these tasks, we aim to provide a more nuanced picture of student scientific literacy, to inform both educational practice and assessment in science classrooms.

Reframing and Measuring Engagement with Science and Technology – Hope, McCarty, and Polman

This paper focuses on the fourth goal of the Science Literacy through Science Journalism (SciJourn) project: educating students to become engaged with science and technology, not just in school but throughout their lives. We believe that the Science, Technology, Engineering and Mathematics (STEM) fields need to follow a path similar to that blazed by Rosenzweig and Thelen (1998) who reframed the discussion of how educated citizens *understood* history by conducting research on how citizens in the United States were actually *engaged with* the past. We see this as aligned with the framing of science literacy as "public understanding of and engagement with science and technology."

Many recent studies of science education interventions focus mainly on "engagement" as indicated by student achievement in the science classroom (Lichtenstein et. al, 2008; Markowitz, 2004; Martin, 2005). Fewer studies of organized education programs consider science engagement related to students' personal lives. While still focused on the outcome of academic achievement, Lau and Roeser (2002) posited that engagement involves multiple facets, including positive feelings and focused attention during the learning activity as well as amount of time spent on school assignments or other science-related tasks during non-school hours. Barton and colleagues (Basu & Barton, 2007; Furman and Barton, 2006) studied urban minority youth in after-school programs, finding that connecting science experiences with students' own future plans, in a social learning environment that supported student agency, led to what they considered a sustained interest in science and to shifts in identity. Ethnographic research from the Learning in Informal and Formal Environments Center (e.g., Barron, 2006; Zimmerman & Bell (2007), has shown the myriad ways that youth engage with science and technology activities in the out of school hours, including personally meaningful experiences at home that school people seldom know about.

Although research shows the public does engage with science and technology, the public's engagement with free-choice science learning is poorly understood (Falk, et al, 2007) and has not been fully researched (Falk, et.al, 2007; Korpan, et al, 1997). Data gathered about books being read, television programs watched, games played, and Internet searching, could lead to insights of how people learn science and influence practices in schools (Korpan, et al, 1997).

We believe that a coherent concept of engagement, which captures what is meaningful about the term as it is generally used, includes three facets: **Behavior**, or actual involvement with science and technology ideas and tools; **Interest**, or openness to and stance toward the science and technology in the moment; and **Identity**, or ways that the science and technology connects to people's identity affiliations, in the past, present, and future. These facets have been operationalized in a small research study that will result in a written survey intended for broader use.

Following Fowler's (2009) recommendations, the Youth Exploring Science and Technology (YEST) survey was developed based on previous surveys and the literature, utilizing interviews and verbal think-aloud protocols to refine the survey instrument with a subset of the project participant population, and then administered the pilot survey to a broad audience. A select group of seven teen participants in the Saint Louis Science Center's youth development program contributed to the development of the survey in summer 2009; case studies of their engagement with science and technology were constructed based on observations, interviews, and analysis of drafts and final science news articles created by these youth. In addition to this group, several hundred students of 13 teachers from 10 schools participating in the wider research project were administered surveys in Fall 2009 (prior to the introduction of science journalism related activities), and will be administered parallel surveys at the end of the school year.

At this time, the survey consists of five sections: demographics/background (8 questions), science behaviors (10 questions), technology behaviors (20questions), interest in science and technology inside and outside school (12 questions), future (5 questions). Questions relating to identity are interspersed throughout. By June 2010, at the time of the paper presentation, pilot survey results will be collected, analyzed, and available for inclusion in the presentation. The revised survey structure and items will be presented as well.

Preliminary results of case studies from Summer 2009 give a sense of how engagement may shift through youth participation in the sort of science journalism practices taking place in SciJourn. Max (all names are pseudonyms) was in the summer before his 12th grade, and the survey revealed he was highly engaged in reading and consuming technology-oriented media, although he was not otherwise a big reader. He had strong interests in science and technology, and connected his identity in the present and future with potential computer technology or science careers. Although he did not have much initial interest in researching and writing science news stories, and did not see himself as a writer at all, he responded to the challenges put before him, and produced stories on the program, the health risks of tattoos, and electric cars. Thus, he expanded his engagement in communicating with others about science and technology, and appears to have begun to refine his identity. Khadijah was also in the summer before 12th grade, and her identity was tied more to her general interests in reading, writing, and arguing, and her plans for becoming a lawyer and advocate for youth in foster care. Her engagement in science news reporting allowed her to connect her identity as a writer with science, especially social science concerns, such as the school dropout rate for children in foster care, and how social networking affects the life of teens.

In order to understand the means by which for America's youth connect with learning opportunities, science educators should better understand how youth are engaged with science and technology in their daily lives. The Youth Engagement with Science and Technology survey described in this paper stands to provide a more valid measure of engagement than is presently available. With this tool, programs can pay attention to how individuals with different engagement profiles learn, and can measure the impacts of in-school and out-of-school programs on engagement.

Building an Apprenticeship Community of Practice for Science Journalism – Polman, Saul, Newman, Pearce, and Graville

Within the SciJourn project we are in the process of building a distributed community of practice centered on apprenticing students and teachers into the authentic production of a science newspaper we call *The SciJourner* (http://www.scijourner.org), with the support of a diverse university team. Since our goals involve fostering and driving learning through the critical consumption and production of science news rather than maximizing readership or ad sales, the community of practice can be seen as a cognitive apprenticeship (Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989) for science learning that is a hybrid of traditional journalism.

Wenger's (1998) research revealed the importance of brokering and boundary objects to the transfer and transformation of practices across communities of practice. As described above, the SciJourn project is taking practices from traditional science journalism, and moving them into a distributed learning environment that encompasses teachers' classes in multiple schools as well as a youth program at the Saint Louis Science Center. As a Ph.D. chemist who worked over 20 years as a science journalist and managing editor, Alan Newman has been our primary agent **brokering** journalistic practices to our nascent community. In addition, we have a diverse set of additional science journalism advisors who provide input. Other members of our project team broker practices from literacy education, journalism education, and science education in formal and informal learning environments. Wenger's concept of **boundary objects** refers to artifacts, documents, terms, and concepts around which communities of practice can organize their interactions. In this paper presentation, we will describe the brokering and boundary objects that have emerged thus far in our project.

The development of this community thus far has been as follows. In 2008-09, the team of university-based science educators, literacy educators, researchers and journalists began clarifying the links between science journalism and science literacy through literature review and the research with professional journalists described above. At the same time, we implemented what we refer to as "alpha" and "beta" models of a science journalism curriculum and news writing units in two schools, including the classes of one of our PIs (Farrar). We shared results of this with our advisory board, a key journalism advisor, our external evaluator, and our partners at SLSC at two advisory board meetings, to inform our plans for expanding our implementation and research. In the summer of 2009, 14 teachers from 10 high schools participated in the 3-week SciJourn professional development under the direction of Wendy Saul and with the help of Newman and Turley. The teachers also wrote news stories and produced a print edition of *The SciJourner* with Newman as editor, and also co-developed pilot mini-lessons and science journalism units with us. Also during summer 2009, 8 teenage youth from the SLSC participated in the project during their summer 5-week youth development and work program, learning to research and write science news stories, and producing three print editions of *The SciJourner* with Newman acting as managing editor, and the support of three SLSC staff including one professional novelist. During the 2009-2010 school year, the teachers are implementing their own and others' lessons and units and participating in the research. At the same time the development team, which includes Saul, Newman and Pearce, visits classes with the express purpose of refining lessons so they can be used in the summer of 2010 and 2011 as models that can be used for debriefing and discussion. SciJourn curricula is being piloted in biology, environmental science, physics, physical science, English, research, applied biology and chemistry, chemistry, and advanced biology classes. The school districts vary by location and SES (rural, urban, suburban and urban parochial). Although a goal was to implement various aspects of the project during the school year so that teacher efforts culminated in students writing articles for *The SciJourner*, several of the teachers are focusing more heavily on reading than writing. Teachers from the 2009 cohort will meet several times as a group with the SciJourn team during the year. Individual meetings with the teacher group are also held regularly to focus on their activities, concerns and to debrief lessons.

Key boundary objects that have emerged thus far in the project include: 1) the genre of science news articles (beginning with a lede and moving in an "inverted triangle" structure from more important to less important information) vs. the traditional school-based "5-paragraph essay"; 2) story pitches delivered in a "fishbowl" activity; and 3) the related notions of sources, credibility and attribution. So far in schools and in the youth program, teachers and facilitators found that they had to actively work to overcome students' prior experiences with the 5-paragraph essay structure as normative for all non-fiction writing in schools. The SciJourn team and teachers have developed ways of revealing and learning the genre, and it has become a boundary object for moving students out of "writing as usual in school." Journalists traditionally pitch story ideas to editors and groups before being given the go-ahead on assignments, and we have refined a model for pitches that combines this practice from the journalism community with a fishbowl structure borrowed from schooling. In our hybrid, students do some research on story ideas, then one pitches their story to an adult editor as they both sit in the middle of a circle. The editor asks questions, makes suggestions, and helps the student reporter refine their idea, and the people around the edges of the circle also chime in. At the end of the pitch, the editor and group decide whether to move forward on that story. Afterward, the student who made the pitch moves to the editor's chair, and another student pitches. In this way, learners experience modeling and coaching (Collins, Brown, and Newman, 1989) and then begin to appropriate ideas even further as they are asked to model the ways of thinking exhibited by editors. Routinely, students quickly begin asking peers what makes their story interesting to readers (contextualization), what or who their potential sources are, etc. Finally, the journalistic notions of using multiple sources, concern with the credibility or reliability of sources, and attributing sources are all becoming part of the vernacular of science classes in a way that they were not previously. The science teachers in our project have been receptive to these terms and the thinking behind them, and they are implementing them in reading-focused activities in school that take less time than having students write and research new stories.

Several additional instances of people brokering practices and their possible variations within this nascent community of practice are worth noting. The persona and manner that Newman takes on with students both in schools and in the youth program, as a professional editor focused on ideas and concepts in the draft and final products, makes for different feedback norms than most students have previously experienced. In several cases, students have been surprised at the amount of markup provided by Newman in electronic documents returned by him using Microsoft Word's Track Changes. Early on, we began looking for ways to introduce changed attitudes toward extensive feedback as productive rather than merely providing negative judgment, as many traditional school papers with "a lot of red" would signify. We have also pushed the notion that "science and technology can be connected to anything" in order to welcome individual learners' interests and story ideas, but we know that school curricular requirements as well as the knowledge of facilitators will sometimes limit the possibilities for transforming personal topic interests (e.g., tattoos, social networking) into science news stories. Teachers with different backgrounds and in different subject areas (biology, chemistry, environmental science, or English) bring varying assets and vary in what sorts of science news relates to their learning goals. Thus, we will monitor how different classes, contexts, and facilitators deal differentially with welcoming and transforming student ideas into stories.

Conclusion

This symposium will present a reframing of the notion of science literacy, exploring the projects' progress at fostering a scientifically literate citizenry through a focus on the practices and ways of thinking developed by journalists. Implications for research on learning and educational practice will be discussed.

References

American Association for the Advancement of Science. (1989) *Science for all Americans*. Washington, D.C.

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development, 49*, 193-224.

Basu, S. J., and Barton, A. C. (2007). Developing a sustained interest in science among urban minority youth. *Journal of Research in Science Teaching*, *44*(3), 466-489.

Bodmer, W. (1985). *The public understanding of science*. Royal Society: London.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*(January-February), 32-42.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationships to science education reform. *Journal of Research in Science Teaching 37*(6), 582–601.

Department of Education, Institute of Education Sciences. http://nces.ed.gov/programs/coe/glossary/s.asp

Devlin, K. (1998). Rather than scientific literacy, colleges should teach scientific awareness. *American Journal of Physics 66*(7), 559–560.

diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge, UK: Cambridge University Press.

Edelson, D. C., & Reiser, B. J (2006). Making authentic practices accessible to learners: Design challenges and strategies. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge, UK: Cambridge University Press.

Eisenhart, M., Finkel, E., Marion, S. F. (1996). Creating the conditions for scientific literacy: A Re-Examination. *American Educational Research Journal 33*(2), 261–295.

Falk, J.H., Storksdieck, M., & Dierking, L.D. (2007). Investigating public science interest and understanding: Evidence for the importance of free-choice learning. *Public Understanding of Science, 16*, 455-469.

Fensham, P. J. (2004). Increasing the Relevance of Science and Technology Education for All Students in the 21st Century. *Science Education International 15*(1), 7–26.

Fowler, F.J. (2009). *Survey research methods*. Thousand Oaks, California: SAGE Publications, Inc.

Furman, M., and Barton, A. C. (2006). Capturing urban student voices in the creation of a science mini-documentary. *Journal of Research in Science Teaching, 43*(7), 667-694.

House of Lords (2000). *Science and society*. Her Majesty's Stationary Office: London.

Hurd, P. D. (1998). Scientific literacy: New minds for a changing world. *Science Education 82*(3), 407–416.

Korpan, C. A., Bisanz, G. L., & Bisanz, J. (1997). Assessing literacy in science: Evaluation of scientific news briefs. *Science Education*, *81*(5), 515-532.

Korpan, C.A., Bisanz, G.L., Boehme, C., & Lynch, M.A. (1997). What did you learn outside of school today? Using structured interviews to document home and community activities related to science and technology. *Science Education, 81,* 651-662.

Korpan, C. A., Bisanz, G. L., Dukewich, T., Robinson, K. M., Bisanz, J., Thibodeau, M., Hubbard, K. E., & Leighton, J. P. (1994). *Assessing scientific literacy: A taxonomy for classifying questions and knowledge about scientific research* (Tech. Rep. No. 94-1). Edmonton, AB, Canada: University of Alberta, Center for Research in Child Development.

Krajcik, J., et al. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *The Journal of the Learning Sciences, 7*(3 & 4), 313-350.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lau, S., & Roeser, R. W. (2002). Cognitive abilities and motivational processes in high school students' situational engagement and achievement in science. *Educational Assessment*, *8*(2), 139-162.

Laugksch, R. (2000). Scientific literacy: A conceptual overview. *Science Education*, *84*(*1*), 71-94.

Laugksch, R. & Spargo, P. (1996). Development of a pool of scientific literacy test-items based on selected AAAS literacy goals. *Science Education, 80*(2), 121-143

Lehrer, R., & Schauble, L. (2006). Cultivating model-based reasoning in science education. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge, UK: Cambridge University Press.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.

Lichtenstein, M. J., Owen, S. V., Blalock, C. L., Liu, Y., Ramirez, K. A., Pruski, L. A., et al. (2008). Psychometric reevaluation of the scientific attitude inventory-revised (SAI-II). *Journal of Research in Science Teaching*, *45*(5), 600-616.

Mallow, J. V. (1991). Reading science. *Journal of Reading, 34*, 324-338.

Markowitz, D. G. (2004). Evaluation of the long-term impact of a university high school summer science program on students' interest and perceived abilities in science. *Journal of Science Education and Technology*, *13*(3).

Martin, A. J. (2005). Exploring the effects of a youth enrichment program on academic motivation and engagement. *Social Psychology of Education*, *8*(2), 179-206.

Micheals, S., Shouse, A. W., & Schweingruber, H. A. (2008). *Ready, set, science! Putting research to work in K-8 science classrooms*. Washington, DC: National Academies Press.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

Norris, S. P. (1995). Learning to live with scientific expertise: Towards a theory of intellectual communalism for guiding science teaching. *Science Education*, *79*, 201-217.

O'Neill, D. K., & Polman, J. L. (2004). Why educate "little scientists?" Examining the potential of practice-based scientific literacy. *Journal of Research in Science Teaching, 41*(3), 234-266.

Pea, R. D. (1993). The collaborative visualization project. *Communications of the ACM, 36*(5), 60-63.

Polman, J. L., Saul, E. W., Newman, A., and Farrar, C. (2008). Science literacy through science journalism. Proposal to the National Science Foundation Discovery Research K12 program. Unpublished report.

Rosebery, A. S., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *The Journal of the Learning Sciences, 2*(1), 61-94.

Rosenzweig, R., and Thelen, D. (1998). *The presence of the past: Popular uses of history in American life*. New York: Columbia University Press.

Ruopp, R., Gal, S., Drayton, B., & Pfister, M. (Ed.). (1993). *LabNet: Toward a community of practice*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Schwartz, D. L., & Heiser, J (2006). Spatial representations and imagery in learning. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge, UK: Cambridge University Press.

Shamos, M. (1995). *The myth of scientific literacy*. Rutgers University Press: New Brunswick, N.J.

Trefil, J. (1996). *Scientific literacy*. Annals of the New York Academy of Sciences 775, 543–550.

Turner, S. (2008). School science and its controversies: or whatever happened to science literacy? *Public Understanding of Science 17*, 55–72.

Zimmerman, H. T. & Bell, P. (2007, April). Seeing, doing, and describing everyday science: Mapping images of science across school, community, and home boundaries. Paper presented at National Association of Research in Science Teaching (NARST), New Orleans, LA.

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"Wherever You Go, There You Are:" Examining the Development and Integration of Individual Identity Across Multiple Domains and Contexts

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Abstract: This symposium brings together researchers focused on issues of learning and identity development. We examine how the development of identity relative to a particular domain-specific learning environment—such as a leadership seminar, a nature trail guide program, a writing class project, or a teacher professional development course—can be better understood by looking at learners as whole persons, relative to their other experiences and identities. In other words, we investigate evolving identity *within* contexts by looking more broadly at participant identity *across* contexts. The session will present findings from this research, share methods for accomplishing this difficult work and making it manageable, discuss implications for further theory-building about identity, and provide recommendations for designing learning environments with identity development in mind.

Introduction

Identity has only recently begun to emerge as a focal point in educational research, as educators and scholars now struggle with not only the constructivist idea that learners' shape their own meanings of domains, content, and contexts (Palincsar, 1998), but also the more thorny and difficult assertion that learners shape their own subjectivity toward, attitudes about, and affinity or hostility for all aspects of their educational endeavors (Sfard & Prusak, 2005). Further, researchers of cultural identity have articulated the phenomenon that aspects of learners' identities may be positioned by institutions and cultures such that they conflict in various ways with success in school or success in particular academic domains (Davidson, 1996; Nasir & Saxe, 2003). Clearly, as educators and researchers, we ignore identity at our peril.

Yet identity is a slippery concept and difficult to pin down. Individual identity has been described by research and theory as a constant sense of self, or a fluid and ever-changing performance (Buckingham, 2008; Goffman, 1959). Identity development has likewise been framed as a consistent trajectory, or a rapidly shifting current (Erickson, 1968; Gee, 2001). Nowhere are these paradoxes more obvious than when we follow the same individuals across multiple contexts and domains, as in connective ethnography (Leander, 2008), or when we hear the coherent life narratives that emerge from a host of disparate experiences (Bruner, 1991). Thus when research focuses on solely one context in the lives of learners, we leave great gaps in our understanding and insight.

The papers on this panel represent research that attempts to bridge these gaps. We examine how the development of identity relative to a particular learning environment—such as a leadership seminar, a nature trail guide program, a writing class project, or a teacher professional development course—can be better understood by looking at learners as whole persons, relative to their other experiences and identities. In other words, we investigate evolving identity *within* contexts by looking more broadly at participant identity *across* contexts. Our methods for these studies vary. Some actively follow participants through different contexts they inhabit, while others rely on the participants to make those boundary-crossing connections via interviews, essays, life maps, or other narrative means. In all cases, however, participant voices and participant stories are key, since our work is founded on the idea that identities and selves are constructed and reconstructed through narrative (Ochs & Capps, 1996). In the abstracts that follow, representing those voices and narratives is difficult given length restrictions, but participant stories and cases will be a vital part of the conference session.

Trail guide self-perception and domain-expert identity at an environmental reserve. Emily Evans (University of California, Davis)

Non-formal education programs in outdoor settings are common methods to impart land management messages and promote environmental stewardship (Ham, 1992; Widner & Roggenbuck, 2000). For many of these programs, with low budgets and limited staffing, their ability to recruit and retain volunteer guides and educators has a direct impact on the quantity and quality of programs available to the general public. This study sought to find out why volunteers choose to become involved with a guided educational hike program and how their perceptions and past experiences shaped their interest in guiding and in the Reserve.

When social interactions, such as teaching and learning, take place in natural settings, the environmental context of those interactions directly impacts the meanings ascribed to the environment and the nature of the social interaction. (Anderson, 2004; Clayton, Clayton, & Opotow, 2003; Neilson, 2009). The case of the volunteer guide program is a means to explore these issues of identity at the intersection of social and natural environments. This study explores how guides think of themselves in relation to the social and environmental context of the Reserve and how these perceptions influence their practice as a guide.

To answer these questions, the researcher interviewed guides and observed them in training and leading walks. The researcher also had a participant-observer role in guide training, by enrolling in and going through the guide training program with a cohort of guide volunteers. Participants for the study were recruited from this cohort of volunteers. Guides were interviewed either in-person or on the phone; interviews were audio recorded and transcribed. Fieldnotes were taken during guided walks, which were then matched to interview transcripts from guides (although not all participants had both interviews and walk observations). In interviews, guides were asked about their initial motivations, experiences leading the outings, and their interest and past experiences with non-formal teaching and learning in outdoor settings. Analysis of interviews and observations of the guided outings revealed three main characteristics of active guides: guides were motivated by an interest in teaching and learning, had a previous relationship to the place, and held an image of themselves that matched their perceived image of a guide.

This issue of image compatibility is critical to a focus on identity. Guides with some domain background such as plant biology or ecology, and who viewed their responsibility as educating visitors in the science of the reserve, made use of their existing expertise in their volunteer teaching. Yet on guide walks, the researcher observed that visitors to the reserve were not always engaged by taxonomic terminology and technical explanations of the reserve ecosystem, a phenomenon that some expertise-focused guides were aware of and frustrated by. Guide walks also revealed that some volunteers who lacked domain expertise, and who considered domain expertise important, were flustered on walks by visitors asking scientific or environmental questions that they could not answer. Yet image compatibility was not always related to domain expertise. Included in the participant pool were successful guides who identified more as artists or nature lovers, and thus lacked a background in environmental science or biology, but who viewed their responsibility more in terms of generating visitor enthusiasm and connection to the reserve. One example was an artist who led walks focused on finding spectrums of color in the reserve in different seasons; her walks contained virtually no scientific information at all yet still managed to engage visitors and create a positive walk experience. Retention in the guide program was the least successful for those who had a perceived image of a guide (as expert, inspiring, charismatic, educational, etc) that they could not match with their own identities and strengths.

This case study demonstrates that guides have different perspectives on what it means to be a non-formal educator, and that their perceptions of the guide identity are related to their motivations to participate. A prescribed identity of what it means to be a volunteer educator, such as domain expertise, may dissuade a potential volunteer from participating, if that image does not match their own self image. For land managers and education program coordinators interested in attracting and retaining volunteer leaders, carefully outlining the expectations of a guide and allowing for diverse perspectives on the role of volunteer educators may encourage a broader population of volunteers to participate and, in turn, a broader audience of visiting participants.

Life maps and the multi-contextual development of undergraduate leadership identity. Elizabeth Faber (Humboldt State University)

American institutions of higher education are working to develop relevant and meaningful learning experiences that prepare young people for leadership in a knowledge-dense, adaptive, and multicultural society (The Boyer Commission, 1998). But how does a college student learn to become a leader? This study explores the process of learning leadership across multiple contexts through the lens of identity development theory (Baxter Magolda & King, 2004; Erikson, 1968; Lord & Hall, 2005; Marcia, 1994; Rangell, 1994).

Existing theories of college student leadership development fall short in that they either focus primarily on one college context such as student government or athletics (Dugan, 2006; Hall, Forrester & Borsz, 2008) or lack specifics about the importance of reflective practices in the identity development in young, aspiring leaders (Logue, Hutchens & Hector, 2005; Posner & Brodsky, 1992). This qualitative study explores the learning outcomes and leadership narratives of undergraduate student leaders at a large public university. Six student leaders were recruited from the past participants of a leadership seminar on campus taught by the author, as well as through the social networks of those participants. Through narrative and artifact-driven interviews ranging from one to two hours in length, the student participants reflected deeply on their learning and development in college. They mapped their leadership experiences through lifelines—timelines showcasing their many involvements across curricular, co-curricular, extracurricular, and community-based contexts in college. The interviews revealed that these college students lead across multiple aspects of their identities: ethnic, social, academic, professional, etc.

The study also explores three new areas not described by existing literature in which young adults develop a leadership identity: identifying and committing to a core personal mission, developing emotional intelligence, and experimenting with peer teaching of leadership. Regarding core personal mission, interviews revealed that students were highly reflective about making connections across their various leadership experiences and finding common themes. One example is a Native student who was also a Cultural Studies major and led across social and academic groups on campus as well as in community service. This student articulated that across all these areas, her focus was on teaching others about connection to the land and repatriation of artifacts. Given that students themselves are generating these across-context missions, it is all the more crucial, then, that research on leadership development move beyond a focus on singular contexts for study.

Regarding emotional intelligence, students articulated that they struggled with handling frustration appropriately and dealing with difficult people, and that part of their growth as student leaders involved developing concrete strategies for these kinds of personal and interpersonal challenges that could transfer across situations. While existing research has examined emotional aspects of leadership in terms of enthusiasm for leadership and one's own motivation to lead, dealing with negative emotions in leadership has not been a focus of inquiry yet in the broader field and is recommended as an implication of this study. In terms of peer teaching, one of the hallmarks of college student leadership contexts, and one that has yet to be dealt with in existing research, is a continuous turnover of participant leaders. Undergraduate students are on campus for four to five years, and they may attain significant leadership positions only in their last two or three years of their enrollment at the university. Thus by the time students have learned how to lead effectively in any given context, they are already on the verge of graduating and being replaced by other students in those positions. The student leaders in this study reflected on how they might effectively pass on what they had learned to the next group of student leaders in their various contexts, but they described that they were given little support for this peer teaching process. This is clearly another area for research and development on college student leadership.

In closing, this study's focus on learning leadership through identity development is unique in the literature on college student leadership development and both complements and complicates the primary Leadership Identity Development model (Komives, Longerbeam, Owen, Mainella, & Osteen, 2006). The use of lifelines to promote reflection and guide narrative-based interviews is also a new and effective method both for research and practice. Other recommendations for college student leadership development include active opportunities for reflecting and connecting across leadership contexts to articulate a core personal mission, and an explicit emotional intelligence focus in both research and training on dealing with negative emotions and difficult people. In terms of peer teaching, this study suggests the practical need for leadership development programs, as well as individual leadership contexts, to build in acknowledgement of and support for the high turnover of student leaders, and to create opportunities for peer teaching of leadership. Research on peer teaching could effectively examine leadership identity from the new perspective of how students think about their "legacy" as they graduate, and also investigate students' implicit theories of learning leadership through research observations of how they instruct their peers.

Identity tensions among teachers as online professional development participants and novice bloggers. Cynthia Carter Ching (University of California, Davis)

More and more teachers are turning to reading blogs in order to find web resources for education, and using blogs as pedagogical tools to encourage their students to write for a "real" audience (Martindale & Wiley, 2005; Williams & Jacobs, 2004). Yet research on teachers-as-bloggers is relatively rare. While a pioneering study by Luehmann (2008) examined the case of a highly competent and prolific teacher blogger, this study takes on a group of teachers as novice bloggers and uses Gee's identity theory (2001), to address the questions of what factors affect teachers' attitudes toward blogging, experiences with creating blogs, and meanings they make out of blogging as a social, educational, professional, and personal activity.

Blogging is a highly productive context for examining questions of identity for a number of reasons. Nardi and colleagues argue that most personal blogs fall into at least one of a few categories: blog as documentation, blog as muse, blog as confessional, blog as commentary, blog as catharsis, and blog as community resource (Nardi, Schiano, Gumbrecht, & Swartz, 2004). In each of these functions, and sometimes in several different functions within the same blog, writers work to position themselves in complex ways in relation to their audience, their topics, and, in many cases, in relation to the hosting technology itself. While most naturalistic studies of blogging end up examining a self-selected population, those who have already internalized the value of blogging and decided to create an online identity and voice for themselves, this study examined the case of a cohort of practicing teachers in an online program who were given the task of short-term blogging as a course assignment.

The context for this study was an online cohort of thirty-seven teachers enrolled in an MA program for practicing teachers with a focus on global issues in education. In addition to participating in live online meetings, teacher participants posted conversations asynchronously on a CMS discussion board and worked throughout six weeks on their major assignment for the third course, taught by the author, which was to develop a blog and make at least three entries reviewing educational websites about globalization. Teachers were encouraged to think of their blogs as both an opportunity to use the lens of the course readings to analyze educational websites (blog as commentary) and as a resource for other teachers who might be looking for similar web-based tools for teaching about globalization (blog as community resource). Out of the thirty-seven teachers, only three had prior experience with blogging in a personal context, involving sharing pictures and anecdotes from travel and family life (blogging as documentation). No participating teachers had ever blogged before from their professional perspective and voice as teachers. Data for this study include the archived feeds from all live meetings (12 course meetings for two hours each) wherein participants regularly talked about and referenced their career experiences at their schools sites, teachers' discussion board postings about their developing blogs and ensuing threads of responses and replies, and the teachers' blogs themselves.

Using Gee's identity framework (2001), data were analyzed using axial coding to determine various different identities teachers were displaying throughout the course, in their blogs, in their discussions of themselves as teachers and bloggers, and tensions that occurred between these identities. Even aside from blogging, some participants experienced tensions between their reported institutional and discourse identities as expert and/or gifted teachers within their schools, versus their emerging institutional and discourse identities as "problem" students in the online program (i.e., those who often needed help with troubleshooting their online access, difficulties uploading work to the College of Education server, etc). These "problem" identities, both in the online program in general and in the blog assignment, were often associated with teachers' assertions about their nature identities, which they had also adopted as discourse identities—that of being "a dinosaur" (i.e., too old to be fully comfortable with online technologies) or somehow being inherently "hopeless" with computers. Additionally, those teachers who initially displayed an affinity identity as technology enthusiasts had little trouble setting up their blogs and personalizing their blog aesthetic, but some of these teachers still had difficulty writing in their blogs, as they struggled with how to establish and convey their discourse identities online and find voices for evaluating educational websites. In most cases, teachers who had never blogged before and teachers who had family blogs before the course both experienced some social anxiety regarding the public nature of blogs (Nardi, Schiano, & Gumbrecht, 2004). Thus there emerged an additional tension between their discourse and institutional identities as authorities within their schools, or their affinity identities as previous family bloggers, versus taking on a discourse identity as a blogging educational authority to the online public-at-large.

This study demonstrates the importance of examining teachers' use of and meaning making with technology from an identity perspective, rather than an exclusive focus on training, since teachers in this study were daunted not primarily by the technical task of setting up and maintaining a blog, but by the tensions this requirement provoked in their ideas of skill, voice, authority, and self.

From Home to School and Back Again: Intersecting Trajectories of Identification in a Student's Development as a Writer. Deborah Fields (UCLA)

How can students build on their experiences, knowledge, and values from different parts of their lives (i.e., their identities) to develop an "academic identity," or a sense of self as interested in, good at, and having a future in some academic discipline such as science or writing (e.g., Barton, Tan & Rivet, 2008; Carlone & Johnson, 2007)? In this paper I use boundary objects and narrative analysis to unpack how one student developed a trajectory of identification as a writer, particularly as a writer that had a positive influence on other people.

This presentation represents part of a larger connective ethnography (Leander, 2008) following two 11 year-old children in many places of their lives during their sixth grade year, from October 2008 to August 2009. Data collection was theoretically driven to study how youth acted in different social spaces (their "identities-in-practice" – e.g. Barton et al, 2008), how the youth thought about themselves (what I call their "identities-in-narrative") and how others thought about them (others "identities-in-narrative" about the youth). To this end data include over 200 hours of observation of different subjects at school, sports practices, music lessons, performances, play with peers, and time with family (to focus on "identities-in-practice") and more than 50 interviews with the two youth and important adults in their lives (to focus on self- and others- "identities-in-narrative"). In analysis I constructed narratives (Clandinin & Connelly, 2000) of *trajectories of intersections* based on events and narratives in the data to understand the consequences of youths' intersecting trajectories of identification. Then using grounded theory (Charmaz, 2000), I identified common themes across the different trajectories of intersections that might account for either productive connections or unresolved conflicts between identities.

In this presentation I discuss one trajectory of intersections across the life of an 11 year-old boy named Wynn. The instigating artifact that stimulated this trajectory was a letter he wrote to Dr. Seuss as part of an everyday classroom assignment, a letter for which he subsequently won a significant award. In his letter Wynn drew together personal conflicts about his bi-racial heritage; a beloved book from his childhood, *The Sneetches*; and his current social studies project in civil rights, which he described as "what all of my ancestors have done to each other." In itself, the letter acted as a powerful connecting artifact between different areas of his life that helped him to resolve conflicts in how he saw himself and how others treated him. A first place award for the letter further led to ripple effects across social spaces of his life: classmates began listening more carefully to his writing in class, extended family cited his award and the letter as evidence that Wynn was "smart," and African-American and bi-racial members of his church expressed how he had touched their hearts and that his writing was powerful. Eventually Wynn himself took up this narrative of himself as a good writer and at the same time began to change his daily practices to include more writing during his free time.

I argue that multiple things supported the development of Wynn's identity-in-narrative and identity-in-practice as a writer. Both the letter and the award acted as boundary objects (Star & Griesemer, 1989) that signified Wynn as an accomplished writer to different groups of people. The certification of the letter through the award he won magnified the impact of the letter. Both the certification and his mother's brokering of the letter to family, church members, and peers supported others talking about Wynn as "smart" and a good writer, and about his writing as touching their lives. Finally, the ways that Wynn was characterized as a writer tapped into values of different communities: academic achievement (particularly at school and home), leadership and diversity (at church), and creativity (at home). Boundary objects, certification, brokering, and shared values are themes found not only in the case of Wynn and his trajectory of identification as a writer but across other trajectories of intersections found in the larger study. I will discuss the implications of these findings for supporting productive intersections of identities.

Doing Cross-Contextual Work: On Method

While the papers on this panel differ in terms of their basic methodological approach—interviews, observations, connective ethnography, discourse analysis of texts and online conversations—there are some critical intersections that are worth noting. First, all the studies are qualitative in nature, and they all have engaged meaningfully with presentation of findings and also hermeneutic interpretation through theoretical and critical lenses. Related to the qualitative nature of inquiry is a post-positivist approach wherein we are not so much concerned with the objective validity or accuracy of the narratives we hear from participants. Instead we argue that the stories participants carry with them from experience are more important and more powerful for shaping identity than the actual events themselves (Bruner, 1991; Ochs & Capps, 1996). Thus our boundary-crossing work to examine identity in multiple contexts is not for the purpose of somehow "triangulating" data or validating participant reports from one location to another, but rather to fully trace the terrain of participants' narratives through the worlds they inhabit, on their terms.

Second, in all the studies on the panel, the researchers are co-participants in at least one context under study, thus having some already-existing connection to the participants and the contexts they inhabit (Atkinson & Hammersley, 1994). This not only facilitates subject recruitment and data collection, as well as conversation during interviews, such that researchers can ask informed questions about the shared context and participants can respond with abbreviated insider language without explaining every detail, but it also seems to push participants to do more identity-positioning and boundary-crossing rhetorical work in interviews, reflections, etc, almost as if they are thinking, "You know me in *this* context, but let me explain myself in *that* context."

Finally, third, in three out of four of the studies on the panel, written texts are of critical importance. Participants construct written artifacts—a lifeline, a blog, an essay—and then that artifact becomes a focal point for reflection, a fulcrum for personal change or revelation, and the crux of research inquiry. Writing is an artifact of practice that is authentic, crystallizing, and useful for research as an anchor for further analysis, but it is also a valuable kind of data in and of itself, particularly when examining identity. As described by Bazerman and Prior, the aim is to perform discourse analysis on written texts and their surrounding narratives, "so as to uncover signs of social identities, institutions, and norms as well as the means by which these social formations are established, negotiated, enacted, and changed through communicative practice," (Bazerman & Prior, 2004).

Symposium Structure

The session will take the form of a traditional 90-minute paper session, with brief opening chair's remarks and approximately twelve minutes per paper, followed by discussant comments and audience question-and-answer. Our discussant, Na'ilah Suad Nasir, from UC Berkeley, is an authority on cultural identity, culture and mathematics practices, and the sociocultural and practice-related shaping of identities across contexts. Her work represents one of the earliest attempts to connect learning practices in and out of school among African American mathematics students, situate these practices within institutional and cultural contexts, and elucidate important tensions among these phenomena (e.g., Nasir, 2002). Her comments will speak to common themes among the papers, provide suggestions for future research, and frame some productive topics for discussion with the audience during question-and-answer.

References

Anderson, J. (2004). The ties that bind? Self and place identity in environmental direct action. *Ethics, Place & Environment, 7*(1-2), 45-57.

Atkinson, P. & Hammersley, M. (1994). Ethnography and participant observation. In N. Denzin & Y. Lincoln (Eds.), *Handbook of Qualitative Research.* Newbury Park, CA: Sage Publications, pp. 248-261.

Barton, A., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science: How urban girls position themselves with authority by merging their social worlds with the world of school science. *American Educational Research Journal, 45,* 68-103.

Baxter Magolda, M., & King, P. (2004). *Learning partnerships: Theory and models of practice to educate for self-authorship*. Sterling, Virginia: Stylus Publishing, LLC.

Bazerman, C. & Prior, P. (2004). Introduction. In C. Bazerman & P. Prior (Eds.), *What writing does and how it does it: An introduction to analyzing texts and textual practices.* Mahwah, NJ: Lawrence Erlbaum, pp. 1-10.

The Boyer Commission Report on Educating Undergraduates in the Research University. (1998). *Reinventing undergraduate education: A blueprint for America's research universities*. Retrieved from http://naples.cc.sunysb.edu/Pres/boyer.nsf/

Bruner, J. (1991). The narrative construction of reality. *Critical Inquiry, 18,* 1-21.

Buckingham, D. (2008). Introducing identity. In D. Buckingham (Ed.), *Youth, identity, and digital media.* The John T. and Catherine D. MacArthur Foundation Series on Digital Media and Learning. Cambridge, MA: The MIT Press, 1-24.
Carlone, H. & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*, 1187-1218.
Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research*. Thousand Oaks, CA: Sage Publications, 509-535.
Clandinin, D. J. & Connelly, F. M. (2000). *Narrative inquiry: Experience and story in qualitative inquiry*. San Francisco: Jossey-Bass Publishers.
Clayton, L. W., Clayton, S., & Opotow, S. (2003). *Identity and the natural environment: The psychological significance of nature*: MIT Press.
Davidson, A. (1996). *Making and molding identities in schools: Student narratives on race, gender, and academic engagement*. Albany, NY: State University of New York.
Dugan, J. (2006). Explorations using the social change model: Leadership development among college men and women. *Journal of College Student Development*, 47(2), 217-225.
Erickson, E.H. (1968). *Identity: Youth and crisis*. New York: Norton.
Gee, J. (2001). Identity as an analytic lens for research in education. *Review of Research in Education, 25,* 99-125.
Goffman, E. (1959). *The presentation of self in everyday life.* New York: Doubleday.
Hall, S., Forrester, S., & Borsz, M. (2008). A constructivist case study examining the leadership development of undergraduate students in campus recreational sports. *Journal of College Student Development*, 49(2), 125-140.
Ham, S. H. (1992). *Environmental interpretation: A practical guide for people with big ideas and small budgets*. Golden, CO: North American Press.
Komives, S., Longerbeam, S., Owen, J., Mainella, F., & Osteen, L. (2006). A leadership identity development model: Applications from grounded theory. *Journal of College Student Development*, 47(4), 401-418.
Leander, K. M. (2008). Toward a connective ethnography of online/offline literacy networks. In D. Leu, J. Cairo, M. Knobel, & C. Lankshear (Eds*.) Handbook of research on new literacies.* New York: Erlbaum, 33-65.
Logue, C., Hutchens, T., & Hector, M. (2005). Student leadership: A phenomenological exploration of postsecondary experiences. *Journal of College Student Development*, 46(4), 393-408.
Lord, R., & Hall, R. (2005). Identity, deep structure and the development of leadership skill. *The Leadership Quarterly,* 16, 591-615.
Luehmann, A. L. (2008). Using blogging in support of teacher professional identity development: A case study. *Journal of the Learning Sciences, 17,* 287-337.
Marcia, J. E. (1994). The empirical study of ego identity. In H. A. Bosma, T. L. G. Graafsma, H. D. Grotevant & D. J. de Levita (Eds.), *Identity and Development: an interdisciplinary approach* (pp 67-79). Thousand Oaks, CA: Sage Publications.
Nardi, B., Schiano, D. J., & Gumbrecht, M. (2004). *Blogging as social activity, or, would you let 900 million people read your diary?* Paper presented at the Computer Supported Collaborative Learning Conference, Chicago, IL, November.
Nardi, B., Schiano, D. J., Gumbrecht, M., & Swartz, L (2004). Why we blog. *Communications of the ACM, 47* (12), 41-46.
Nasir, N. (2002). Identity, goals, and learning: Mathematics in cultural practice. *Mathematical Thinking and Learning, 4*, 211-245.
Nasir, N. S. & Saxe, G. B. (2003). Ethnic and academic identities: A cultural practice perspective on emerging tensions and their management in the lives of minority students. *Educational Researcher, 32*(5), 1-14.
Neilson, A. L. (2009). The power of nature and the nature of power. *Canadian Journal of Environmental Education, 14*, 136-148.
Martindale, T., &Wiley, D. (2005). Using weblogs in scholarship and teaching. *Tech Trends, 49*(2), 55–61.
Ochs, E. & Capps, L. (1996). Narrating the self. *Annual Review of Anthropology, 25,* 19-43.
Palincsar, A. (1998). Social constructivist perspectives on teaching and learning. *Annual Review of Psychology, 49,* 345-375.

Posner, B., & Brodsky, B. (1992). A leadership development instrument for college students. *Journal of College Student Development*, *33*(4), 231-237.

Rangell, L. (1994). Identity and the human core: The view from psychoanalytic theory. In H. A. Bosma, T. L. G. Graafsma, H. D. Grotevant & D. J. de Levita (Eds.), *Identity and development: An interdisciplinary approach* (pp. 25-40). Thousand Oaks, CA: Sage Publications.

Sfard, A. & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational Researcher, 34*(4), 14-22.

Star, S. L. & Griesemer, J. R. (1989). Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, 19(3), 387-420

Widner, C. J., & Roggenbuck, J. W. (2000). Reducing theft of petrified wood at Petrified Forest National Park. *Journal of Interpretation Research, 5*(1), 1-18.

Williams, J. B. & Jacobs, J. (2004). Exploring the use of blogs as learning spaces in the higher education sector. *Australasian Journal of Educational Technology, 20*(2), 232–247.

Understanding a future with multiple pasts: Projects on metahistorical understanding

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Abstract: History learning has been of interest to learning scientists for many years, though it has not been investigated as vigorously as the Science-Technology-Engineering and Mathematics (STEM) disciplines. This symposium presents four projects that are united by two goals: helping young learners understand what makes the discipline of history unique, and helping learning sciences researchers understand how insights from research in STEM disciplines may transfer to work in history education. The research spans three countries and both formal and informal learning environments.

Objectives

The discipline of history has been of interest to learning scientists for many years, though it has not been investigated as vigorously as the Science-Technology-Engineering and Mathematics (STEM) disciplines. The participants in this symposium are united by two goals: helping young learners understand what makes the discipline of history unique, and helping learning sciences researchers understand how insights from research in STEM disciplines may transfer to work in history education.

Helping students to understand and appreciate historical accounts has always been difficult work. However as western societies increasingly recognize cultural diversity, a new level of challenge has been added. The pressure to understand and account for multiple accounts of past events is steadily increasing (Banks, 2008; Seixas, 2004; Takaki, 1993), and without an understanding of why two carefully researched, honestly reported historical accounts may disagree, students may hold either a cynical view that history is "written by the victors", or an "anything goes" conception in which all accounts are equally valid. Such conceptions undermine participation in democratic society. This symposium brings together researchers who are addressing this challenge through the design of technology-intensive learning environments.

Theoretical Background: What makes history unique?

At first blush, what historians do may not seem so different from what scientists do. Scientists make careful observations, bring questions to bear on evidence and test possible explanations and interpretations against this evidence (National Committee on Science Education Standards and Assessment, 1996). So do historians (Howell & Prevenier, 2001). However, the historian's questions and the nature of the evidence available to address them are substantially different. Historical questions deal not only with what happened in the past, but with change over time, and with the human significance of events. Even events that have been studied thoroughly before can attain new significance and attract new curiosity as we learn more about "how things turned out." For example, the questions that will be asked about the events of September 11, 2001 will be different 50 years from now than they are today. However the historian (unlike the scientist) cannot "re-run the experiment" under different conditions to answer a specific question.

This begins to suggest how honest, well-trained historians can differ in their interpretation of past events; yet many students do not have mature conceptions about conflicting accounts of the past. This is due largely to the fact that textbook-driven instruction (which is common worldwide) shields students from varying perspectives on historical events and personalities. History textbooks often present a single, homogenized perspective on the events they cover, written in an impersonal "voice of History" (Wineburg, 2001) that obscures the decisions made by the historian in constructing the account.

The participants in this symposium share the goal of developing students' understandings of the reasons why historical accounts may differ. These are part of a larger set of "metahistorical" conceptions that scholars have studied for many years (Lee, 2004; Shemilt, 2000; Wineburg, 2001), including historical significance, causes and consequences, perspectives, constancy and change. How can learning sciences researchers influence these conceptions, and what previous scholarship will help us?

O'Neill, "Compassionate Canada?"

Together with colleagues at Simon Fraser, O'Neill recently developed a curriculum unit to lead 11th grade Social Studies students to more mature conceptions about why historical accounts differ. Students spent two weeks pursing a thorny historical question using a variety of online source materials, and getting advice along the way from history Ph.D. students serving as "telementors" (Single & Single, 2005). The unit was developed in collaboration with three seasoned Social Studies teachers, whose goal was to develop students' metahistorical ideas without sacrificing the coverage of mandated curriculum.

In the unit, students were invited to interrogate Canada's popular image (echoed in textbooks) as the world's do-gooder. Students were asked "Has Canada become a more compassionate country in the last 100 years?" The design team favored this question because it addressed change over time, and dealt with the entire scope of the year's history curriculum. The unit could thus be used either as a pre-exam review, or (for more adventuresome teachers) to kick off the year.

Based on teacher input, the researchers assembled an online archive of primary source documents covering seven historical cases. Some of the cases illustrate the compassion of Canada's government or its people towards those in need (e.g. Canada's response to Tamil refugees in the 1980s), while others call that compassion into question (e.g. the internment of Japanese Canadians during World War II). In some cases, the government has issued an official apology to people it has wronged, and provided compensation for its past actions; but even in these cases it is not clear what apologies or compensation indicate about how the government or individual citizens might respond to similar cases in the future.

Students were assigned to groups of four, each of which pursued the overarching question of the unit using evidence about a different historical case. This design deliberately orchestrated cognitive conflict between groups of students, and within students' own minds in order to induce conceptual change (Johnson & Johnson, 2009; Limon 2001). As they progressed through the unit, students formulated positions on the central question of the unit, which were critiqued by volunteer telementors. At the conclusion of the unit, a "horseshoe debate" was conducted in which each group presented its stance on the question of the unit based on its assigned case, then literally stood on a large horseshoe shape on the school library's floor to indicate how close it stood to the "yes" (Canada has become more compassionate) or "no" (it has not) side.

The implementation reported for this symposium took place in three sections of Mr. George's Social Studies 11 class at Hanover Secondary, involving almost 90 students. Hanover Secondary is a public school within walking distance of some of the wealthiest and the poorest Vancouver-area neighbourhoods, and serves 500 students whose families speak many heritage languages.

A survey was developed to assess the unit's impact on students' metahistorical conceptions, and was administered to every student, pre and post. Survey questions included:

- What makes somebody a historian?
- Why do historians write new books about events that were already written about before?
- If a historian is learning about the events of a period and finds two stories about them that disagree, what should she do?

Students responded to each question by rating their agreement with four statements that appealed to more or less mature metahistorical ideas described by Shemilt (2000). Statistical analysis of students' responses showed that over the course of the unit, students overall made significant gains in their appreciation of the idea that historians must make educated guesses when evidence is limited. It was also found that when students reported receiving particular kinds of advice from their online mentors (such as alternate interpretations of the sources students were working with) they tended to lose faith in the notion that there is always one true story to be told about a past event (O'Neill & Guloy, 2010).

Our experience showed areas in which the unit design could be improved as well. For example, in whole-class discussions at the end of the unit, some students told us that they felt their answer to the major question of the unit (had Canada become more compassionate) was predetermined as *yes*, because the historical cases depicting a lack of compassion were not matched with similar current-day events. In their view one *had* to assume that improvement had been made in 100 years! It became evident to us and the teacher that his students knew little about cases of abuse in Canada's contemporary environment, though these certainly exist and could be integrated into our materials for future iterations. With further refinement, the team expects both the curricular framework for this unit and the survey measure of metahistorical conceptions to be useful in many other contexts.

Ben-David Kolikant, "Doing history together": A collaborative investigation by Israeli Jewish and Arab students of their shared past of conflict

The "Doing History Together" project brings Israeli Jewish and Israeli Arab students together to collaboratively investigate their shared past of conflict. In these activities, students use primary and secondary source materials, such as the writings of Jewish, Arab, and British historians, to write historical accounts collaboratively in a Wiki environment. This environment enables students of all backgrounds equal access to the public writing space, and hence to revise, comment, and challenge the text written so far. The project team involves Israeli Jewish and Israeli Arab historians and learning sciences researchers.

This activity design was inspired, in part, by Contact Theory (e.g. Amir, 1969), which describes the conditions that need to be fulfilled in order to have a fertile encounter between people from conflicting groups. For example, in order to promote collaboration and reduce competition among narratives, students have the freedom to choose whether they will write a consensual account on the event, or an analysis of the essence of their disagreement. We encouraged students to pinpoint the issues that the "other side", being mediated by their culture and sense of belonging, chose to ignore, resist, or accept 'automatically' when interacting with historical text (Wertsch, 1998). Our design hypothesis was that such discussion would promote historical thinking and more mature metahistorical conceptions.

A primary objective is to generate awareness that the language one chooses to use encrypts one's ideology (Bakhtin, 1981). The secondary sources that students receive on the Balfour Declaration (an event they study) demonstrate this. In 1917 Lord Balfour, then a minister of foreign affairs in the British government, issued a document addressed to Lord Rothschild, conveying the sympathy of the British government to the establishment of a Jewish national home in Palestine. In Jewish sources the event is referred to as the Balfour declaration, Arab sources call it the Balfour promise. The word "promise" implies a stronger commitment of Britain to the Jews than "declaration" does. Britain made a similar "promise" to the Arabs previously (the Hussein-McMahon correspondence), and hence deceived them.

"Doing history together" has been implemented in two rounds. In the first, six groups at the university level participated. This phase enabled us to fine-tune the assignment and the analysis tools. The second round involved 120 Jewish and Arab high-school students, who were asked to work in foursomes, each including a pair of Arabs and a pair of Jews. Data collected in the second round included questionnaires about students' concerns and expectations (pre and post), students' individual essays concerning the events studied (pre and post), joint essays produced by the foursomes (as well as all drafts), scripts of the e-communication, and post-interviews with a sample of the students.

Four out of six groups at university level produced joint answers, two of which inclined towards the Jewish narrative, and the other two inclined towards the Arab narrative. (The other two groups stopped the conversation in early stages.) Three out of the four completed conversations were "charged" in terms of the moral judgment employed by both Jewish and Arab participants, vis-à-vis the historical agents of the "other" side. The encounter with historians' writings in the presence of interlocutors from the "other side" brought about a growth in students' understanding of history as interpretive in nature. Here we briefly describe two common topics of discussion between bi-ethnic groups.

(a) Terminology. Students discussed terminology either as an outcome of their reading of a source, or when needed, to agree on the terminology to use for the group's joint essay. This segment is taken from a class discussion initiated by a Jewish student (JS1) before the students turned to work in groups:

1. JS1: I read the sources and in one of them instead of Israel it is written Palestine, why?
2. AS1: That's the name. Before you came here.
3. JS1: The place has a name. Israel. You can't change it just because you don't like it.
4. AS1: It is not a matter of liking. I suggest that we search and see how it was entitled in the period we are studying, and use that name.

The different terminology used by the Arab historian bothered JS1, so she initiated a discussion on it, and suggested the name "Israel." The correspondence between her and AS1, an Arab student in lines 2&4, demonstrates "presentism," students bringing present-day controversy to the discussion. In line 4, SA1 (perhaps in an attempt to reduce the tension) suggested to investigate the name used back then. In essence, he utilized historiography as a way out of controversy.

Similarly, when AS2 (an Arab student from another group in the first round) was asked during an interview to describe the dynamics of the discussion within his group, he referred to his group's discussion on the terms "declaration" and "promise": "They [Jewish peers] said 'declaration'. We said 'promise'. So we [Arab peers] [said], 'Listen. It's a declaration but it has the same importance as a promise.' "

(b) Controversy within the sources. All the students noticed that the historians whose writing they read "disagree", i.e. each suggests a different hypothesis about the event. The group responses to the controversy varied. During the pilot study, two groups suggested that each participant try to construct his or her own hypothesis. For example, in the following excerpt, JS3 summarizes the contradictions among historians as to whether Britain was aware of the consequences of issuing the declaration, and suggested this action: "So Friedman [Jewish historian] is basically the only one who says that Britain knew that a Jewish state would be established here and supported it. Sykes [British historian] says the opposite, and so does al-Hout [Arab historian]…. What is your opinion? Your personal opinion?" This brought about vivid discussion in these groups as they constructed a chain of counter arguments to the hypotheses suggested.

Analysis of the second round data shows similarities to the results from the first round. Students' e-discussions were embedded with "hot" (emotional) segments, yet despite the virtual nature of the encounter and the lack of shared personal history, there were few incidents of vandalism (using inappropriate words or deleting the work of others). Further, most groups strove to produce joint answers.

Polman, Narrative metacognition and story diagrams as scaffolds for the critique and construction of history narratives

Working with historians from the Catoctin Center for Regional Studies in Frederick, MD, an intervention was developed in which youth critiqued existing historical narratives, and constructed competing narratives of a local history event. Both critique and construction utilized mediational frameworks aimed at scaffolding the evidence-based and narrative aspects of historical thinking. These activities utilized a four-part model of narrative metacognition and computer-based story diagrams or "storygrams" (Polman, 2006).

This symposium presentation will report on qualitative research from this intervention in which youth critiqued and created "empirical narratives." Interpretation of the student case studies is augmented by structured interviews with two trained historians. The study focused on a summer camp entitled "Telling the Stories of the Past: Creating Digital Documentaries about Controversial Local History". The camp met for six hours per day for one week during summer 2007. Four 12-14 year-old boys (one African-American and three European American) participated. The camp curriculum was co-designed by the author, historians at a regional history center, and the instructor (a doctoral student in American Studies), and focused on local history leading up to and during the United States Civil War.

One highlight of the week related to metahistory was analysis of two "digital documentaries" about the role a regiment played in a battle. Analysis used "narrative metacognition" elements. Metacognition is a powerful aspect of thinking across disciplinary domains (e.g., Bruer, 1993; White & Frederiksen, 1998). The following types of metacognitive practices were used as prompts on a paper form used to scaffold the youth critiques, as the literature suggests they could contribute to more sophisticated understanding of empirical narratives (Polman, 2006): monitoring perspectives, considering precedents, analyzing storytelling craft and symbolism, and recognizing the "story frames" used to "spin" accounts.

Good history teachers encourage learners to focus on the perspectives and biases of those who created the sources they are using, especially in initiatives involving youth in the "doing of history" research utilizing primary sources (e.g., Levstik & Barton, 1997). Similarly, in critiquing the two accounts, the young men in this study readily picked up on the influence of perspective: one youth described how the teller of the first tale was "proud of the Northern fight put up", in contrast to another which characterized the teller of the other tale as taking a "negative perspective". The "precedents" or existing accounts with which the hearer is familiar also influence credibility, and the youth were able to recognize important precedents they recalled related to these accounts. In this case, the youth saw precedents for these tales about a battle in their recollection of other accounts where a regiment was outnumbered like that of the Battle of Thermopole (retold in the movie *300*), or overcame great odds as in *The Lord of the Rings*. The goal of this prompt was to target law-like precedents, where previous legal decisions shape reactions of the courts to new cases which are essentially narratives crafted to link to precedents that will provide beneficial interpretations—and thus legal decisions (Bruner, 2003). But the way the precedents prompt worked for these particular accounts and these youth related more to the third narrative metacognition item, about storytelling craft—they could see the way that the teller was trying to craft a heroic or tragic tale to appeal to viewers. In literature and language arts classrooms, students often analyze storytelling craft and symbolism that helps create meaning in fictional stories, but such considerations are rare in the context of history or journalism. Nonetheless, compelling metaphors or images, either explicit or implicit, strengthen the reception of empirical narrative texts or multimedia artifacts (Beach and Myers, 2001). In this case, the youth were able to recognize how colors such as red were used to symbolize violence, an upward shot of a soldier statue reinforced the heroic interpretation of one commentary, and tone of voice clarified the negative message of the other commentary. Finally, "frame recognition" is an essential aspect of a critical stance toward empirical narratives. Although accusing political opponents of spin has become commonplace, all sides in political arguments place events in a preferred frame; the question is how honestly or deceitfully. Several authors (e.g., Lakoff 2004) have written on how framing influences meaning interpretation. Critical consumption of empirical narratives can include attention to facts excluded by the narrative frame, as well as unsupported assumptions bolstered simply because they make sense in the storyline. In this setting, the framing of the first tale was seen by the participants in the inclusion of some facts and the exclusion of others. For instance, the pro-regiment story mentioned that the regiment later played a role in the Confederates' surrender at Appomattox; it did not mention any particular soldier's death as described in the more negative account.

A second metahistorical highlight of the intervention was analysis and diagramming of competing interpretations of a local lawyer and U.S. Supreme Court justice's position on slavery. These 12-14 year old boys were challenged by the difficulty of using primary and secondary texts from the 19th century to make sense of the legal and ethical debates around slavery, and we attempted to scaffold their analysis with a story diagram ("storygram") tool. The primitive categories for the version of storygrams explored in this study were based on Wertsch's (1998) interpretation of Kenneth Burke's pentad. Storygrams describe each event using the pentad. Each event is centered on the action (*what* happened), carried out by agents (*who* did it), utilizing cultural tools (*how* they did it), in order to serve goals (*why* they did it), within the context of some scene or interpreted context (*where/when* it happened). In the web-based computer application (http://www.storygraph.org), each element of a storygram can be linked to supporting evidence. After the boys' had initial difficulty diagramming their ideas in the Storygraph computer program individually with reference to the source documents, the group convened as a whole the next day for a group diagramming process, which Polman facilitated. The coaching technique of prompting the learners with questions and suggestions, and then showing them how to do the steps in the Storygraph computer program while they carried out the same steps as the facilitator on their computers proved useful in engaging the youth.

Finally, the camp youth participation in the research, writing, and creation of digital documentaries about a local battle from the U.S. Civil War revealed the utility of metahistorical scaffolds. For this activity, two boys were asked to create stories defending the notion that the battle was a greater victory for the North, while the other two were asked to support the idea that the South was the bigger victor in the battle; they used the Storygraph program to plan their accounts, and were encouraged by facilitators to consider the narrative metacognition elements. The Storygraph computer tool proved particularly useful as a kind of diagrammatic storyboard/outline for evidence-based accounts. It acted as a prop in organizing the gist of the story, and discussing which elements of it were well-supported by evidence, and which were assumptions. Epistemologically, the most difficult aspect of the learning these relatively young children faced was the idea that two accounts that disagree could both be factually accurate, but differ because of perspective and selection. The youth struggled with this notion, as exemplified by initially insisting one side or the other had to "win" the argument about whether the North or South was the greater victor in the battle, until one proclaimed, "maybe it was a tie." Two of the youth acknowledged the possibility of competing perspectives in their statements and narratives, while another chose to discount the competing perspective. After seeing contradictory factual details described in primary sources, the fourth participant dwelled on his personal revelation that "history may not be true."

Radinsky – Building nuanced historical narratives around geographic data

The development of metahistorical reasoning includes learning to make sense of potentially conflicting and contradictory narratives (Lee, 2004). But integrating multiple historical narratives also goes beyond interpreting authored accounts like primary-source documents or secondary-source explanations: it also includes the "emplotment" of what Wertsch (2004) calls "specific narratives" (p. 51) built in classroom discourse. This process of "emplotment" includes constructing the significance of historical data whose meaning might at first appear to be direct and unambiguous.

This study examined the ways high school students and teachers constructed and problematized interpretations of historical census data, displayed in geographic information system (GIS) interactive maps, and constructed multiple ways to make sense of the data observed, within a curricular narrative about the African American Great Migration(s) of the early and mid 20th century. These "emplotments" of the data maps also incorporated historical documents, prior knowledge of students and teachers, and concepts introduced in a mini-lecture and in discussion. The study made use of an online, public-use GIS for browsing and querying historical U. S. census data, *GIS for History* (www.gisforhistory.org), developed by the author (Radinsky, 2008; Radinsky, Loh & Lukasik, 2008).

Common explanatory narratives about the Great Migration in high school textbooks include a standard set of historical actors, themes, and "plot points": African Americans left the South in large numbers to escape poverty, Southern racism, and/or the sharecropping system that had replaced *de jure* enslavement after the Civil War. They moved to Northern cities like New York and Chicago, where industrial jobs were available to them due to the shortage of white workers and the need for military production, both caused by the World Wars. Railroad lines like the Illinois Central were common means of leaving the South, accounting for settlement patterns in these cities.

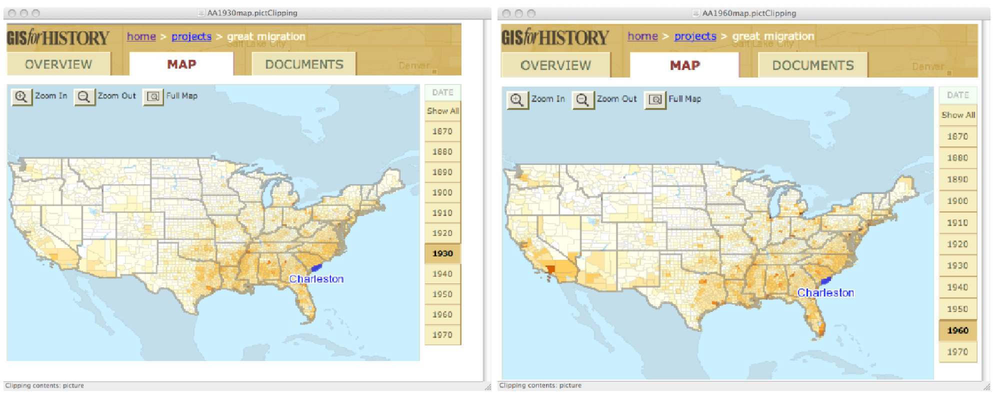

Figure 1. *GIS for History* maps showing African American population (darker shades) by county in 1930 (left), and in 1960 (right).

GIS maps (Figure 1), like historical photographs or documents, can serve to reinforce key points of such a narrative, but can also be used to perturb it, afford questions, or bring out nuances. In this excerpt from a whole-class discussion of the GIS map on the overhead, multiple and competing observations and interpretations emerge for historical phenomena that might have occurred between 1930 and 1960. The excerpt begins as the teacher (the author, who co-taught the unit) has just facilitated a series of observations about where African Americans lived in 1930 (left side, Fig. 2). The class is asked to imagine and predict how the patterns they have observed (i.e., most African Americans living in the Southeast, few in most of the North and West) will change when the map is changed to the census year 1960.

1. Teacher: I'm going to change the year from 1930 to 1960. How is it going to change?
2. Byron: They will start moving.
3. Renee: They'll be mostly in the North
4. Teacher: OK, they will start moving, will be mostly in the North.
5. Kimberly: But they'll be spread more evenly
6. Shakiya: The population may increase too
7. Teacher: {Can you clarify that? What do you mean?}
8. Shakiya: Like, people are gonna have children, and the population will change {because of that}
9. *[TEACHER CHANGES MAP TO 1960 –right side, Fig. 2]*
10. Angela: OK, they may {…} There is more, and they are more spread, going west and north, but it still looks the same
11. Renee: A couple of spots turned red – here in California, and kind of here *[pointing]*

12. Stephanie: {And in Florida and … there are} sprinkles, {and like some} spots.
13. Teacher: So then in Florida {there are some} sprinkles and some spots. Excellent.
14. Stephanie: There are large amounts of {sprinkles}
15. Teacher: {When you say} sprinkles, what does that mean?
16. Stephanie: They are {mainly} in certain places
17. Angela: {They could be} free spaces, where it's like they can have more rights and {freedom}

Here students articulate elements of the standard narrative of the Great Migration: Byron predicts movement (line 2); Renee predicts that they will go to the North (line 3); Angela confirms this with her observation of movement towards the west and north (line 10); and Angela goes on to hypothesize that a search for rights and freedom might be a motivation (line 17).

Even this brief excerpt opens doors to other possible narratives. Renee's prediction that "they will be mostly in the North" (line 3) is problematized by the 1960 map as soon as it appears: in the words of Angela, "it still looks the same." That is, the greatest concentration of African American population remains in the Southeast – "they" are not "mostly in the North," as predicted. This point might indicate the need for a narrative to explain why most African Americans did *not* leave the South during this time.

Another point that emerges is the complex pattern of population concentrations within and across regions, described by Stephanie as "sprinkles" and "spots" (lines 12-16), explainable by migrations of previously-dispersed rural populations into urban centers. Stephanie's observation directly challenges Kimberly's prediction that "they'll be spread more evenly," suggesting competing narratives that might be explored. Also, Stephanie's identification of such "spots" in Florida raises a provocative counter-narrative: in some cases, the Great Migration was a movement *southward.* This seemingly simple "plot point" sets up Angela to hypothesize about the nature of those "spots" not in terms of their geographical placement or urban status, but rather as "free spaces." This is a noteworthy possibility: a narrative about free spaces in the South is substantially outside the traditional plotline, and affords meaningful discussion of how an oppressed people might create "free spaces" in a region that has been associated (in the standard historical narrative) primarily with slavery and sharecropping.

These examples suggest how complex geographic and historical data can become part of a process of problematizing simplified historical accounts. Data showed that the most commonly-articulated explanations by the end of the lesson (identified through coding of student answers on a 4-question pre-post assessment) were predictable parts of the traditional narrative: e.g., that the migration was a move *from* the South (evidenced by 67% of students on the post assessment), and *from* rural areas (evidenced by 50%). However, only 38% specified it as a movement *to* the North, perhaps reflecting these kinds of discussions in each of the four classes studied that troubled the "to the North" narrative. On a map-based assessment, while a majority of students (72%) identified a Northern city as a likely in-migration area, and a Southern rural location as a likely out-migration area (66%), there were 41% who also identified a Southern city as a likely in-migration area (though we had hoped for higher numbers on all of these). Similarly, the number of students mentioning racism as a *push* force for the migration increased from the pre to the post in each class. However, the small amount of the increase (from 24% to 36%) disappointed us. It seems that this mechanism was problematized for students by documents and discussions that revealed the intense racism African Americans encountered in the urban North.

These findings, and others to be presented in the talk, suggest directions for future work exploring the ways multiple, conflicting historical narratives might be productively developed in classrooms and leveraged for teaching metahistorical understanding.

Discussion

Each of the contributions to this session builds upon a unique foundation within learning sciences theory and a unique set of technological affordances, to develop curriculum and pedagogy that promise to enrich students' metahistorical conceptions. In each of the presentations we also see researchers building upon the empirical findings of previous learning sciences research beyond the domain of history. As a whole, the work presented here provides promise that the worth of learning sciences research can transcend current national policy environments and the disciplines in which it has traditionally focused. In the ways explored, students may be brought to an appreciation of how history differs from other disciplines – including its unique strengths and uses, the unique characteristics of the evidence it considers, and the ideologically "loaded" nature of its narrative framing and the language in which narratives are shared. Students' conceptions of these unique aspects of history may be influenced for the betterment of democratic society by the design of new media and schemes for their use in curricular and extra-curricular settings.

References

Amir, Y. (1969). Contact hypothesis in ethnic relations. *Psychological Bulletin, 71*, 319-342.

Banks, J. A. (2008). Diversity, group identity and citizenship education in a global age. *Educational Researcher, 37*(3), 129-139.

Bakhtin, M. M. (1981). *The dialogic imagination: Four essays by M. M. Bakhtin* (C. Emerson, & Holquist, M., Trans.). Austin: University of Texas Press.

Beach, R., & Myers, J. (2001). *Inquiry-based English instruction: Engaging students in life and literature*. New York: Teachers College Press.

Bruer, J. (1993). *Schools for thought: A science of learning in the classroom*. Cambridge, MA: MIT.

Bruner, J. (2003). The narrative construction of reality. In M. Mateas & P. Sengers (Eds.) *Narrative intelligence*. Amsterdam/Philadelphia: John Benjamins Publishing.

Howell, M., & Prevenier, W. (2001). From Reliable Sources: An Introduction to Historical Methods. Ithica, NY: Cornell University Press.

Johnson, D. W., & Johnson, R. T. (2009). Energizing learning: The instructional power of conflict. *Educational Researcher, 38*(1), 37-51.

Lakoff, G. (2004). *Don't think of an elephant!* Vermont: Chelsea Green.

Lee, P. (2004). Understanding history. In P. Seixas (Ed.), *Theorizing Historical Consciousness*. Toronto: University of Toronto Press.

Levstik, L., & Barton, K. (1997). *Doing history: Investigating with children in elementary and middle schools*. Mahwah, NJ: Lawrence Erlbaum Associates.

Limon, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. Learning and Instruction, 11, 357-380.

National Committee on Science Education Standards and Assessment. (1996). National Science Education Standards. Washington, DC: National Academy Press.

O'Neill, D. K., & Guloy, S. (2010, April). *The Historical Account Differences survey: Enriching methods for assessing metahistorical understanding in complex school environments.* Paper presented at the Annual Meeting of the American Educational Research Association, Denver, CO.

Polman, J. L. (2006). True stories, storied truth: Stitching narrative and logico-scientific discourse together in an age of "spin". In S. A. Barab, K. E. Hay, & D. T. Hickey, *Proceedings of the International Conference of the Learning Sciences 2006*, pp. 557-563. Mahwah, NJ: Erlbaum.

Radinsky, J. (2008). GIS for History: a GIS learning environment to teach historical reasoning. In Alibrandi, M. & A. Milson (Eds.), *Digital Geography: Geo-spatial Technologies in the Social Studies Classroom:* 99-117. Greenwich, CT: Information Age Publishing.

Radinsky, J., Loh, B. & Lukasik, J. (2008). GIS tools for historical inquiry: Issues for classroom-centered design. *Journal of the Association of History and Computing,* XI(2).

Seixas, P. (2000). Schweigen! Die kinder! or, does post-modern history have a place in the schools? In Stearns, Seixas & Wineburg (Eds.), *Knowing, Teaching and Learning History: National and international perspectives.* New York & London: New York University Press.

Seixas, P. (Ed.). (2004). *Theorizing Historical Consciousness*. Toronto: University of Toronto Press.

Shemilt, D. (2000). The caliph's coin: The currency of narrative frameworks in history teaching. In P. N. Stearns, P. Seixas & S. Wineburg (Eds.), *Knowing, teaching and learning history: National and international perspectives* (pp. 83-101). New York: New York University Press.

Single, P. B., & Single, R. M. (2005). E-mentoring for social equity: review of research to inform program development. Mentoring & Tutoring, 13(2), 301-320.

Takaki, R. T. (1993). *A different mirror: A history of multicultural America*. Boston: Little, Brown & Co.

Wertsch, J. V. (1998). *Mind as action*. New York: Oxford University Press.

Wertsch, J. V. (2004). Specific narratives and schematic narrative templates. In P. Seixas (Ed.), *Theorizing Historical Consciousness.* Toronto, Canada: University of Toronto Press.

White, B., & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction, 16*(1), 3-117.

Wineburg, S. (2001). Historical thinking and other unnatural acts: Charting the future of teaching the past. Philadelphia: Temple University Press.

On the Process and Outcomes of Inquiry Learning: Changing Approaches to Assessment

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Abstract: Inquiry learning is an educational approach that involves a process of exploration, asking questions and making discoveries in the search for new understandings. Researchers however are divided about the value of the approach. In the symposium, it is argued that one of the reasons for this controversy is the way that inquiry learning is assessed. Consequently, we aim to present papers which reflect on the challenge of assessing inquiry learning by describing the prevailing approaches to assessment and how technological and theoretical advancement is changing these approaches. The aim is not just to describe these approaches but reflect upon the opportunities that are created and difficulties that must be overcome as we pursue the goal of assessing the processes and outcomes of inquiry learning.

Introduction

Inquiry-based learning involves learners asking questions about the natural or material world, collecting data to answer those questions, making discoveries and testing those discoveries rigorously (e.g., de Jong, 2006). It is an idea with a long history (Dewey, 1916; Bruner, 1961) and many researchers and educators argue for the benefits of an inquiry approach to science (e.g. Dunbar, 2000; Duschl, 2008; Linn 2006).Yet, this approach remains controversial with debates still ranging about its effectiveness (e.g., Klahr & Nigram 2004; Kirschner, Sweller, & Clark, 2002; Hmelo-Silver, Duncan, & Chinn, 2007). One complicating factor in attempting to resolve this debate is that researchers are divided about how best to assess inquiry learning: should we focus on the process on inquiry or its outcome and if outcomes, what is it that inquiry learning help students develop? Consequently researchers working in inquiry learning have produced in depth analysis of the processes of inquiry learning: they have shown how it develops over time, how different learners' participate in inquiry learning and the ways that teachers or technology can scaffold inquiry learning (e.g., Kuhn, & Pease, 2008; Quintana et al 2004; de Jong & van Joolingen, 1998). The outcomes of inquiry learning have been seen in terms of domain knowledge at different levels and in different modes, inquiry skills, nature of science and scientists; attitudes to science and science self-efficacy (e.g., Hickey et al 2003, Linn & Hsui, 2000; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Fraser, 1981; Ketelhut; 2007; Linn 2006). With such a variety of approaches and their implicit value systems, it is perhaps not surprising that this inquiry debate still rages.

The papers presented in this symposium reflect on the challenges of assessing inquiry learning. The paper by de Jong and Wilhelm aims to provide a sucient overview of the range of methods and concepts that researchers have used to assess inquiry learning. It summarizes the traditional approaches and points forwards to how new technological approaches avilable to researchers are increasing the sophistication by which we can measure the process of inquiry learning. As a complement, Hickey, Filsecker and Kwon focus on how theoretical advances in our understanding of inquiry learning change our approach to assessment. As cognition is seen as increasingly situated, the nature of the evidence required to understand learning by inquiry changes. This provides difficulties for researchers then asked to show an individual's proficiency in inquiry learning. Hickey et al describe an approach to inquiry assessment, participatory assessment, which is designed to address this challenge. Ainsworth et al describe the problem of engaging learners' with assessment. They argue that traditional outcome tests of inquiry learning can under-represent learners' understanding of the inquiry process by requiring completion of pen and paper tests that do little to motivate learners. They present an approach – Inquiry Comics – which presents a narrative of a character's investigation of a meaningful question and ask students to respond to the character's decisions. Finally, Clarke-Midura, Mayrath, and Dede also tackle the problem of student engagement with assessment but with a decidedly more high tech solution – that of immersive virtual environments. They reflect on the opportunities that such an approach brings but also helpfully share the problems they face in developing an innovative form of assessment.

The issue of how we understand the processes and outcomes of inquiry learning is one that has no simple answer. The purpose of bring together the papers in this symposium is to reflect upon whether inquiry learning assessment is providing the evidence that researchers, educators and policy makers need to improve 21st century science learning. We therefore envisage a lively debate with members of the audience led by our discussant Cindy Hmelo-Silver.

Assessment and inquiry; issues and opportunities

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Inquiry learning is an educational approach that involves a process of exploration, asking questions and making discoveries in the search for new understandings (National Science Foundation, 2000). In a typical (computer based) inquiry learning task, learners conduct experiments to test hypotheses about the relationships between variables in a particular knowledge domain (de Jong, 2006). Inquiry learning tasks vary in the constraints they pose to learners. Tasks may vary from open-ended, self-paced tasks in which learners follow their own particular inquiry paths, generating their own questions and hypotheses to tasks in which research questions and hypotheses are defined by an instructor. Although any particular study takes a stance somewhere along this continuum, there are still many routes possible for learners during the learning process and what is learned may differ between students. As a result a variety of types of learning outcomes are possible, ranging from different types of knowledge to specific skills. Assessing these can be done after the learning process outside the learning environment but also on-line during the process on the basis of the learners' interaction with the inquiry environment and the products (e.g., hypotheses, models) produced. In case of collaborative learning chat data can be included in this analysis. A specific challenge with on-line assessment is that there is no single "norm" behavior to which the learners' actions can be compared. This presentation sets out to structure the challenges and potential solutions for the assessment of inquiry processes and outcomes.

Since inquiry learning is an educational approach, domain knowledge is the first most obvious concept addressed. Posttests measuring different types of knowledge (e.g. content, structural and conceptual knowledge) and transfer tests have been applied. There is nothing specific to inquiry learning about these types of tests. However, the concept of intuitive knowledge is primarily seen only in inquiry learning and tests have been developed for this (Swaak & de Jong, 1996). On-line representations of domain knowledge include learner-generated models, concept maps, or research reports that are produced while learning. Automatic assessment of these products that represent domain knowledge is now being developed (see e.g., Bravo, van Joolingen, & de Jong, 2009).

Another concept pertains to the assessment of specific inquiry skills. Again a division can be made with a measurement outside the learning environment and one in which on-line interactions are the basis for the assessment. Outside the learning environment (e.g., as a post-test) inquiry skills have been measured with the use of paper- and- pencil tasks. The concept of critical thinking skills shares many characteristics with inquiry, e.g. the Watson-Glaser Critical Thinking Appraisal® test includes scales that call upon data interpretation and drawing conclusions. The Test of Science Processing (Tannenbaum, 1971) and the Test of Integrated Science Processes (Padilla, Okey, & Dillashaw, 1983) were developed to assess science skills (e.g., variable identification, hypothesis formation, operationalization, experimentation and data interpretation). Another way of assessing inquiry skills is using a task that includes all aspect of inquiry, but is domain-independent, thereby controlling for the effect of prior knowledge. Evidence on the validity of this method, however is still lacking.

Other concepts that have been related to inquiry learning are assessments of epistemological beliefs (Kuhn, Cheney, & Weinstock, 2000) or tests that call upon knowledge about the workings of science (Nature of Science, see Chen, 2006). Several motivational concepts, such as attitudes and self-efficacy towards science have been measured using questionnaires.

Computer technology enables extensive logging of actions performed in digital learning environments and data mining techniques are currently used to extract patterns indicative of specific learning behaviours. Inquiry skills are often induced from the inquiry cycle. These skills pertain to the formulation of hypotheses, systematic experimentation (e.g., usage of the CVS) and data interpretation, although other labels have been used. Various other skills, for example metacognitive skills also have been object of research. In fact, inquiry learning relies heavily on regulative processes. Learning process data may include specific activities of learners (e.g., values assigned to input variables), chatlogs of collaborating learners, and even neurobiological measures (van Leeuwen, van der Meij, & de Jong, submitted).

The characteristics of the different assessment and measurement techniques are as manifold as the concepts measured. They involve criterion measures (e.g., a model score calculated on the basis of the actual model in the task, and descriptive measures (e.g., measures indicative of transformative or regulative processes), individual and group measures (e.g., questionnaires measuring epistemological beliefs), and process data collected unobtrusively or explicitly (e.g., with prompts). Assessment is performed by teachers, researchers, sometimes peers and sometimes automatically.

The goals of assessment include grading, but also informing learners (online support) and creating a basis for pedagogical interventions. In both cases, the system may present hints to learners to optimize learning (Veermans, de Jong, & van Joolingen, 2000). System based assessment of online activities may even be focused on collaborative activities. For example, monitoring online communication using chat may provide for real time information of the contributions of the different collaborators to the learning process or provide hints about what is best to communicate about (Anjewierden, Chen., Wichmann, & van Borkulo, submitted). Of course many validity issues have to be solved using these system-based assessment techniques for these purposes, but progress is being made towards automatic online support in inquiry learning environments.

Many concepts, measurement and assessment techniques are applied with regard to inquiry. The open-ended and self-directed nature of inquiry makes it hard to define hard criteria for grading and aptitude in inquiry, but both the assessment of learner behaviour and learning outcomes are indicative of emerging understandings and "good" inquiry skills. System-based assessment of inquiry learning to support learning is promising, but also hindered by the fact that there are various effective inquiry paths, which raises several validity issues (e.g., vary several variables at a time may be unwise in general, but functional in the orientation phase). The current presentation will give a structured overview of issues involved illustrated with examples from running projects (e.g., the SCY project) that show what problems are encountered and how solutions to these problems are implemented.

Participatory Assessment: Supporting Engagement, Understanding, and Achievement in Scientific Inquiry

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Tensions over educational assessment and measurement are central to ongoing debates about inquiry-oriented science education. This presentation sheds new light on this issue by (1) reviewing widely-appreciated tensions over assessment of inquiry-oriented vs. more expository science instruction, (2) revisiting these tensions using newer situative views of measurement and assessment, (3) introducing a participatory assessment model that addresses these tensions, and (4) showing how this model was used to foster communal engagement, individual understanding, and aggregated achievement in three design studies of leading technology-based inquiry curricula.

The debate over assessing inquiry reflects the conflict between different views of what it means to "know" and therefore what counts as authentic evidence of that knowledge. Hickey & Zuiker (2005) examined how *associationist*, *rationalist*, and *situative* views of cognition support different assumptions about knowledge of inquiry and what those assumptions mean for evidence. The associationist perspective characterizes knowledge as numerous specific associations regarding behavior (i.e., stimulus-response) and/or cognition (e.g., if-then). Hence, they support more direct instructional methods that efficiently teach those associations, and then use conventional recognition/recall tests to reliably measure how much individuals have learned. Antithetically, the rationalist perspective on cognition characterizes knowledge as a smaller number of higher-order conceptual schemas that vary from one person to the next. This supports constructivist inquiry-oriented instruction and the use of more open-ended problem solving and performance-oriented assessments of learning. These assessments are more subjective and less reliable than conventional tests; to some this makes them less "scientific" as well. Schwartz, Lindgren, & Lewis (2009) argue that constructivist pedagogies are often evaluated through non-constructivist means. They point out measures of "efficiency at remembering, executing skills, and solving similar problems" are "*something of a mismatch to larger constructivist goals"* (p. 35). Our presentation will examine this tension, and summarize advances in constructivist assessments (e.g., Schwartz and Bransford, 1998).

We then explore these tensions using newer situative perspectives on cognition. In their examination of the broader debate over constructivism, Gresalfi and Lester (2009) suggest that "learning is about more than a change in memory but about a change in ability to interact with resources in the environment" (p. 265). As Greeno and Gresalfi (2008) pointed out, this assumption casts doubt on the validity of the entire enterprise of assessing and measuring individual proficiency. Such highly contextualized (i.e., "situated") characterizations of proficiency ultimately require more interpretive evidence which can account for the broader technological and social context of knowledgeable activity. But these methods do not yield the evidence of individual proficiency that other stakeholders demand. We will examine this issue and summarize the burgeoning literature on situative assessment (e.g., Gee, 2003; Moss et al., 2005) and discursive approaches to assessment and formative feedback (Hickey & Anderson, 2007).

The presentation will conclude by describing a comprehensive approach to assessment that addresses these tensions. Participatory assessment uses design-based refinement of informal discursive assessment and feedback to align inquiry curricula to constructivist assessments of individual understanding; once sufficiently large gains in understanding are obtained, achievement gains are formally measured using external achievement tests. Results from three inquiry learning projects that employed this model will be summarized, including *GenScope* (Hickey et al., 2003; 2006), three NASA multimedia curricula (Taasoobshirazi et al., 2006; Anderson et al., 2007), and the Taiga ecological science curriculum in the *Quest Atlantis* videogame (Barab, et al., 2007; Hickey, et al., 2009). For all but one of the NASA curricula, gains in understanding and achievement were statistically significant and equal to or larger than the gains in comparison classrooms using expository curricula to teach the same content.

Engaging students with assessment: Inquiry cartoons.

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Personal Inquiry (PI) project aims to enable learners to explore questions to which they genuinely want to know the answer, carry out investigations that relate to their own needs and concerns, and analyse and interpret findings (e.g. Anastopoulou et al 2009; Scanlon et al, 2009). These inquiries are designed to link the school classroom and the children's community (such as homes, parks, leisure facilities). Learners are supported by teachers and by the PI Toolkit which runs on netbook computers with connected data probes and is designed to scaffold the process of inquiry learning through scripts (dynamic lesson plans). These are lofty aims, and of course, we face the challenge of evaluating the extent to which we achieve them. Consequently, we have evaluated many aspects of the processes and outcomes of inquiry science. The paper reflects upon one of these: the development of inquiry skills. The central challenge we faced was to design an inquiry process test that was: a) informative to researchers and teachers; b) a valuable learning experience in its own right, not 'just a test' and; c) one that engaged students – for personal learning we needed personal assessment.

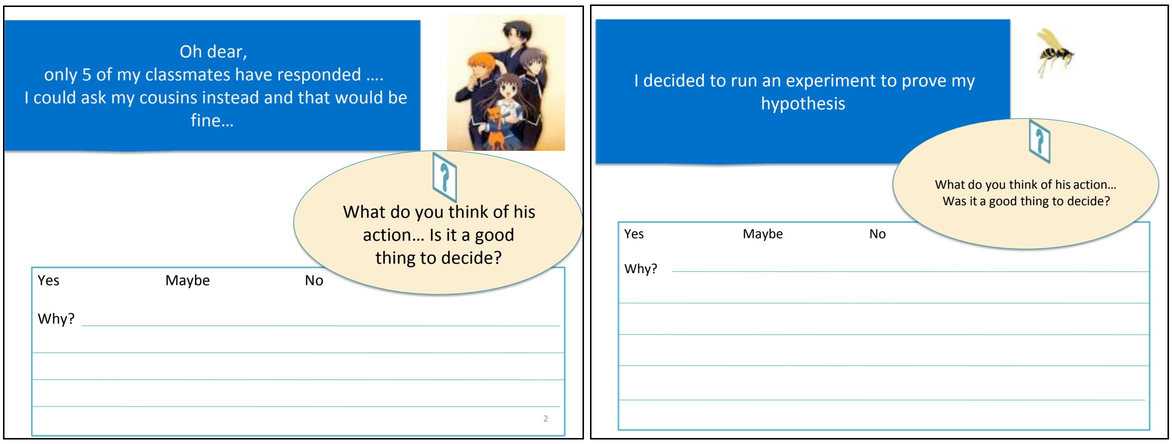

Figure 1. Two sample comic page (a) addresses what students understand about choosing appropriate samples; b) explores aspects of their understanding about hypothesis testing. Note these examples are taken from the middle of extended narratives.

The solution we have trialed is Inquiry Comics. These assessments are related to Concept Cartoons™ (e.g. Keogh & Naylor, 1999) which are cartoons of children discussing different (correct and incorrect) ideas about scientific phenomena in everyday settings. Concept Cartoons have a number of uses including promoting argumentation, stimulating children's own investigations, and formative assessments (e.g. Keogh & Naylor, 1999; Chin & Teou, 2009). Inquiry Comics share with Concept Cartoons™ the principles of minimal text, visual representation, familiar everyday settings, and correct and incorrect statements of scientific ideas. However, we use a comic form (a series of connected events presented in sequence to form a narrative) to present a character's inquiry process from the early stages of choosing a topic to investigate, through to selecting appropriate methods, collecting data, presenting it and drawing appropriate conclusions. At each stage in the process, the character makes decisions about aspects of scientific investigations that are known to be difficult for learners, such as judging veracity of source information, data collection, controlling variables, hypothesis testing, and drawing appropriate inferences from data (e.g. de Jong 2006; Kuhn, Pease, & Wirkala, 2009; Schauble, Glaser, Duschl, Schulze, & John, 1995). Sometimes those decisions are appropriate and sometimes less so (see Figure 1 for a decision considered to be less appropriate).

There are a number of challenges that we have faced in creating Inquiry Comics. It is, of course, difficult to create informative situations with minimal text. We also need to trade off the benefits of a full inquiry cycle and the resulting potential to probe understanding of the inquiry process at all stages with the length of the comic book which would result from such a complete activity. We needed dialogue that was easy to read, lacked jargon and that kept learners' attention. This was a particular necessity for the current project as we used Inquiry Comics as summative assessment so learners read them silently and did not discuss their meaning with peers or teachers (unlike the typical use of Concept Cartoons™). The comic form required a consistent narrative so any decision made by the character needed to continue through the comic. This obviously posed little problem for appropriate decisions but when the character was portrayed as making a decision that would threaten the veracity of the whole investigation (such a mischoosing a sample), this needed to be resolved within the comic. On these occasions, after the learners had been invited to write their interpretation of the investigator character's choice, a teacher or friend character would intervene to nudge the investigation back on course. Again this needed to be done with a light touch and in minimal text. Finally, given our requirements to use Inquiry Comics as pre and post-tests, we needed to create parallel version of each comics. Consequently, we needed similar topics to investigate and which contained the same methods. It is not clear in our first attempts with this technique the extent to which we have achieved this objective.

However, there were a large number of benefits to using Inquiry Comics. Students' performance on the tests revealed a depth of understanding that was not visible through other assessments (e.g., we had previously trialed asking students to design their own investigations). They were motivated and engaged with the comics, again far more so that with our other written tests. Analysis of their responses has revealed when learners are responding superficially (e.g. '*not a fair test'*) rather than more deeply (why something might not be a fair-test). This might be difficult to achieve in a multiple choice style of assessment. Their post-test responses also shed light on problems they had faced during their own investigations (e.g. their sensitivity to the problems of accurate on-going data collection).

The use of Inquiry Comics seems a promising addition to the battery of approaches to assess inquiry learning. We created comic books but they could also be adapted and used within other forms of Technology Enhanced Learning. They can be used summativly as we have done but also could be used for formative assessment and, of course, like Concept Cartoons™ for many other teaching and learning processes.

Measuring Inquiry: New Methods, Promises & Challenges

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Contemporary views of science education regard scientific inquiry and the ability to reason scientifically as the essential core of science education (American Association for the Advancement of Science (AAAS), 1993; Chinn & Malhotra, 2002; NRC, 1996; Krajcik et al, 1998; Songer et al, 2003). According to White and colleagues, scientific inquiry is an active process comprised of four primary components: theorizing, questioning and hypothesizing, investigating, analyzing and synthesizing (White & Frederiksen, 1998; White, Frederiksen & Collins, in preparation). Measuring these inquiry processes as well as the products that result from the processes has long been a challenge for educators and researchers (Marx et al, 2004); however, advances in technology and measurement are creating new possibilities for assessing both process and product (Pellegrino, Chudowsky & Glaser, 2001; Behrens, 2009). There are three themes that this symposium is addressing: what inquiry is and is not, the best way to teach inquiry, and the best way to measure inquiry. We have chosen a widely accepted definition of what inquiry is by White et al, described above, and are focusing our work on the latter, how to best measure inquiry.

One such possibility for measuring inquiry comes in the form of immersive virtual assessments (IVAs). IVAs are three dimensional (3-D) environments, either single or multi-user, where digitized participants engage in virtual activities and experiences. Each participant takes on the identity of an avatar, a virtual persona that can move around the 3-D environment. IVAs allow us to create and measure authentic, situated performances that are characteristic of how students learn inquiry (NRC, 2000). These immersive environments have advanced capabilities for student experimentation and data analysis in a virtual setting, such as working with large data sets, GIS map visualizations, and simulated models of phenomena unobservable to the naked eye. Further, these environments enable the automated and invisible collection of very rich and detailed event-logs on individual learners in real-time, during the very act of learning (Pellegrino et al, 2001). Such event-logs provide time-stamped records of the details of students' actions while they interact with the IVA. Our prior work on using immersive technologies for learning environments lead us to believe that assessments delivered via this technology will be more motivating and engaging (Clarke, 2006; Clarke & Dede, 2009). We hypothesize that some students will be less likely to "freeze up" when taking the assessment and will try harder on these assessments than on paper-and-pencil and multiple choice tests.

In order to measure inquiry process and products in situ, we are using the Evidence Centered Design framework (Mislevy, Steinberg, & Almond, 2003) to develop IVAs for measuring inquiry at the middle school level, grades 6-8. These assessments are intended to be part of a standardized component of an accountability program. Our work on developing assessments for measuring inquiry is guided by the knowledge, skills, and abilities that underlie White and colleagues four components of scientific inquiry, e.g., theorizing, questioning and hypothesizing, investigating, analyzing and synthesizing. We are designing tasks that allow us to observe students gathering appropriate data, interpreting data, drawing conclusions, and providing evidence. The design of our tasks allows us to capture evidence of student learning outcomes and processes that contribute to an ongoing student model of proficiency in inquiry.

While IVAs are promising in their potential for studying student performances and learning trajectories, they also come with a cost. The field does not have a common model or algorithm for modeling the complexity of student learning and behaviors (Behrens, 2009). In our design process, we have had to work through the following challenges and issues such as: *how do we ensure task dependency without disrupting the flow of the inquiry process? What model best fits our data for proficiency? How do we score process separately from content? How do we measure a learning progression?* These and other issues will be addressed in more depth in the presentation.

If we succeed in addressing the challenges and issues on how to measure inquiry, we believe we will aid in the discussion of what inquiry is and also cast light on how to best teach inquiry. Only through deep understanding of how to measure and model inquiry will we better understand the best methods for teaching it (i.e. direct instruction vs problem-based learning debate).

References

American Association for the Advancement of Science. (1993). Benchmarks for science literacy: A Project 2061 report. New York: Oxford University Press.

Anastopoulou, S., Sharples, M., Wright, M., Martin, H., Ainsworth, S., Benford, S., Crook, C., Greenhalgh, C., & O'Malley, C. (2008) Learning 21st Century Science in Context with Mobile Technologies. In J. Traxler, B. Riordan & C. Dennett (eds.), Proceedings of the mLearn 2008 Conference: The bridge from text to context, Wolverhampton, UK: University of Wolverhampton, pp. 12-19.

Anderson, K. T., Zuiker, S., & Hickey. (2007). Classroom discourse as a tool to enhance formative assessment and practise in science. *International Journal of Science Education*, 1721-1744.

Barab, S., Zuiker, S., Warren, S., Hickey, D., Ingram-Goble, A., Kwon, E. J., et al. (2007). Situationally embodied curriculum: Relating formalisms and contexts. *Science Education*, 91(5), 750-782.

Behrens, J.T. (2009). Response to Assessment of Student Learning in Science Simulations and Games. A NAS-commissioned response paper.

Bravo, C., van Joolingen, W. R., & de Jong, T. (2009). Using co-lab to build system dynamics models: Students' actions and on-line tutorial advice. *Computers & Education, 53*, 243-251.

Chen, S. (2006). Development of an instrument to assess views on nature of science and attitudes toward teaching science. *Science Education, 90*, 803-819.

Chinn, C. A., & Malhotra, B. A. (2001). Epistemologically authentic scientific reasoning. In K. Crowley, C. D. Schunn, & T. Okada (Eds.), Designing for science: Implications from everyday, classroom, and professional settings, (pp. 351-392). Mahwah, NJ: Erlbaum.

Chin, C., & Teou, L. Y. (2009). Using Concept Cartoons in Formative Assessment: Scaffolding students' argumentation. *International Journal of Science Education*, 31, 1307-1332.

Clarke, J. (2006). Making Learning Meaningful: An exploratory study of using Multi-User Virtual Environments for teaching inquiry in middle school. *Qualifying Paper presented to the Committee of Degrees at Harvard Graduate School of Education*, Cambridge, MA.

Clarke, J., & Dede, C. (2009). Design for Scalability: A Case Study of the River City Curriculum. *Journal of Science Education and Technology*, 18(4), 353-365.

de Jong, T. (2006). Technological advances in inquiry learning. Science, 312(5773), 532-533.

Dewey, J. D. (1916). Democracy in education. New York: Macmillan

Duffy, T. D., & Jonassen, D. H. (1991). Constructivism: New implications for instructional technology? Educational Technology, 31(5), 7–12.

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. Review of research in education, 32, 268–291.

Fraser, B. (1981). TOSRA: Test of science related attitudes. *Australian Council for Educational Research*.

Gee, J. P. (2003). Opportunity to learn: a language-based perspective on assessment. Assessment in Education: Principles, Policy & Practice, 10(1), 27-46.

Greeno, J. G., Collins, A. M., & Resnick, L. B. (1996). Cognition and learning. In Berliner, D. C. & Calfee, R. C. (Eds.), Handbook of educational psychology (pp. 15-46). New York: Macmillan Library Reference USA, Prentice Hall International.

Greeno, J. G., & Gresalfi, M. S. (2008). Opportunities to learn in practice and identity. In Moss, P, Pullin, D. C, Gee, J. P, Haertel, E. H., & Young, L. J (Eds.), Assessment, equity, and opportunity to learn (pp. 170–199). Cambridge, MA: Cambridge University Press.

Gresalfi, M. S., & Lester, F. (2009). What's worth knowing in mathematics? In S. Tobias & T. D. Duffy (Eds.), *Constructivist instruction: success or failure?* Routledge.

Hickey, D. T., & Anderson, K. T. (2007). Situative approaches to student assessment: Contextualizing evidence to support practice. P. Moss, Ed.) *Yearbook of the National Society for the Study of Education: Evidence and Decision Making*, *106*(1), 264–287.

Hickey, D. T., Ingram-Goble, A. A., & Jameson, E. M. (2009). Designing assessments and assessing designs in virtual educational environments. *Journal of Science Education and Technology*, *18*(2), 187-208.

Hickey, D. T., Kindfield, A. C. H., Horwitz, P., & Christie, M. A. T. (2003). Integrating curriculum, instruction, assessment, and evaluation in a technology-supported genetics learning environment. *American Educational Research Journal*, *40*(2), 495.

Hickey, D. T., & Zuiker, S. J. (2005). Engaged participation: A sociocultural model of motivation with implications for educational assessment. *Educational Assessment*, *10*(3), 277-305.

Hickey, D. T., Zuiker, S. J., Taasoobshirazi, G., Schafer, N. J., & Michael, M. A. (2006). Balancing varied assessment functions to attain systemic validity: Three is the magic number. *Studies in Educational Evaluation*, *32*(3), 180-201.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42*(2), 99-107.

Keogh, B., & Naylor, S. (1999). Concept cartoons, teaching and learning in science: an evaluation. *International Journal of Science Education, 21*(4), 431-446.

Ketelhut, D. J. (2007). The impact of student self-efficacy on scientific inquiry skills: An exploratory investigation in River City, a multi-user virtual environment. *Journal of Science Education and Technology, 16*, 99-111.

Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction. Effects of direct instruction and discovery learning. *Psychological Science*, *15*(10), 661–667.

Krajcik, J.S., Blumenfeld, P., Marx, R.W., Bass, K.M., Fredricks, J., & Soloway, E. (1998). Middle school students' initial attempts at inquiry in project-based science classrooms. Journal of the Learning Sciences. 7(3&4), 313-350.

Kuhn, D., Cheney, R., & Weinstock, M. (2000). The development of epistemological understanding. *Cognitive Development*, *15*, 309-328.

Kuhn, D., & Pease, M. (2008). What Needs to Develop in the Development of Inquiry Skills? *Cognition and Instruction, 26*(4), 512-559.

Kuhn, D., Pease, M., & Wirkala, C. (2009). Coordinating the effects of multiple variables: A skill fundamental to scientific thinking. *Journal of Experimental Child Psychology, 103*, 268-284.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6).

Linn, M. C. (2006). The knowledge integration perspective on learning and instruction. *The Cambridge Handbook of the Learning Sciences*, 243-264.

Linn, M. C., & Hsi, S. (2000). *Computers, teachers, peers: Science learning partners*: Lawrence Erlbaum.

Marx, R.W., Blumenfeld, P.C., Krajcik, J.S., Fishman, B., Solloway, E., Geier, R., & Tal, R.T. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. Journal of Research in Science Teaching, 41, 1063–1080.

Mislevy, R. J., Steinberg, L. S., & Almond, R. G. (2003). On the structure of educational assessments. Measurement: Interdisciplinary Research and Perspectives, 1, 3–62.

Moss, P. A., Pullin, D., Gee, J. P., & Haertel, E. H. (2005). The idea of testing: Psychometric and sociocultural perspectives. *Measurement: Interdisciplinary Research and Perspectives*, *3*(2), 63-83.

National Research Council. (1996). National Science Education Standards: observe, interact, change, learn. Washington, D.C.: National Academy Press.

National Research Council. (2000). How People Learn: Brain, Mind, Experience, and School. Washington, DC: National Academies Press.

National Science Foundation (2000). An introduction to inquiry *Foundations. Inquiry: Thoughts, views and strategies for the k-5 classroom.* (Vol. 2, pp. 1-5).

Padilla, M. J., Okey, J. R., & Dillashaw, F. G. (1983). The relationship between science process skill and formal thinking abilities. *Journal of Research in Science Teaching, 20*, 239-246.

Pellegrino, J. W., Chudowsky, N., & Glaser, R. (2001). Knowing what students know: The science and design of educational assessment. Washington, DC: National Academy Press.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., et al. (2004). A scaffolding design framework for software to support science inquiry. *Scaffolding: A Special Issue of the Journal of the Learning Sciences, 13*(3), 337-386.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching*, *41*(5), 513–536.

Scanlon, E. Littleton, K., Gaved, M., Kerawalla, L., Mulholland, P., Collins, T., Conole, G., Jones, A., Clough, G., Blake, C. and Twiner, A. (2009) Support for evidence-based inquiry learning: teachers, tools and phases of inquiry. In Proceedings of the 13th Biennial Conference of the European Association for Research on Learning and Instruction (EARLI), Aug 25-29 2009, Amsterdam.

Schauble, L., Glaser, R., Duschl, R. A., Schulze, S., & John, J. (1995). Students' understanding of the objectives and procedures of experimentation in the science classroom. *Journal of the Learning Sciences, 4*(2), 131-166.

Schwartz, D. L., & Bransford, J. D. (1998). A time for telling. *Cognition and Instruction*, *16*(4), 475–522.

Schwartz, D. L., Lindgren, R., & Lewis, S. (2009). Constructivism in an age of non-constructivist assessments. In S. Tobias & T. D. Duffy (Eds.), *Constructivist Instruction: Success or Failure?* Routledge.

Songer, N. B., Lee, H. -S., & McDonald, S. (2003). Research towards an expanded understanding of inquiry science beyond one idealized standard. Science Education, 87, 490-516.

Swaak, J., & de Jong, T. (1996). Measuring intuitive knowledge in science: The development of the what-if test. *Studies in Educational Evaluation, 22*, 341-362.

Taasoobshirazi, G., Zuiker, S. J., Anderson, K. T., & Hickey, D. T. (2006). Enhancing inquiry, understanding, and achievement in an astronomy multimedia learning environment. *Journal of Science Education and Technology*, *15*(5), 383-395.

Tannenbaum, R. (1971). The development of the test of science processes. *Journal of Research in Science Teaching, 8*, 123-136.

Tobias, S., & Duffy, T. D. (Eds.). (2009). *Constructivist theory applied to instruction: Success Or failure?* Routledge.

van Leeuwen, T., van der Meij, J., & de Jong, T. (submitted). Event-related potentials as a window on external representations.

Veermans, K. H., de Jong, T., & van Joolingen, W. R. (2000). Promoting self directed learning in simulation based discovery learning environments through intelligent support. *Interactive Learning Environments, 8*, 229-255.

White, B., & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. Cognition and Instruction, 16(1), 3-118.

White, B., Collins, A., Frederiksen, J. (in preparation). The Nature of Scientific Meta-Knowledge.

Wiggins, G., & McTigue, J. (2000). *Understanding by Design, standards-based instruction and assessment.* Association for Supervision and Curriculum Development, Alexandria, VA.

Transformative Play: Games as 21st Century Curriculum

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Abstract: In this presentation, we will discuss the design history, comparison studies, and scaling research focused on four units we have designed based on our theory of *transformational play*. The goal is to both discuss the power of these designs, but also the challenges of scaling such innovative learning experiences internationally. These four units (one focused on mathematics, science, language arts, and social studies) are situated in an online, multiplayer videogame called *Quest Atlantis*, supporting over 25,000 children worldwide. Each presented unit has gone through multiple iterations of implementation, analysis, and redesign, informed by empirical data and our evolving theoretical framework. In reviewing both results from comparison studies and differences in international engagement with the units, our accounts will illuminate the theory transformational play, how the theory has shaped design and interpretations of findings.

Introduction

We, as a society, are in the middle of a troubling transition in which teachers and schools are held increasingly accountable for students' acquisition of particular content but, at the same time, are facing a generation of students who view the curriculum as largely irrelevant to their own lives. This is, in part, because while much of the world is experiencing significant change in the ways we engage content, most K-12 classrooms continue to operate with an underlying cultural logic of "print-based" literacies and pedagogies in which the teacher dictates the learning process and textbooks determine what is true. Given this emphasis, it is not surprising that as students progress in the American educational system, their academic performance and engagement decreases when compared with other countries (UNESCO Institute for Statistics, 2007). This is especially true for students who are disenfranchised from classroom structures that focus on compliance without rationale, position content as facts to be memorized, and position students as objects to be changed as opposed to empowered change agents. In fact, a central argument of the papers in this symposium is that such positioning of person and content is pedagogically ineffective, personally disempowering, and conceptually inadequate if our goal is to prepare youth for meaningful participation.

The concern with students' meaningful participation is not new; Resnick (1987) stated that the fundamental challenge facing educators is to align the gap between how learning content occurs in schools and how it is used outside of schools. Specifically, she concluded that "schooling is coming to look increasingly isolated from the rest of what we do…the packages of knowledge and skills that schools provide seem unlikely to map directly … from school to out-of-school use." While such a perspective inspires new visions of the possible, *realizing* those possibilities in the context of schools has proven to be a significant challenge. Our work attempts to realize some of these possibilities by leveraging the tools and technologies associated with online videogames (Gee, 2003; Squire & Jan, 2007). We believe that videogames have the potential to bridge this gap because they, unlike any other form of curriculum, can offer entire worlds in which learners are central, important participants; a place where the actions one takes has a significant impact on the world; and a place in which *what* you know is directly related to what you are able to do and, ultimately, who you become.

For the last decade, we have been working to understand the power of videogames for supporting learning, translating emergent insights into design work from which we have continued to evolve our insights as they are cycled back into subsequent designs and analyses (Barab et al., 2007; Barab, Gresalfi, Dodge, & Ingram-Goble, in press). In this symposium we simultaneously advance a theory and report on the curricula we have designed, with the goal of illuminating for others the possibilities of leveraging game-based technologies and methodologies to support content learning in actual schools. Building on this theory and our own experiences designing for and studying student learning, we have begun to build a theory of *Transformational play,* which describes a strategy for situating the learner and curricular content within a play context. The idea of transformational play highlights relations among the three interconnected elements of person, content, and context. Specifically, transformational play involves positioning students as empowered actors who must understand and enlist academic content in order to effectively transform problematic scenarios.

The purpose of this symposium is to overview a series of comparison studies that investigated the power of transformational play in terms of its instantiation in three designs (one focused on mathematics, science, and language arts) situated in an online, multiplayer videogame called *Quest Atlantis* (http://QuestAtlantis.org. Each unit that will be presented in the session has gone through multiple iterations of classroom implementation, analysis, and redesign, informed by empirical data and our evolving theoretical framework about transformational play. In this presentation, we describe comparison study implementations of the designed units, first overviewing how the designs were intended to support learner intentionality, content legitimacy, and contextual consequentiality and then how they supported such positioning in practice. In building the latter characterizations, we looked through field notes, captured video, submitted work, interviews, and in-game log files from which to build implementation profiles. Using these data forms and the pre-determined focus on the elements of transformational play (person, content, and context), one researcher built initial claims and then worked with another researcher to form these into final arguments as presented below. The focus here is not to simply demonstrate that our designs scored significantly higher than the controls. Instead, our claims are theoretically motivated with the goal of shedding light on mechanism and further justifying the value of transformational play as a powerful theory for education.

Taiga Fishkill: Example 1 of Transformational Play

The Taiga Fishkill unit is an interactive narrative set within an aquatic habitat (Taiga National Park) where a serious ecological problem has resulted in many fish dying. Students are hired as environmental scientists whose job is to investigate the fish population decline, and propose solutions for the problem. To prepare the student for this role, the curriculum begins with an over-worked scientist, Abby, asking the visiting player to make several observations of and corrections to conditions of fish tanks she is using to run some experiments (see Figure 3). In one tank, the student identifies the dissolved oxygen in the tank as low, causing the fish to breath near the surface, and in another they observe that a significantly acidic pH has killed some fish. As the player is scaffolded through resolving each tank's problems, Abby becomes impressed by the player's growing sophistication at analyzing and solving the problems, and recommends that they may use this understanding to solve the fish population decline problem at the local national park where Abby used to work—thereby, *legitimizing* the disciplinary content.

Experiential *consequentiality* is supported by creating key decision points that require leveraging disciplinary formalisms, and enable the player to observe and interrogate the consequences of those decisions. For example, in investigating the problem, students are introduced to concepts such as erosion, eutrophication, water quality, and system dynamics. As they are introduced to what these concepts *mean,* they experience *how* these concepts *have meaning* by making decisions about how to improve water quality. Students, for example, may decide to target the role of nitrates in the water by asking the indigenous tribes, who are farming near the water, to stop their activity; they might focus on the role of erosion by asking the loggers to leave the area, or they might attribute the cause of the fish death to overfishing, and ask the commercial fishing company to close. After making this decision, students are able to see the consequences of their recommendation by traveling to a future world and considering the ramifications of their decision. *Intentionality* is supported by positioning students as expert helpers who can impact the situation by determining the cause of in the diminishing fish population. Players are asked to carry out various investigations into the health of the waterway and the impact of the nearby park activities—and non-player characters treat them as if they have the skills and dispositions to succeed. More specifically, they interview people with various perspectives on the problem, collect and analyze data to develop a hypothesis about the problem, propose an informed and practical solution, and examine the impact of their recommendation—all practices designed to position them in the role of a scientist. Because there is no clear "right answer," students have to balance between what the data are telling them about the river, their own values about the park community, and their sympathies that might lie with some community groups. Thus, their decisions about *how* to improve the park, and their positioning as an environmental scientist (as opposed to a student) who makes scientifically knowledgeable decisions, becomes an opportunity to become a scientist.

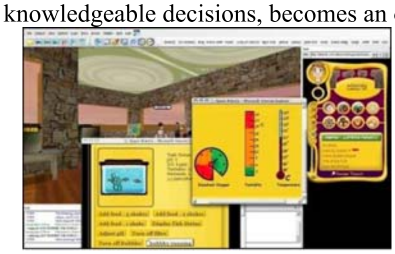

Figure 2. Screenshot from Taiga Fishkill showing a popup sequence associated with the fishtank

A comparison study was conducted with four equivalent classes in a suburban school (see Arici, 2008). The Traditional condition curriculum was text-based, and activities were teacher-led. The 3D MUVE condition was virtual-based, and placed the teacher in the role of resource, while students uncovered information within the larger structure of the Quest Atlantis virtual world. Both conditions were taught by the same teacher, presented with the same domain content, and assignments were aligned so that they were highly similar in their tasks. However, the traditional condition's lessons involved lecture, class discussion, and nicely organized notes, with micro-contexts serving as examples (a new exemplar for each new concept taught, as typically found in textbooks). The 3D multiuser virtual environment (MUVE) condition's lessons were embedded within a macro-context, the story of Taiga, where all science content was distributed in the game, needing to be uncovered and solved, within the overarching narrative about the fish decline in a local river.

The posttest showed significant learning gains for both conditions. However, the QA group learned significantly more than the traditional group as indicated by a repeated measures analysis of variance [$F(1,115) = 6.53$, $p < .01$]. Further, the delayed posttest, administered at an 8 week delay, showed the 3D MUVE groups ($M = 23.65$, $SD = 5.85$) also scoring significantly higher than the traditional groups ($M = 18.4$, $SD = 6.52$) [$F(3,87) = 5.73$, $p < .001$]. Also, twice during the study, students were interrupted from their activities (both groups doing an equivalent assignment) to respond to a series of questions on their current state of engagement in the task at hand. Comparison between conditions showed that the 3D MUVE groups ($M = 6.50$, $SD = 2.10$) scored significantly higher engagement and enjoyment than the traditional groups ($M = 2.64$, $SD = 1.94$) when collapsing across group membership [$t(104) = 9.73$, $p < .001$]. Further, when asked why you were doing this activity, 98% of the traditional said because they were required while only 54% of the 3D MUVE students selected this reason with 46% selecting that they were doing the activity because "they wanted to be doing it," not because required. Additional measures of engagement included the degree to which students opted to participate in non-required activities. In the 3D group, 38 out of 51 (74.5%) opted to do the optional quests, while in the traditional group only 2 out of 54 (3.7 %) did the 'extra credit.'

While these results demonstrated the power of the intervention for supporting important outcomes, it was also our goal to illuminate why transformational play was a powerful design pedagogy. Toward this end, our qualitative examination of both classrooms focused in on the positioning of person, content, and context. As a first example, we contrast two dialogues over similar scientific data to illuminate the power of positioning the data in terms of a fantastical problem.

Traditional Curriculum	Intervention Curriculum
G1: What did you get for Site A? G2: good, ok, good, ok, good, ok. G3: that's what I got. G1: For site B, I got ok, ok, bad, bad, ok, bad. G2: For Site C, I got good, ok, good, ok, ok, bad. G1: Would 0.3 count as being good? G3: I got ok, ok, bad. This continues until they finish all of the list… G1: Good! So I only missed one! G2: Hey, he opened the blinds! G1: It's sunny! G3: I'm wearing shorts on Sunday to the thing. G1: What thing? G3: I have practice Sunday. G2: Hey, I got new volleyball shoes and they are awesome! I had basketball shoes earlier which is fine, but I didn't want to scuff them. And so I got new Asic shoes, and they are like… G3: Really grippy? G2: yeah, and I got new knee high socks too. G1: I don't get like the questions. G2: What are the main water quality concerns at sites A and C? (reads question) G1: It's like really cold in here. G2: Mr. Summers, (whining) we need help! G1: Why is he talking to Daniel when he knows we need help?? G2: My pupils are really big. They are a little smaller right now, but they are usually really big. G3: you have a freckle on your eye! G2: I love that freckle!	G1: Okay, no Turbidity. That is good. G2: I think this one is really bad. I'm pretty sure. G1: Now I want to check water sample A. What do I do? G2: Just look at each of the chemical indicators, for A, B, and C. So, like with pH, look up the level at site C, and then look, it is in a range that is listed here as being 'very good' for aquatic life! Oh good! Okay, now you do it. The pH… G1: It is very good for…. Wait… (reading aloud while typing) The chemical indicator for A, B and C is very good for 'aquatic life'. Okay, so then go on to the next one, Dissolved Oxygen. Okay, for the chemical indicator, D.O., the level is unhealthy in sample A. Okay, Location A, it is a very unhealthy level, but it is fine in the other places. (turning to friend) And the p is lower case in the 'pH'. G2: Hey, I know why everything is worse at C. Because that is where everything ends up… see (pointing to Y shaped river, with C at bottom)… see, this is where the rivers come together, so everything bad ends up going there! G1: Okay. I'm on phosphates, what are you on? Holy cow! The phosphates are like so frickin' high! Can I say they are 'bad'? That's like a kindergarten word, but okay. G2: Okay. Now, turbidity… Ohh! That's not very good. Look at the turbidity. G1: Talking aloud while typing… 'The aquatic life might be a little stressed, as shown in sample…'

These contrasting cases illuminate the differences in both the kind of intention that students form as they work on a context that they are trying to transform, and in the legitimacy of the way content is taken up when it becomes a tool to be used to solve meaningful problems. This positioning changes the experience of learning from compliance to engaged participation where the feedback from the context frames participation as opposed to teacher reprimands.

The legitimacy of content was further substantiated because there is an object of refutation, grounding the conversation in terms of particulars that have substance, instead of what could conceivably be abstracted content. This is evident Chris and Jake's interaction as they analyze data.

Chris: "Whoa! Look at the temperature for B! That's WAY over. Way too high!
Let's go get the third one!"
Jake: "Okay!" (They each went to get the sample in Taiga).
Jake: "Now back to the lab. Let's compare it to the first two."
Just then the bell rang.
Chris: "Awwww! I'll do the next one at home."
[while packing up their bags, they continued]
Jake: "But man, did you see that temperature? Twenty-two degrees CELCIUS!"
Chris: "No man, that's twenty-two POINT FIVE! Way too high."
Jake: "That can't be good for the fish."
Chris: "Yeah! I know!"

This grounding in particulars is bolstered when student choices impact the response of the world, creating an even stronger sense of situational agency.

J: At first I thought the Mulus were to blame, because the chief was mean to me, and I didn't like him.
S: That's because you were mean to him first! [referring to choices the other student made in game]
J: Yeah, yeah. I know. … But you have to go more by the information that the charts give you, like the water samples and chemicals (indicators) in the water. You need to conduct tests on the water before you can really decide what is going on.

Because videogames provide a sense of consequentiality, intentionality involves more than simply caring, and legitimacy involves more than contextualizing, but instead the contextual responsiveness leads to a way of acting; leading to the development of what some have called *dispositions* towards engaging.

Ander City: Example 2 of Transformational Play

The Ander City unit positions students as political arbitrators when a child who lives in the city contacts them for help. Their current mayor is up for re-election, and he is running under a campaign of innovation. His opponent is challenging the mayor's innovative agenda, and claims that traditional methods of running the city are superior. The problem is that although both candidates completely disagree with each other, they BOTH claim that they have proof to support their claims. Is someone lying? Desperate for help, the children of Ander city hire Questers to become statistical consultants who can help them figure out who really is making the best decisions for kids. The unit targets three key ideas in statistics: different statistical tools can reveal different insights into data; statistical tools can be used opportunistically to support different perspectives; and beliefs can shape interpretations of results. In this way, students learn about both how to use statistical tools such as mean, median, and mode, and also learn *how they work* as mechanisms for making decisions about the world. In this unit, *intentionality* is supported as players are positioned as central decision makers in determining which candidate is making the best decisions for the town; as students learn more about the decisions the candidates are making, they can support one candidate or the other through the statistical tools that they choose to leverage. *Legitimacy* is supported by designing scenarios that allow for different recommendations based on the disciplinary tool that is leveraged. By designing the data so that students' choice of tool is directly linked to the outcomes, we serve to position students' disciplinary decisions as having legitimate impact on the decision that is made. Finally, *consequentiality* is supported by allowing students' decisions to impact the final outcome for the town as to whom is eventually elected mayor.

Ander City was part of a comparison study that involved comparing two matched curricular units about statistical data analysis. The units were parallel in that they both targeted the same key ideas (measures of center, distribution, sampling, graphing) and included "contexts" which situated students' mathematical engagement. The units differed, however, with respect to the *details* of the contexts (actual situations and duration of storyline); the *form* of the unit (paper-based activities vs. online videogame); and the *designed accountability* structures (teacher or unspecified external reviewer vs. fictional protagonists. Two 7th grade classes were included in the study, both taught by the same teacher. Students in these classes ranged from 12-14 years of age. Although the classes were not tracked, one class' achievement was generally lower than the other, and the students in the lower-scoring class were identified by the classroom teacher as "less motivated" than the higher-scoring class. The lower-scoring class used the immersive videogame (Quest Atlantis) for their statistics unit; the higher-scoring class used the comparison curriculum (comparison). Results of the comparison suggest that the Ander City class learned more. Specifically, a repeated measures ANOVA revealed a significant effect for curriculum, $F(1,23)=5.355$, $p=.03$. These results suggest that students using Quest Atlantis improved significantly more than the comparison class, despite their lower pre-test score.

The differences between these implementations can be understood in part by considering the extent to which students were positioned relative to the units. Seen clearly through their submitted work and in whole-class discussions, students in the Quest Atlantis classroom appeared to be playing transformationally with content, while students in the comparison classroom were grounded more profoundly solely in the domain of mathematics. For example, one of the first decisions that students have to make concerns which brand of bike is safer—the innovative brand that Mayor Enoch supports, or the traditional brand that the city has always used, which Mr. Grant prefers. Students collect data on both brands of bikes, and then analyze the data however they choose. In the response that follows, we can see how the student was positioned relative to the activity, specifically, that the student was acting with intention, in order to take action on a legitimate context, the outcomes of which were consequential.

"I analyzed the data by making a bar graph then added each 10 skids up and came out with speedy spokes for the answer as which is most reliable bike to stop soon enough before wrecking into something. But I just noticed that the Speedy Spokes skid can be anywhere from 30 in. to 54 in. and the Rollin steady skids were from 43 in. to 55 in. I would much rather be on a Rollin Steady bike because it is more consistent to what we are looking for here in Ander City so you don't run into the cars at stop sign. The reason why I chose range for the analysis is because I just thought that with a more consistent stopping bike that you wouldn't be worrisome about you stopping before the traffic or in the traffic this is why I chose the range for my analysis."

Evidence that the student was positioned with intentionality can be seen first in the students' use of the first person in describing her decision: throughout the recommendation, the student positions herself as the agent, both in terms of describing what she did to analyze the data (lines 1-4), and in terms of her personal ideas about safety (lines 4-8). More specifically, the student was adopting an intention when she made a decision about the kind of statistical tool that she could use in order to best represent the potential outcomes of interest. It is clear that the situation also was legitimate for the purposes of using disciplinary tools to make sense of situations; specifically, the student was able to discuss what she understood about the two brands of bikes based on the tools that she used to analyze the data. For example, in considering the minimums and maximums of both data sets, she discovered something important about the situation that she hadn't previously noted. Likewise, it's clear that the student is aware of the potential consequence of her (disciplinary) decision on the context, when she considers what it means to be safe (being able to predict when you would be able to stop, a statistic that is revealed by her use of the mean).

Differences between the ways that students are positioned relative to the content and the context can also be seen in whole-class conversations that took place around core activities. When the students playing Ander City were asked to decide which brand of bike was better, they answered in terms of both the content *and* the context, thus revealing their positioning with intentionality as they act with legitimacy on designed contexts that are responsive to their decisions. Consider the following conversations that took place in two classrooms taught by the same teacher:

T: Somebody explain to me, how on earth, how we as Mayor Enoch people who LOVE him, could look at Mr. Grant and think 'Gosh, he has some valid points.' How on earth could Mr. Grant POSSIBLY have valid points when he agrees totally NOTHING with what Mayor Enoch is saying?
St: Well it is of course…it could work either way, because, um, Rollin' Steady, you have…I might be getting mixed up but you have a more likely that you're going to have a better braking distance, but on the other hand, it's also got the HIGHEST braking distance. So=
T: =you mean a more consistent braking distance?
St: But its also got a high braking distance, so you got, either way, you could be screwed either way, it depends on what you want.

This exchange, which took place in the Quest Atlantis classroom, highlights the teacher's consistent positioning of the students as active decision-makers who have the right and obligation to make sense of the designed context. The student's response to this query reinforces this positioning, as he is able to think about the consequences (being screwed—i.e. crashing the bike) of the decision that he might make depending on which element of his analysis he prioritizes—consistency or average stopping distance. In contrast, the conversation that unfolded in response to a similar activity in the comparison classroom reveals different positioning:

T: What cool thing did you notice that this data has in common?
St: They both have the same median and mean
T: Their mean and median is both the same. So, does that mean it doesn't matter which machine my factory has?
Sts: (five second pause)
T: So, if you were a factory owner, or someone who's looking at that, does it matter which machine you use? They're both the same, right? The mean and the median are the same.
St: Not the mean
T: well, it has the same average
St: It doesn't matter.
T: Oh, it doesn't matter which one you use?

This exchange refers to a very similar activity using quite similar data (two different candy bagging machines which bag the same average amount of candy, but are different in terms of consistency). However, the tone of the conversation, specifically with respect to the consequentiality of decisions, is quite different. The teacher's opening question lacks the emotional valence of the QA example, and, unsurprisingly, the students' response is likewise relatively context free. Indeed, the students initially conclude that because the data sets have the same average, they must be equivalent, suggesting that they had not considered the relationship between the context of the data, that is, the implications of offering for sale bags with dramatically inconsistent amounts of candy in them. In theory, this context should be of significant personal relevance to the students, as it relates to candy and getting what you pay for. In reality, however, the students were quite distanced from the context of the problem, and did not act with noticeable intentionality in solving the problem. Instead, they leveraged the first tool they had available to them (average), and left the implications of their decisions (consequentiality) unexamined.

Modern Prometheus: Example 3 of Transformational Play

Modern Prometheus is a relatively new addition to the Quest Atlantis project. Modern Prometheus was developed with the goal of better understanding the potential of converting a classic piece of literature, like Mary Shelley's Frankenstein, into a transformational play space (see Figure 4). The Modern Prometheus unit focuses on persuasive writing, as students are asked to convince others to share their perspective on particular ethnical dilemmas. In particular, students grapple with the role that ethics play in science and technology, whether and when ends justify means in the battle with a plague, and the importance of companionship. The unit culminates with students making a decision about whether the Doctor Frank's creation is 'human,' and trying to persuade others about whether or not its life should be saved.

To support *intentionality*, players initially receive a letter from their mother, pleading with them to visit Doctor Frank and assist him with "anything he needs." Stepping off the train as they arrive in the plagued town, players make their way through the town square, meeting each of the major townspeople and gaining a sense of the desperation regarding the plague. They speak to people who have lost loved ones, family members, and friends. This establishes the player as an insider to the story, and also more generally as a citizen needing to care for the well being of others. Players are positioned as having a legitimate role, working as a writer where they engage and develop persuasive writing skills. The play space and motivation to help the doctor provides a *legitimate* reason for becoming proficient at writing persuasively. Players have to reflect on the town happenings and their own beliefs, and then use both evidence and their own opinions to craft an argument supporting or opposing the doctor's experiments that can convince even the most committed dissenters.

Experiential *consequentiality* is threaded throughout the unit. As an example, very quickly after making their way to the doctor's lab players engage the first ethical dilemma of the Unit: they decide whether or not to take a package from the crypt in the cemetery, a task that involves lying to the constable. It is in this moment that they experience their first sense of consequentiality with the philosophical notion of ends justifying means. Given the choice they make at this point, they begin to develop a stronger reputation with either the doctor or with the constable. Likewise, as students begin to write for the paper, they develop a reputation, which is recognized by characters in the space who refer to his or her skills and accomplishments.

Figure 3. Screenshot from Modern Prometheus World

We conducted the comparison study research in inner-city, 7th-grade classrooms with over 90% of the students in the implementation classrooms receiving free-and-reduced lunch. All data comes from the classrooms of one teacher. The Control classes went through a persuasive writing unit based off a novel that had been assigned to the class, called The Clay Marble. Students in the control group spent the first 45 minutes of the day, (period 1), listing to the teacher's audio recording of the book, while they read or followed along in their own copies. Later in the day, the students would complete their assignments in the computer lab, where they followed a worksheet with explicit instructions of what to write. Overall, both units took 10 classroom days. We initially compared the post-test learning gains of both groups. There were significant learning gains for the control group from pretest (M=7.16, SD=3.72) to posttest (M=11.22, SD=4.98), [t (31) = 8.75, $p < .001$], as well as for the experimental group from pretest (M=8.55, SD=3.77) to posttest (M=14.67, SD=3.52), [t (32) = 14.85, $p < .001$]. While both groups had large effect size gains (control=1.22, experimental=1.83), as would be expected from a two-week lesson with an experienced teacher, the repeated measures using Hotellings (1931)

T2 statistic showed the experimental condition had significantly more learning gains, $f(32,31)=11.03$, $p < .001$. In terms of student engagement, 86% of students in the experimental group enjoyed or strongly enjoyed the activity while only 22% did in the control group. Also, when asked if they wish they were doing something else, 71% of the experimental group said not at all while 70% of the control said definitely. Lastly, when asked about their main reason for completing the activity, 95% of the control students said they wanted to get a good grade or their teacher required them, while only 30% of the experimental condition that these were their reasons for doing the activity with most students saying that they did it because they wanted to be doing it. As further evidence of student engagement, one researcher recorded an average of 10 teacher reprimands to stay on task a day for the control while there were under three per day for students assigned the experimental condition.

Given these significant differences, similar to the above two discussions, we were also interested in better understanding the implementation experiences of the two units. Our goal was to gain insight into the ways that the classroom system itself is shaped by the two curricula, specifically so that we could understand the circumstances of this and future implementations. While not all students took up the role to the same extent, by in large students in the experimental condition were positioned as *change-agents* who were uniquely skilled to persuade and care for others in order to help resolve the deadly conflict in Ingolstadt. When interviewed, students described their intention and position in the curriculum as people who were on a mission to help change Ingolstadt. When explicitly asked, "What's going in on in Ingolstadt?" students often described the conflict or situation in terms of a first person role, one who found themselves as positioned within the narrative, as a protagonist, who is there to fulfill a mission and help a town get rid of the plague. Jose said, "I'm pretty much there to find a cure and stop people from dying." Another student, Alexus, said: "Um there's like this plague and people are getting sick and possibly dying and we're trying to go and um like people to stop the plague." Unlike the treatment condition where participants were positioned by the teacher and curriculum as *change-agents* in relation to the task, in the control group the teacher positioned students *agents-to-be-changed.*

In this case the teacher simply positioned students in their more common school role as agents who needed to change their ability to write robust persuasive articles in a short time. In her instruction to the whole class, the teacher tells students that they need to spend time *practicing* essay planning, drafting and revising because of an important upcoming standardized writing test (EOG). Below is an excerpt from an interview with Tianna, a motivated student who acknowledged her position as an *agent-to-be-changed.*

Researcher: Why are you doing this assignment in here?

Tianna: Because we have a big writing test coming up and they're using them on computers and she (Teacher) wanted us to get use them on computers and not just writing like we normally do.

Researcher: Do you enjoy this assignment?

Tianna: I do because it helps me like; I know it's going to help me do better on my writing test. I think I will be very prepared this time.

Importantly, it might be argued that this is a more legitimate use of the content than, say, to save a fictional village from a fictional page, even if in the fantastical scenario it is more consistent with the use of persuasive writing in the real world. More generally, in terms of the positioning of content of persuasive writing, in the treatment it was a tool that possessed necessary *use-value* for allowing a cure to be found. In contrast, the control group content uptake was *exchanged* good grades. The use value was evident in the following interview:

> Kristena said: Right now in Ingolstadt there is a plague going on and it's deadly! And right now our character is a person whose um whose she is immune to the plague and right now she is an *investigative reporter* … there are some people who think he's [the doctor] crazy and some people don't and they still want to cure the plague like, she has to like find evidence for that [supporting the thesis of the argument]."

In an interaction the player has with the in-game doctor, we see in his submission the simultaneous legitimacy of content and the player's belief that his previous actions on an in-game uniform issue had consequences:

> Doctor frank, persuasive writing can change the world in many ways. THe way people write persuasive writing makes it powerfull!! For example... when I wrote my persuasive argument about wearing school uniforms i wrote to CONVINCE people!! If you have good evidence supporting what your thesis is (your side you are on) then people will listen to you even if it a really bad idea.

Lastly, below is a transcript from an interview with a girl who had just completed the final mission in Plague. In the interview, she explains that from seeing all the people dead, a result from her choice of thesis, she was reconsidering what it would have been like if she would had allowed the doctor to continue his research.

> Interviewer: What did you find out?
>
> Girl: Well, I found the creation and Tina and Gene
>
> Interviewer: do you feel that you made the right decision for doing that?
>
> Girl: I don't know. I talked to the Fabric Lady and she said that people aren't caring about each other anymore, for the good of Ingolstadt. It's kind-a sad because people are starting to die. Henry died and the Constable is coming down with it (the plague) I feel that a lot of people are dying.
>
> Interviewer: Do you feel responsible for their death?

Girl: Kind-a, because of my paper, they went [thesis was to stop the doctor] I feel bad for the Doctor.

Interviewer: Really?

Girl: People kicked him out of his lab and his house and … Because they wanted to stop him from putting in his experiments. And I think they were too extreme

What is interesting here is the expressed remorse at the consequences of her decision to write a persuasive essay that was printed and resulted in the doctor's being forced to discontinue his practice.

Conclusions

Games have become one of the most popular forms of entertainment in our society, recently surpassing Hollywood in annual sales. Games are popular in part because they are fun. However, it is not simply their entertainment value that should be gaining the interest of educators. Instead, we have argued that it is the way that games can draw players in, capturing their interests, time, commitment, and passions, which is the real value of the medium. Toward communicating the power of games, we have developed a theory of transformational play. Designing for transformational play involves establishing academically useful and meaningfully engaging situations where learners adopt goals, have legitimate roles, and develop increasingly sophisticated relations to disciplinary concepts and those situations in which they have value. In such contexts, there is a shift from dispensing facts and transmitting content to a commitment to supporting students as they enter into conceptually illuminating situations where they develop passions and apply content understandings.

Games allow us to do this in ways that heretofore were not possible. Even when there are appropriate resources to support a field trip to a local park, for example, it is unlikely for the experience to cleanly illuminate the need for particular content understandings, and even less likely that students will be able to meaningfully transform some problematic aspect of the context—most parks are unwilling to put the future of their park in the hands of a 10 year old. Indeed, most teachers would be challenged to arrange classroom materials in a manner that could truly immerse learners in a dramatic narrative in which they act as protagonist, find legitimate roles, and interact meaningfully and consequentially with the storyline. In contrast, because we are designers of virtual worlds, we can ensure that game play success requires learning disciplinary content and that the problems are approachable by young children, even embedding pedagogical scaffolds in the game world or cuing teachers when just-in-time lectures will likely have value.

More than a simulation, games support playing, allowing players to become someone and do things that we are unlikely to do in the "real world." During play, one engages a space of possibility, negotiating rules and roles and discovering the potentialities for growth within and across the boundaries of fantasy and "reality." Through play, we transcend the borders of reality, and it is this potential that, in our opinion, gives play the power to support meaningful learning. In the types of videogames we develop, the learner becomes a character that engages in storylines and takes on roles that the learner would not in real life. Ironically, it is the act of play and the affordances of the fictional world that legitimizes disciplinary content, providing learners with opportunities to engage authentic and consequential disciplinary tasks not usually available in schools.

References

Arici, A. (2008). *Meeting kids at their own game: A comparison of learning and engagement in traditional and gaming contexts.* Bloomington, IN: Doctoral Dissertation, Indiana University.

Barab, S. A., Gresalfi, M., & Arici, A. (2009). Why educators should care about games. Educational Leadership 67(1), pp. 76-80.

Barab, S. A., Gresalfi, M., Dodge, T., & Ingram-Goble, I. (in press). Narratizing disciplines and disciplinizing narratives: Games as 21st century curriculum. To appear in *International Journal for Gaming and Computer Mediated Simulations.*

Barab, S. A., Zuiker, S., Warren, S., Hickey, D., Ingram-Goble, A., Kwon, E., et al. (2007). Situationally Embodied Curriculum: Relating Formalisms and Contexts. *Science Education.*

Gee, J. P. (2003). *What video games have to teach us about learning literacy.* New York: Palgrave/Macmillan.

Hickey, D., Ingram-Goble, A., & Jameson, E. M. (2009). Designing assessments and assessing designs in virtual educational environments. *Journal of Science Education and Technology, 18*(2), 187-208.

Resnick, L. B. (1987). The 1987 Presidential Address: Learning in school and out. *Educational Researcher, 16*(9), 13-20.

Schaffer, D. W., Squire, K., Halverson, R., & Gee, J. P. (2005). Video Games and the Future of Learning. *Phi Delta Kappan, 87*(2), 104-111.

Squire, K., & Jan, M. (2007). Mad City Mystery: Developing scientific argumentation skills with a place-based augmented reality game on handheld computers. *Journal of Science Educ. and Tech., 16*(1), 5-29.

Steinkuehler, C. A. (2006). Massively multiplayer onine video gaming as participation in a discourse. *Mind, Culture, and Activity, 13*(1), 38-52.

UNESCO Institute for Statistics. (2007). *PISA 2006: Science competencies for tomorrow's world*. Paris, France: Organisation for Economic Cooperation and Development.

Symposium: Internationalizing the Learning Sciences from Formal to Informal Learning Environments

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Abstract: This symposium brings together researchers at the frontier of an emerging subcommunity of the learning sciences that looks toward developing methodologies and infrastructures with the potential to lead towards an integrated agenda of global research in the learning sciences, spanning both the developed and the developing world, in both formal and informal learning environments. It explores how emerging technologies and methodologies could be further developed to this important end, building on work already in progress.

Overview

In recent years there has been a growing awareness that research in the Learning Sciences community could be significantly strengthened by intensifying the extent to which it draws in researchers from underrepresented regions. While the methodologies we have developed and applied in our own backyards and the yards of our close colleagues have served to build up a substantial body of knowledge that we can be proud of, we understand as a community that we stand to gain tremendous insights from diversifying our target student populations from those that are primarily in Europe and North America to regions such as East Asia, South Asia (including India), as well as Africa.

Currently, and unfortunately, there is surprisingly little exchange between the educational research communities of the US and Western Europe and other parts of the world such as Asia where substantial bodies of educational research are conducted but not well known in the West. Other countries such as India have less well developed traditions of formal research in education, but nevertheless have much to add to this international exchange. In India, for example, achievement in mathematics ranks among the top worldwide, which suggests that they have something to teach us while learning about areas where they rank less well in comparison to the West, such as innovation (Steinbock, 2008; de Haan & Narayan, 2008). We hypothesize that systemic differences in the educational systems between countries (Ma, 1999) introduce unknown random factors that interact with key independent variables and thus make it unclear the extent to which results from experimental studies within Asia, for example, generalize to the West, and vice versa. Recent evaluations of Western teaching practices within Asia cast doubt that findings can be transported wholesale from one community to the other without an understanding of what these variables are and how they interact with key educational interventions (Chang et al., 2006; Chang & Tsai, 2005; Chang, 2001).

While we fully appreciate that the concerns of the Learning Sciences community are much broader than international comparisons of standardized tests, it cannot be denied that large scale international comparison studies such as TIMSS (http://nces.ed.gov/timss/) and PISA (http://www.pisa.oecd.org/) have revealed significant differences in achievement between countries that raise questions we much consider. Despite the well known limitations of such standardized measures of achievement, differences between national educational systems undoubtedly exist and raise questions for learning science researchers to address in order to understand these differences. Corresponding large-scale comparisons of teaching practices, such as the well-known TIMSS video study (Stigler & Hiebert, 1999), reveal systematic differences in teaching style across countries. Nevertheless, due to the impracticality in controlling for differences in these comparisons in past studies, work to date investigating the reasons for these differences may be considered limited. Thus, while differences in teaching practices between countries are known to exist, what is not known is how these differences in individual teaching practices interact with systemic differences between countries that lay the foundations for learning within individual countries. And thus, policy makers who would seek to raise scores on standardized tests within their home countries are left with more questions than answers. Culture and its implications for learning is one example of a concern that is orthogonal to what is captured by typical international comparison studies based on standardized tests. Thus, we benefit from acknowledging that controlled cross-cultural studies within the Learning Sciences (e.g. Vatrapu, 2008) help us identify gaps in our current understanding of cognition, learning, and the use of technology in service of learning and instruction. Deeper understanding arising from this kind of work holds the potential to help us reach towards insightful ways to appropriate lessons learned from international comparison studies.

In some regions, such as India, research in the learning sciences as we know it within our international Society is less well developed, and thus an effort to build up collaborations and infrastructure will require a lengthier, concerted effort. The field of Information Communication Technology for Development (ICT4D) has already made strides towards developing technologies and methodologies for technology-supported education and education research within these contexts, which was featured in a CSCL 2009 symposium (Evans et al., 2009), although the focus of this work has been distinct from that of the core Learning Sciences community. We see this earlier symposium as a welcome and synergistic effort to build a bridge from the ICT4D community into the Learning Sciences community. In this proposal, we respond by continuing the conversation by inviting both Learning Sciences researchers and ICT4D researchers to discuss together how to build effective bridges between communities and learn from one another. We believe that this conversation will extend Learning Sciences research to address the challenges of education in the developing world, and in turn identify new research challenges in this space while providing valuable opportunities to challenge our thinking about learning in the developed world at the same time.

Symposium Themes

Recent research in the Learning Sciences community and the ICTD community works towards reaching beyond past limitations, in a wide spectrum of learning contexts, from the "traditional" classroom context, all the way to informal learning environments. This symposium brings together researchers who are working towards internationalizing the Learning Sciences across this spectrum, from formal learning contexts (Rosé and Kam; Laferriere and Law) to informal learning (Moraveji; Kam), or spanning the gap in between (Vatrapu). Each talk argues in a different way that sharing of educational tools and resources internationally would provide an infrastructure that could be used to broaden our understanding of cognition and learning.

One crosscutting theme throughout this symposium is the potential role of educational technology in raising new questions about cognition and learning, adding new insights to our storehouse of knowledge about international education. The presenters have been chosen from a range of backgrounds, such that the symposium will explore the tensions between the cognitivist and sociocultural traditions of learning, design research vs. controlled studies, and local relativisms vs. global universals, as they pertain to the internationalization of the Learning Sciences. The diversity of perspectives is intended to facilitate a lively discussion that re-examines the ideological assumptions behind our methods and theoretical constructs, as well as the historical and cultural processes that shaped them. Finally, presenters will articulate their conceptualizations of culture and its relation to learning.

We have included 5 talk abstracts for this panel style discussion. Each presenter will have 10 minutes to present an overview of their work. The discussant will then conduct an extended panel discussion, which will include questions from the audience.

LearnLab India: Towards "In Vivo" International Comparative Education Research

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LearnLab India is a recent effort in the Pittsburgh Science of Learning Center (PSLC, http://www.learnlab.org), which is devoted to studying human learning in realistic contexts using state-of-the-art technology. This effort represents one endpoint on the formal learning to informal learning spectrum in that it is specifically focused on highly controlled classroom studies, which have been termed "in vivo" studies because they occur within "live" classrooms rather than laboratories, with a strong emphasis on balancing high internal validity with high external validity.

The PSLC LearnLab model has been successful in over 50 schools in the United States. It brings state-of-the-art intelligent tutoring technology such as Cognitive Tutors (Koedinger et al., 1997) and Collaborative Learning environments that trigger context sensitive support into realistic contexts (Kumar et al., 2007; Chaudhuri et al., 2009). Furthermore, it brings the ability to study human learning in a rigorous way through analysis of logged data related to student interactions with and through the technology on a moment by moment basis through application of datamining, text mining, and speech mining technology (Prata et al., 2009; Gweon et al., 2009; Rosé et al., 2008). LearnLab India is a partnership between PSLC and the larger School of Computer Science community at Carnegie Mellon University with the Indian Institute for Information Technologies in Hyderabad (IIIT-H). LearnLab India will be housed at the three campuses of Rajiv Gandhi University of Knowledge Technologies (RGUKT, http://www.rgukt.in), which is an educational outreach by IIIT-H to the rural youth of Andhra Pradesh, India. The goal of LearnLab India is to help RGUKT students, most of whom attended non-English-medium schools prior to college, to succeed in English-medium university coursework at RGUKT.

As planned outreach in connection with this effort, the PSLC is sponsoring an Internship Program in Technology Supported Education (http://www.cs.cmu.edu/~cprose/winterschool/index.html), with the goal of building bridges between institutions of higher learning in India and top ranking universities in the United States, beginning with but not limited to Carnegie Mellon University. This program will begin in December 2009 with a Winter School in which 130 undergraduates from around India will come together for an intensive two-week program to learn about research in the Learning Sciences and participate in short-term projects related to the LearnLab India effort.

As an example of planned research, drawing both from cognitivist and socioculturalist learning traditions, we propose to use language technologies to study the learning process itself as well as important social processes connected with that, which play a key role in second language learning, identity formation and commitment to a lifelong learning path. We will build on our prior work, where text mining and speech processing technologies are developed and used to track key patterns in the interaction between students in learning groups (Gweon et al., 2009; Joshi & Rosé, 2007). We will target patterns that are predictive of how much students are learning from the interaction or how well or poorly project teams are functioning together. The research will also draw on earlier research on how videogames can create more engaging learning experiences. Currently an effort is in progress to deploy a collaborative vocabulary building game built on top of the Basilica framework (Kumar et al., 2009).

A current comparative effort in progress is focused on an information literacy unit that will be shared by students at RGUKT and students at Carnegie Mellon University. Two initial pilot studies, one with 10 students and the other with 300 have already begun to reveal differences in information seeking behaviors between students from highly developed areas in India and those of the target user population that suggest principles for needed scaffolding support, which differ from those previously proposed within the mainstream information retrieval literature.

The RGUKT campuses have an annual intake of 6,000 students. The magnitude of the size of the student population available in the research partnership with RGUKT would provide invaluable insights to inform continued research on the effective use of language technologies to support instruction. This partnership would not only greatly accelerate the effort to develop highly effective computer supported instruction because of that magnitude. It would also allow fine grained and finely controlled international comparison studies such as has never before been possible, which holds the potential to transform the field of international comparative education research.

Knowledge Building International Project (KBIP): a Nested Network of Learning and Knowledge Creation

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The Knowledge Building International Project (KBIP 2007-2009) operates on the basis of locally based networks of innovation distributed around the globe. Catalunya (Comconèixer), Hong Kong (KBTN), Quebec (RNS), and Toronto (IKIT) are currently the four main sites. Similar to the Rosé and Kam abstract above, this work represents work primarily within a formal, classroom learning context. Nevertheless, while this work is connected with classroom learning, this work is unique in that it reaches beyond activity within individual classrooms or campus communities to build digital bridges between classrooms in different countries.

Pedagogical and research activities within this international effort are conducted within local university-school-government partnerships connected to one another. Much autonomy is left to the participants (students, teachers, graduate students, and researchers) for the designs of what works within their respective socio-cultural contexts, but they come together as they share a common understanding of knowledge building, and use the suite of tools available (knowledge building principles, Knowledge Forum® software, applets for specific analysis measures to be taken on the fly by researchers, teachers, and students).

As part of the applied cognitive sciences, Knowledge Building (KB) has its own epistemology, and it has become a pedagogical approach focusing on developing classrooms as communities for progressive problem solving and knowledge creation (Scardamalia & Bereiter, 2006). Unlike learning organized in traditional classrooms, the KB process is necessarily an intentional community effort, and is simply not possible as an individual enterprise. Learning takes place as a "by-product" of the knowledge creation process as learners tackle significant problems of understanding. Designing curriculum units for implementation as knowledge building experiences for school age children that can, at the same time, satisfy mandatory curriculum requirements is a challenge that has to be tackled to realize the vision of Education for Knowledge Creation in schools.

Agents (students, teachers, school principals, school district personnel, ministry personnel, university teacher educators and researchers) use Knowledge Forum as a "collaboration space" (asynchronous online discourse). For synchronous discourse, a multi-user web-based videoconferencing system is used. The focus of the students' KB activities in KBIP has been on understanding and tackling issues related to climate change, energy and sustainable development. Typically collaboration at the classroom level is organized in clusters of 2 to 3 classes of students from different countries. Students from these classes engage in KB around a common theme and identify questions and problems. Working on them over a period of several months they contribute hundreds of notes on Knowledge Forum®. In 2008-2009, over twenty videoconferences were held among collaborating classrooms. Additional videoconferences for professional development among teachers from the different sites are also organized throughout the year. School personnel and ministry officers provided guidance and encouragement regarding curricular requirements, university teacher educators and researchers conducted onsite and online professional development workshops. One highlight of the year was the three-day onsite summer institute conducted in Mallorca (Spain), which provided an opportunity for the 30+ participating teachers, teacher educators and researchers to collaborate on designing, facilitating, analyzing and reflecting on the KB work of the 45 primary and secondary students who attended to work on the problem of the sustainability of caves (e.g. tourism effect, cave ecology, installing light in the caves and its impact) as well as visited two famous Mallorcan limestone caves.

Despite the challenges of differences in language, culture and time zone, there have been high levels of motivation shown by teachers and students to participate in KBIP. Implementing KB as a pedagogical approach is an innovation and a challenge, both for teachers and learners. Curricula and facilitation design, as well as classroom practices and culture are necessarily different in the different sites. KBIP forces teachers, learners as well as teacher educators and researchers to make explicit their ideas and assumptions and to learn from each other during the process of collaboration and knowledge building. We will report on specific research results obtained in Hong Kong and Quebec regarding student motivation, online discourse patterns, and students' depth of understanding of critical questions facing our world today.

Supporting and Measuring Global Information Literacy Through Cross-cultural Studies of Web Search

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In contrast to the earlier two abstracts, this work takes us into an informal learning environment within the developing world. Nevertheless, it is connected with the work in progress discussed in connection with Rosé and Kam's abstract above in its focus on information literacy skills. It connects also with the work discussed in the Laferriere and Law abstract in its focus on the internet as an environment to support knowledge sharing and knowledge construction.

Web search is a timely and imperative skill for citizens in information economies or those who participate in interconnected knowledge work regardless of their country. Moving beyond the traversal of digital libraries and into general knowledge acquisition it is a skill that crosses the boundaries between formal and informal learning environments and the developed and developing worlds. While we tend to think of web search as information retrieval rather than learning, much of lifelong learning in modern societies takes place during information seeking on the web, and increasingly internet penetration, and web based technologies, are growing into less developed regions.

Unlike many traditional school disciplines, the topic of web search (part of the broader topic of information literacy) does not belong to any one country or tradition. The technologies involved are culture-agnostic and there is little historical precedence of curricula, learning mechanisms, or best practices. We argue that these factors conspire to make web search an ideal topic to study as a means of integrating global perspectives and expertise in the learning sciences.

Among the sub-skills involved in being information and media literate (i.e. as discussed in Jenkins et al., 2006; Enochsson 2005), the ability to effectively and efficiently find, assess, and synthesize credible and authoritative information on the Internet combine to transcend cultural boundaries. We discuss reasons why Web search (herein referred to as 'search') is an ideal topic of study and alongside planned and ongoing research in a global context.

Academics, instructors, and policy makers have worked to study how search practices are learned in recent years, but much remains unknown. Computer experience, developmental stage, exposure to experts, formal instruction, accurate mental models of search engines and the Internet, and peer interaction each play a role. We plan to focus on *social* factors in particular and study them across cultures as they emerge in distributed and collocated environments.

We have designed and developed tools to support search learning and plan on giving them to schools in different areas in exchange for anonymous usage data that will provide us with the ability to take the global 'pulse' on global information literacy expertise.

To deploy such technologies in classrooms within different countries, we plan to build upon the existing base of dozens of schools worldwide using the Mouse Mischief platform by the authors (Moraveji et al., 2008). Complemented with interviews and classroom observations, this work will illustrate the distribution of expertise in search across the world and how such skills spread socially. These findings will inform the redesign of the tools and design guidelines for systems and curricula aimed at improving information literacy. We anticipate that search expertise may follow a distribution quite different from those in traditional school topics and performance on standardized tests, revealing trends on expertise in the global information economy, helping all countries prepare accordingly.

Information-processing theory posits that the formal mental operations required to conduct purposeful and effective searches (e.g. as required to define abstract keywords) emerge at the corresponding developmental stage. We view the logical steps in search as a partial and abstracted representation of the user's cognitive process. Used as such, the data collected from our systems (or through large-scale studies done using Mechanical Turk) will help us conduct comparisons between users and aggregate them to make comparisons across cultures regarding expertise in Web search. By representing such processes we allow them to be transferred between participants via *cognitive apprenticeship*, a process by which learners can model accurate problem-solving skills by inspecting the transparent processes of instructors (Collins 1987).

At this symposium, we will present results from work on studying the social factors involved in the learning of search and information literacy skills on the Internet. The results will incorporate or have implications for learning across cultural boundaries. We advance that studying search is an ideal platform for a global agenda on research in the learning sciences.

Comparative Informatics: Investigating Cultural and Linguistic Influences in Computer Supported Collaborative Learning

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Similar to the previous two abstracts, this work focuses on technology enhanced learning. However, this work takes its point of departure in the human computer interactional (HCI) aspects of informal and formal learning settings. Currently, the Internet is undergoing a profound shift towards social interaction, participation and collaboration. Many, if not all, of the informal and formal learning settings are situated within this transforming socio-technical landscape. Within this context, the Comparative Informatics (CI) research program studies how participants interact with technology enhanced learning environments in systematically varied experimental contexts of group composition (intra- vs. inter- cultural; same vs. mixed gender) and linguistic mediums (e.g., Danish, Chinese, English). The rest of this abstract is organized into two parts. The first part presents the design of and findings from a laboratory study of an intra- and inter-cultural CSCL system. The second part discusses conceptual and methodological challenges in conducting controlled studies of technology enhanced learning.

Technology enhanced informal and formal learning environments are characterized by socio-technical interactions. Socio-technical interactions involve individuals interacting with (a) technologies, and (b) other individuals through technologies. These two interactional aspects are theoretically conceived as (a) perception and appropriation of socio-technical affordances and (b) structures and functions of technological intersubjectivity (Vatrapu, 2009). Affordances are action-taking possibilities and meaning-making opportunities in an actor-technology system relative to the competencies of the actor and the capabilities of the system. Technological intersubjectivity (TI) refers to how participants interact with, relate to, form impressions of, and have empathetic experiences with each other in technology enhanced settings. The basic premise of the Comparative Informatics research program is that the perception and appropriation of affordances as well as the structures and functions of technological intersubjectivity vary across cultures and languages.

The CulturalReps research project investigated two specific research questions related to the effects of culture on appropriation of affordances and on technological intersubjectivity in a computer supported collaborative learning environment with external representations. The experimental study design consisted of three independent groups of dyads from similar or different cultures (American-American, American-Chinese, Chinese-Chinese) doing collaborative problem-solving in a knowledge-mapping learning environment. Participants interacted through an asynchronous computer interface providing multiple tools for interaction (diagrammatic workspace, embedded notes, threaded discussion) as they worked on an intellectually challenging problem of identifying the cause of a disease outbreak. Based on empirical findings documenting cross-cultural variations in behavior, communication and cognition, several research hypotheses were advanced. Empirical data were collected using demographic, culture and usability instruments; participants' self-perception and collaborative peer-perception instruments; screen recordings and software logs of experimental sessions.

Statistical results showed that members of different cultures appropriated the resources of the interface differently in their interaction, and formed differential impressions of each other. For example, on average, American participants of the experimental study created more evidential relation links, made more individual contributions and were more likely to explicitly discuss information sharing and knowledge organization strategies than their Chinese counterparts. Despite statistically significant differences between the three experimental groups on (a) how they used the tools and resources of the learning environment and (b) how they related to each other during and after their collaborative learning interactions, individual learning outcomes analysis of the essays indicated no significant differences (Vatrapu, 2008).

One interpretation of the individual learning outcomes result is that participants utilized the "alternates for action" incorporated into the learning environment effectively and appropriately from their own cultural standpoints. The results of the experimental study indicate the existence of multiple interactional pathways to learning outcomes in intra- and inter-cultural CSCL. However, more systematic empirical work is needed to (a) establish the existence of and (b) evaluate the efficacy of multiple cultural interactional pathways.

Several theoretical and methodological challenges remain in the design and analysis of controlled studies of cross-cultural and cross-lingual technology enhanced learning systems. Interacting through technology is not unproblematic. First, it makes interaction more difficult. Second, it may not mean, feel, and afford same thing to everyone. With respect to computer supported collaboration, there is a productive tension between the future possibilities envisioned and the present realities documented by empirical research. Information and communication technologies (ICT) are often designed under the implicit assumption that members of different cultures using different languages equally view a given functionality as appropriate for carrying out a given, or that another member observing a given act in an ICT environment interprets it as originally intended by the actor. Given that culture, language, cognition, and action (Aydede, 2004; Gibson, 1979; Gumperz & Levinson, 1996; Kramsch, 1998; Nisbett & Norenzayan, 2002; Noë, 2004; Vatrapu & Suthers, 2007) are intricately intertwined, in a technology driven multi-cultural and multi-lingual world, it is an open empirical research problem that the human computer interaction (HCI) design and development aspects of ICT and collaboration systems still permeate with unexamined assumptions. As can be seen from this symposium submission, learning sciences researchers have begun to critically engage with these issues by employing a rich mix of theories and methods across a diverse set of informal and formal learning settings.

At this symposium, an outline of the conceptual and methodological framework for comparative informatics will be presented. Comparative informatics is the application of the comparative method to the study of information and communication technologies across a diverse set of contexts. According to Ragin (1987, p. x), the comparative method is "especially well suited for addressing questions about outcomes resulting from multiple and conjectural causes where different conditions combine in different and sometimes contradictory ways to produce the same or similar outcomes." Prior and emerging findings from experimental studies will be presented. Implications for design and evaluation of technology enhanced learning will be discussed.

Language and Literacy Learning in Developing Communities via Cellphones

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This final abstract builds on the earlier four by studying mobile learning across multiple cultural contexts in the developing world. Now in its 6th year, the Mobile and Immersive Learning for Literacy in Emerging Economies (MILLEE, http://www.millee.org) research project aims to leverage the increasing ubiquity of the cellphone – the fastest growing technology in developing regions such as South Asia and Africa – to make language and literacy learning more accessible to children in rural areas and the urban slums. The educational intervention involves the design of educational game software that runs on the cellphone. The e-learning games target global languages such as English as a Second Language and Mandarin, so as to empower low-income children from minority-language backgrounds to integrate into the mainstream, global economy.

In the last five years, we have performed 10 rounds of fieldwork in India spanning about 12 months on the ground. We observed that rural Indian children found our earlier game designs – which were subconsciously influenced by our prior experiences with Western videogames – to be non-intuitive. This observation forced us to examine the traditional village games that rural Indian children play everyday, and to perform a cross-cultural analysis of the systematic differences between these games and contemporary Western videogames (Kam et al., 2009a). The results from this analysis have been used to inform subsequent game designs. A semester-long evaluation of the games in an after-school program at a village school site in Northern India demonstrated significant learning gains on spelling skills (Kam et al, 2009b). We are making preparations to conduct a larger-scale evaluation in the form of a controlled experiment with 800 rural children in 40 schools in India. While the project in India targets ESL, we are working with new partners to expand the project into backward regions in Africa (ESL literacy) and China (Mandarin literacy). The longer-term goal is to build a research infrastructure that will collect data for us to engage in cross-cultural comparative studies, so as to explore how we can more effectively perform cross-cultural design and reuse/localize learning objects across multiple cultural settings.

In spite of the above (early) successes so far, the greatest opportunity for mobile learning is to put language and literacy learning within reach of the low-income children who cannot attend school regularly due to child labor challenges such as the need to work for the family in the agricultural fields or households. This informal learning approach calls for the cellphone-based games to be embedded within the social fabric of the children's everyday lives, to be used in times and places such as their homes and fields that are far more convenient than schools. This new phase of the project calls for methodological and conceptual innovations. We have conducted participation-observations to uncover the scenarios in the everyday lives of rural Indian children that are promising for mobile learning, and have ran a semester-long in-situ study in which children in the same village used the games under naturalistic conditions. We will continue to refine our data logging procedures to allow us to study how participants play and learn with the mobile games when researchers are not present.

The challenges with designing technology-supported learning interventions for out-of-school settings are not only logistical, but also theoretical. Our results suggest that our current instructional designs are more effective for improving learning among children who have more years of schooling, vis-à-vis children with less schooling. This implication is hardly surprising; drawing on sociocultural theories of learning which posit that the development of higher-order mental functions occurs through social interaction mediated by signs including language, a landmark study by Scribner and Cole (1981) found that the social practices associated with the institution of schooling led to new ways of deploying their cognitive resources. While most published research in education and the Learning Sciences has centered around learners with access to schooling, if we are indeed to design technologies that truly promote learning among out-of-school children, it follows that more research is needed to understand and account for the cognitive processes employed by the latter.

In this symposium, we will present an overview of our results and an initial conceptual framework on instructional design for out-of-school children. This framework will not only aim to help us design educational applications that improve lives for child laborers, but also inform the design of "bridge programs" that help out-of-school children reintegrate into formal schooling as well as better design adult literacy programs. By working with out-of-school learners in multiple cultural settings that include sub-Saharan Africa to South Asia – two regions on the lowest end of most human development indices, our long-term vision is to establish a research agenda whose intellectual merit is to arrive at a more holistic understanding of human learning and cognition – which will fill the gaps in existing research that is largely rooted in Western traditions and societies.

References

Aydede, M. (2004). The Language of Thought Hypothesis. In E. N. Zalta (Ed.), The Stanford Encyclopedia of Philosophy (Winter 2005 ed., pp. http://plato.stanford.edu/entries/language-thought/).

Chang, C. Y., Hsiao, C. H., & Barufaldi, J. (2006). Preferred-Actual Learning Environment "Spaces" and Earth Science Outcomes in Taiwan, Science Education, 90(3), 420-433.

Chang, C. Y. (2005). Taiwanese science and life technology curriculum standards and earth systems education. International Journal of Science Education, 27, 625-638.

Chang, C. Y. & Tsai, C. -C. (2005). The interplay between different forms of CAI and students' preferences of learning environment in the secondary science class. Science Education, 89, 707-724.

Chaudhuri, S., Kumar, R., Howley, I., Rosé, C. P. (2009). Engaging Collaborative Learners with Helping Agents, *Proceedings of Artificial Intelligence in Education*

Collins, A., Brown, J. S., & Newman, S. E. (1987). Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics (Technical Report No. 403). BBN Laboratories, Cambridge, MA. Centre for the Study of Reading, University of Illinois. January, 1987.

DeHaan, R. L. & Venkat Narayan, K. M. (2008). *Education for Innovation: Implications for India, China, and America*, Sense Publishers.

Enochsson, A. 2005. The development of children's Web searching skills---a non-linear model. http://informationr.net/ir/11-1/paper240.htm

Evans, M., Cagiltay, K., Pal, J., & Sorcar, P. (2009). ICT4D and the Learning Sciences, *Proceedings of the Computer Supported Collaborative Learning Conference*, Rhodes, Greece.

Gibson, J. J. (1979). The ecological approach to visual perception. Boston: Houghton Mifflin.

Gumperz, J. J., & Levinson, S. C. (1996). Rethinking Linguistic Relativity: Cambridge University Press.

Gweon, G., Kumar, R., Rosé, C. P. (2009). Towards Automatic Assessment for Project Based Learning Groups, *Proceedings of Artificial Intelligence in Education*

Jenkins, H., Clinton, K., Purushotma, R., Robison, A. J. & Weigel, M. (2006). Confronting the Challenges of Participatory Culture: Media Education For the 21st Century. Chicago: The MacArthur Foundation.

Joshi, M. & Rosé, C. P. (2007). Using Transactivity in Conversation Summarization in Educational Dialog. *Proceedings of the SLaTE Workshop on Speech and Language Technology in Education*

Kam, M., Mathur, A., Kumar, A., and Canny, J. (2009a). Designing digital games for rural children: A study of traditional village games in India. In *Proceedings of ACM Conference on Human Factors in Computing Systems*, Boston, Massachusetts, April 2009.

Kam, M., Kumar, A., Jain, S., Mathur, A., and Canny, J. (2009b). Improving literacy in rural India: Cellphone games in an after-school program. In *Proceedings of IEEE/ACM Conference on Information and Communication Technology and Development*, Doha, Qatar, April 2009.

Koedinger, K. R., Anderson, J.R., Hadley, W.H., & Mark, M . A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education,* 8, 30-43.

Kramsch, C. (1998). Language and culture: Oxford University Press.

Kumar, R., Rosé, C. P., Wang, Y. C., Joshi, M., Robinson, A. (2007). Tutorial Dialogue as Adaptive Collaborative Learning Support, *Proceedings of Artificial Intelligence in Education*

Kumar, R., Chaudhuri, S., Howley, I., Rosé, C. P. (2009). VMT-Basilica: An Environment for Rapid Prototyping of Collaborative Learning Environments with Dynamic Support, Community Event *Proceedings of Computer Supported Collaborative Learning*

Ma, L. P. (1999). *Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States*, Lawrence Earlbaum

Moraveji, N., Kim, T., Pawar, U., Ge, J., Inkpen, K. (2008). Mischief: Supporting Remote Teaching in Developing Regions. Proceedings of ACM CHI, Florence, Italy.

Nisbett, R., & Norenzayan, A. (2002). Culture and Cognition. In D. L. Medin (Ed.), Stevens' Handbook of Experimental Psychology (3rd ed., pp. 561–597).

Noë, A. (2004). Action In Perception: Bradford Book.

Prata, D. N., Baker, R. S., Costa, E., Rosé, C. P., Cui, Y., de Carvalho, A. (2009). Detecting and Understanding the Impact of Cognitive and Interpersonal Conflict in Computer Supported Collaborative Learning Environments, *Proceedings of the 2nd International Conference on Educational Data Mining*

Ragin, C. (1987). The Comparative Method: Moving Beyond Qualitative and Quantitative Strategies: University of California Press.

Rosé, C. P., Wang, Y.C., Cui, Y., Arguello, J., Stegmann, K., Weinberger, A., Fischer, F., (2008). Analyzing Collaborative Learning Processes Automatically: Exploiting the Advances of Computational Linguistics in Computer-Supported Collaborative Learning, *International Journal of Computer Supported Collaborative Learning* 3(3), pp237-271.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In R.K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 97-118). New York, NY: Cambridge University Press.

Scribner, S., & Cole, M. (1981). *The psychology of literacy*. Harvard University Press.

Steinbock, D. (2008). *Higher Education and Innovation and Competitive Advantages*, in DeHaan, R. & Narayan, K. (Eds) Education for Innovation: Implications for India, China, and America, Sense Publishers

Stigler, J. & Hiebert, J. (1999). *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom*, The Free Press.

Vatrapu, R., & Suthers, D. (2007). Culture and Computers: A Review of the Concept of Culture and Implications for Intercultural Collaborative Online Learning. In T. Ishida, S. R. Fussell & P. T. J. M. Vossen (Eds.), Intercultural Collaboration I: Lecture Notes in Computer Science (pp. 260-275): Springer-Verlag

Vatrapu, R. (2008). Cultural Considerations in Computer Supported Collaborative Learning. *Research and Practice in Technology Enhanced Learning*, *3*(2), 159-201.

Vatrapu, R. (2009). Toward a Theory of Socio-Technical Interactions in Technology Enhanced Learning Environments. In U. Cress, V. Dimitrova & M. Specht (Eds.), EC-TEL 2009, Lecture Notes in Computer Science (LNCS) 5794 (pp. 694-699). Berlin Heidelberg Springer-Verlag.

Increasing Rigor and Generativity in Learning: Connections Between the Disciplines, Children's Lived Experience and Everyday Knowledge A Symposium

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Introduction

Improving school achievement for students from non-dominant backgrounds is increasingly requiring researchers to embrace the complexity of intersections between identity, lived experience, knowledge developed in our everyday lives, and target disciplinary knowledge and practices. The stances towards, understandings of, and engagement with the practices and knowledge children develop in their everyday life are central to engaging in this complexity (Warren et. al, 2001; Lee, 2001; Nasir et. al, 2006). Typically – although not theoretically aligned with notions of constructivist learning theories – many education researchers tend to explicitly or implicitly view children's lives and knowledge developed in everyday life from deficit perspectives that assume a lack of connection or potential alignment with expert disciplinary understandings (Warren et. al, 2001). We argue that a deeper understanding of the disciplines and the associated practices combined with an orientation towards children's practices and knowledge as resources to mobilized can increase the rigor and depth of learning environments for all children (i.e. Hudicourt-Barnes, 2003; Bang et. al, 2007).

This symposium presents three studies by junior scholars who have been trained, in part, at the Chèche Konnen Center (CKC) at TERC. CKC has been engaged in studying the ways in which children's linguistic, intellectual, and cultural strengths can be recognized and mobilized towards more rigorous science teaching and learning. These three studies expand the empirical work conducted from this perspective into new disciplinary domains. The first paper explores representational competence of elementary age Black boys as they interpret and produce architectural diagrams. The paper compares the criteria and dimensions of representations produced by the boys in the study as compared to experts. This paper expands the empirical evidence of the benefit of engaging both a disciplinary perspective as well as a resource framework into the field of engineering and design. The second paper presents a design study of a history classroom that engages students' own local histories and personal identities and works to extend these localized place based identities and narratives to global conflicts and narratives. This work demonstrates the ways in which engagement of students' identities transforms learning in the domain of history for students both by engaging them in more expert forms of historical scholarship as well as positioning them as historical actors and scholars with agency and choice.

The third paper compliments the first two presented by shifting focus from close study of student thinking to teacher thinking. The opportunity to expand learning environments by engaging disciplinary perspectives and viewing students' intellectual strengths at any large scale will require the field to more deeply understand the ways in which to improve the capacity of teachers to more effectively teach children from communities historically placed at risk. This requires professional development opportunities in which teachers can delve more deeply into their own views about students from diverse backgrounds, themselves as cultured and raced individuals, and their understandings of the ways in which race and white privilege are embedded in the historic fibers and institutional structures within the United States (Ladson-Billings & Tate, 1995; Bell, 1992; Harris, 1993). The third paper does just this by presenting a case study of one teacher engaged in a five-year design based professional development research study focused on learning to see and teach to the intellectual strengths of students of color. The teacher in this case study learns to see the intellectual strengths of the Black boy students' in her classroom in the domain of literature and writing. This study demonstrates the ways in which structuring professional development to embrace a disciplinary (in this case a literary perspective) and resource based lens, can transform teacher practice to improve teaching and learning for students from non-dominant communities. Each paper is presented in more depth following this introduction.

Collectively these papers provide domain specific insights into teaching and learning and simultaneously demonstrate the generativity and potential benefit of deeply engaging with children's everyday experiences and knowledge as strengths and resources for designed learning environments across domains. Further, each study uses different complimentary strands of research and theory to explore these dynamics. The work in this symposium takes steps to more deeply understanding, supporting, and leveraging the ways in which diversity – of people, practices, languages, meaning, knowing, histories, goals, values, and the like…in learning environments are an asset and expand the possibilities for human knowing and meaning (Gutierrez et al. 1999; Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes, 2001).

Structure of the Symposium

Megan Bang, Chèche Konnen Center at TERC & American Indian Center of Chicago will serve as chair. We will open the session with a brief 5 minute introduction. We will then present the three papers, each for 15 minutes. Beth Warren, Chèche Konnen Center at TERC, will serve as the discussant. We will leave 25 minutes for questions and open discussion with the audience.

References

Bang, M., Medin, D., & Atran, S. (2007). Cultural Mosaics and Mental Models of Nature. *Proceedings of the National Academy of Sciences*. 104, 13868-13874.

Bell, D. (1992). Faces at the Bottom of the Well: The Permanence of Racism. New York: Basic Books

Gutierrez, K.D., Baquedano-López, P. Tejeda, C. (1999). Rethinking Diversity: Hybridity and Hybrid Language Practices in the Third Space. Mind, Culture, and Activity, 6(4), 286-303.

Harris, Cheryl I. (1993). Whiteness as Property. *Harvard Law Review* 106:1721.

Hudicourt-Barnes, J. (2003). Argumentation in Haitian Creole classrooms. *Harvard Educational Review.*

Ladson-Billings, G and Tate, W. F. (1995). Toward a Critical Race Theory of Education. *Teachers College Record*, 97 (1), 47-68.

Lee, C. (2001). Is October Brown Chinese? A Cultural Modeling Activity System for Underachieving Students. *American Educational Research Journal*, 38(1), 97–141.

Nasir, N. S., Rosebery, A. S., Warren, B., & Lee, C. D. (2006). Learning as a cultural process: Achieving equity through diversity. The Cambridge handbook of the learning sciences, 489–504.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching, 38*(5), 529-552.

Paper 1: Learning to "see" sound: Meaning-making about sound through architectural diagrams among elementary school Black boys

Christopher G. Wright, Tufts University

This work has to primary objectives: 1) To explore the representational criteria that elementary school Black boys utilize in producing and interpreting architectural diagrams; and 2) To identify the sense-making practices that elementary school Black boys demonstrate while producing and interpreting architectural diagrams.

Using meta-representational competence (MRC) as an analytic lens has proven productive in uncovering children's representational competence (diSessa, 2004). It has been used to study how children invent new representations, critique and compare the adequacy of representations, understand the purposes of representations in particular contexts, explain representations, and learn new representations (Azevedo, 2000; diSessa, Hammer, Sherin, & Kolpakowski, 1991; diSessa & Sherin, 2000; Enyedy, 2005; Sherin, 2000).

When a MRC perspective is linked to a view of learning as cultural practice, as in the work of Warren et al. (2001), new opportunities open up for understanding the cultural, intellectual, and linguistic strengths that children from historically non-dominant communities bring to disciplinary learning. Taking this perspective on representational competence as entailing cognitive and culturally-based practices, this study focused on uncovering the knowledge and sense-making practices that Black boys used and developed as they learned to "see sound from an architectural point of view" (Lymer, 2009).

Through an ethnographic case study, I examined 4th grade Black boys' ideas and sense-making practices as they produced and interpreted representations of sound through architectural diagrams. Data included field notes, video footage of the boys' design and critique activities, video footage of individual interviews with the boys, and student-developed representations of sound. Data analysis involved multiple stages of coding based on Yin's (1984) classification of data according to various cross-case analyses.

Results

The boys' representational criteria for the representations developed within architectural diagrams included *completeness* (does the representation show all relevant information), *compactness* (does the representation effectively utilize the space of the architectural diagram), and *precision* (do the representations accurately depict the various aspects of sound). This finding agreed with diSessa's (2004) findings that suggest that kids do similar things to what professionals do and some things that differ. During the production, interpretation, and critique of sound representations, the boys were found to focus on similar aspects of sound as professional architects (White, 2004), such as sound location, sound intensity, and sound generator. The boys' representations differed from those used by architects primarily through the category of "sound type." Architects (White, 2004) utilized conventional symbols for sound, despite the type of sound, while the boys varied their symbols based on the type of the sound (i.e., notes for sounds coming from a parade, letters/words for sounds coming from children playing, and sound waves for the sounds coming from cars and airplanes).

Significance

This study contributes to a broadening of perspective on "what counts" as architectural and scientific knowledge and practices. By investigating the ideas and representational practices that children have, where they draw their experiences from, and how they impact learning and development in social explorations of STEM disciplines provides an in-depth picture of children's experiences and development in these areas.

References

Azevedo, F. (2000). Designing representations of terrain: A study in meta representational competence. *Journal of Mathematical Behavior, 19,* 443-480.

diSessa, A., (2004). Metarepresentation: Native competence and targets for instruction. *Cognition and Instruction, 22*(3), 293-331.

diSessa, A., Hammer, D., Sherin, B., & Kolpakowski, T. (1991). Inventing graphing: Meta-representational expertise in children. *Journal of Mathematical Behavior, 10,* 117-160.

diSessa, A., & Sherin, B. (2000). Meta-representation: An introduction. *Journal of Mathematical Behavior, 19,* 385-398.

Lymer, G. (2009). Demonstrating professional vision: The work of critique in architectural education. *Mind, Culture, and Activity, 16*(2), 145-171.

Sherin, B. (2000). How do students invent representations of motion: A genetic account. *Journal of Mathematical Behavior, 19,* 399-441.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching, 38*(5), 529-552.

White, E. (2004). *Site anlaysis: Diagramming information for architectural design.* Tallahassee, FL: Architectural Media Limited.

Yin, R. (1994). *Case study research: Design and methods – Volume 5.* London: Sage Publications.

Paper 2: History in Schools, Teachers, and Students: Identities and Meaning Making in Middle School Social Studies

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This paper uses qualitative data, including classroom conversations, from one self-contained, multi-ethnic, 7th grade classroom in a public school in Chicago to argue that history, as it is taught in schools, should be aimed at helping students create and participate in democratic structures of everyday life. In doing so, we argue that school has to engage the identities of students. Furthermore, we assert that dialogic approaches to teaching and learning are well suited to accomplish this task (Wells, 1999). In supporting our argument, we describe a collaborative study that investigated the ways in which students engaged in dialogic conversations called "Socratic Seminars" (Adler, 2008).

We draw on work by Holland and Lave (2001) that conceives international, national, and institutional political and economic struggles as mediated by the struggles lived out in the everyday actions of people. That is, history lives in and is created by people, mediated by their everyday lives. For example, the local government in Chicago supports an economic model of increased attention to skilled service sector jobs; privatization of public institutions, including schools; and de-industrialization (e.g. Lipman, 2004). Concurrently, land speculation and real estate development to feed the growing service-oriented workforce has pushed westward, displacing working African American and Latino families further and further from the city center. Students in the school acutely feel the housing crunch as the school experienced a 30% mobility rate during the school year in which the study took place.

One of our goals for the overall classroom learning environment was to create spaces for students to see themselves as "historical actors" (Gutierrez, 2005) and to help them create pathways for participation in democratic life through community-based action (Barton & Levstik, 2004). We believe that for students to author themselves as historical actors, educators need to engage other aspects of students' identities, such as their place-based, racial, and ethnic notions of self. Students' actions toward becoming historical actors took many forms: exploratory conversations in Socratic Seminars, presentation of student-made masks in a "Taino" art show at a local cultural center, a "Culture Show" (dance and poetry) that focused on the African Diaspora in the Caribbean for members of the school community, and peace marches. Students also produced digital videos in which they interviewed other students, school staff, and people in the neighborhood about racism, power, and gentrification in the community. In this paper we focus on Socratic Seminars because they provide the clearest examples of the dialogic character of students' exploration of and theorizing about their relationships to history. In the full paper, we problematize the notion of identity in greater depth and its relation to dialogic constructions of self (Bakhtin, 1981).

The work was conducted through a model of collaborative action research in which the external researcher and the classroom teacher-researcher together created the curriculum, conceived of research questions, devised data collection methods, and analyzed classroom data (Nodie Oja & Smulyan, 1988). We analyzed data from Socratic Seminars, the main data source of this paper, through two iterations. First, constant comparative analysis revealed a number of recurrent themes (Glaser & Strauss, 1967). Themes included hate speech on the radio, attitudes about immigration, sexual activity and its consequences in the teenage years, borders, gentrification, and the presidential election, among others. Students also drew on a range of sources while participating in Socratic Seminar, including articles given by the teacher; horror movies; television; and experiences in the neighborhood, with family members, and at school.

Second, we selected representative examples and conducted a critical discourse analysis of the talk. Such examples have been omitted here for sake of space, but will be presented in the longer paper. In that analysis, we sought to identify the commitments students made to identities within fields of power in local and global contexts (Fairclough, 2003). Particularly, how students mediated conversational topics on national and global scales through reference to their own local histories and personal identities, as well as how their accounts of their identities and the local history of their community were rooted in global conflicts, such as colonization and international transmigration. We further considered how conversations remade and disrupted those processes.

We found that students were able to resist and disrupt discourses of domination, such as realtors and outsiders to the neighborhood naming young people and their neighborhood as "ghetto." They also recognized parallels between international forms of colonization and the colonization of their neighborhood by "yuppies" and real estate speculators. Furthermore, students positioned themselves as agents of change, capable of resisting dominating forces at the intersection of economic, material, political and cultural "fields of power" (Bourdieu, 1991). However, we also identified tensions between disrupting and reifying dominating discourses as students confused and conflated racial and ethnic categories, as well as class and ethnicity, disassociating Black from Puerto Rican and associating White with "expensive."

Implications include an argument for dialogic approaches to Social Studies education that not only engages students in dialogue with each other, but also with the world around them, through intentional efforts to understand local contentious practices, such as struggles over gentrification and affordable housing. Dialogic approaches to teaching and learning can engage students' identities to develop rigorous, engaging, and expansive learning experiences.

References

Adler, M. (2008). *The Paeidia proposal: An educational manifesto.* New York: Simon & Shuster.

Bakhtin, M. M. (1981). *The dialogic imagination.* Austin, TX: University of Texas.

Barton & Levstik (2004). *Teaching history for the common good.* Mahwah, NJ: Lawrence Erlbaum Associates.

Bourdieu, P. (1991). *Language and symbolic power.* Cambridge, MA: Harvard University Press.

Fairclough, N. (2003). *Analysing discourse: Textual analysis for social research.* London: Routledge.

Glaser, B. G. & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research.* New York: Aldine.

Gutierrez, K. D. (2005). Sylvia Scribner Award Address. *American Educational Research Association Annual Meeting. Montreal, Quebec, Canada*

Holland, D. & Lave, J. (2001). *History in person: Enduring struggles, contentious practice, intimate identities.* Santa Fe, NM: School of American Research Press

Lipman, P. (2004). *High-Stakes education: Inequality, globalization and urban school reform.* New York: RoutledgeFalmer

Nodie Oja, S. & Smulyan, L. (1989). *Collaborative action research: A developmental approach.* New York: Falmer Press

Wells, G. (1999). Dialogic inquiry: towards a socio-cultural practice of theory and education. Cambridge, UK: Cambridge University Press.

Paper 3: A Writer's Way: One Teacher's Experience Learning to See Her Students' Intellectual Strengths

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This study investigated how a teacher constructed and learned from the work of a community of practice (COP) that focuses on seeing the intellectual strengths of students of color. Looking in depth at one teacher's experience learning in such a COP, it seeks to provide an understanding of how teachers, working together to study their classroom practice can learn to see these students' strengths instead of looking through a deficit lens. Working within a practice-oriented, situated learning frame (Brown & Duguid, 1989; Lave &Wenger, 1991), I aimed to investigate the teacher's orientation toward her own learning, analyze how she engaged with the resources used to structure practice within the COP (e.g., ideas, cases, texts, classroom transcripts, other participants), and understand whether and how her participation shaped and transformed her classroom practice.

The COP studied was a voluntary collaboration between 11 teachers at an elementary school and 5 educational researchers in a small northeastern city. The collaboration was a five-year design based research study focused on learning to see and teach to the intellectual strengths of students of color. This study focused on one teacher, Maryanne, a white teacher in her mid-fifties who has taught for 18 years. Specifically, this study focused on the fourth year of the seminar and the question Maryanne brought to this COP from her classroom practice which focused on how to understand the writing of an African American boy.

My study took the form of an exploratory case study to document and understand how the teacher's participation shaped and transformed her practice, in particular her relationship with students of color, her orientation to the subject matter, and her stance toward herself as a learner?

To address this question, I conducted three in-depth interviews, each focused on one aspect of my research question. I also recorded and transcribed four full sessions of the COP, during which the teachers presented their work. Transcribing the sessions allowed me to document the teachers' experiences of the COP, both within the group meetings and as they took their learning back to their classrooms. I used a grounded approach (Strauss & Corbin, 1998) to code emerging themes as teachers described their experiences in the data group. I wrote field notes and analytic memos and developed inductive codes, which I then used to construct maps of each teacher's beliefs about learning and how she learned to change her practice (Miles & Huberman, 1994).

I found that her participation in the COP did contribute to Maryanne's work in at least three ways: her relationship to students of color, her orientation to the subject matter, and her stance toward herself as a learner. First, in her relationship, her focus on writing (the subject matter) led her to look at her student's intellect through his use of poetry and metaphor. Second, Maryanne's beliefs about teaching and learning through a disciplinary lens (in this case writing) were at the root of all of her interactions. For Maryanne, a core belief is that "You have to be a writer to teach writing." This view allowed her to build relationships with her African American male students. She began to articulate what he could do, rather than just repeating his challenges. This learner stance also allowed her to see similarities between herself as a writer and her student as a writer. Surprisingly all these changes were possible in this COP even when she publicly, and repeatedly, expressed her skepticism of learning about race, replacing class as the explanation. However it was through her daily practices that she initiated questions regarding the relationship to writing and race. In essence it was through her writing-focused lens that she became interested in seeing race, as she started to inquire about how it played a part in his writing.

This study focuses on learning about race as a part of learning about teacher practice, and not as a separate entity. Understanding these experiences has the potential to offer more informed understanding of the ways to structure teacher learning to support continuous learning in and from practice.

Bibliography

Brown, J. S. & Duguid, P. D. (1989). Situated Cognition and the Culture of Learning. *Education Researcher, 18*(1), 32-34.

Engestrom, Y., & Middleton, D. (Eds.). (1998). *Cognition and Communicative Work.* Cambridge: Cambridge University Press.

Grossman, P., Weinberg, S., & Woolworth, A. S. (2001). Toward a theory of teacher community. *Teachers College Record, 103*(6), 942-1012.

Lave, J. (1996). The practice of learning. In J. L. S. Chaiklin (Ed.), *Understanding Practice: Perspectives on activity and context.* Cambridge: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation.* New York: Cambridge University Press.

Little, J. W. (2002). Locating learning in teachers' communities of practice: Opening up problems of analysis in records of everyday work. *Teaching and Teacher Education, 18*(8), 917-946.

Miles, M. B. & Huberman, A. M. (1994). *Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage Publications, Inc.Putnam, R. & Borko, T. H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Education Researcher, 29*(1), 4-17.

Rogoff, B. (2003). *The cultural nature of human development*. New York: Oxford University Press.

Seidman, I.E. (1998). *Interviewing as qualitative research (2nd ed.).* New York: Teachers College Press.

Strauss, A. & Corbin, J. (1998). *Basics of qualitative research.* Thousand Oaks, CA: Sage Publications.

Warren, B., & M., Ogonowski. (1998). *From knowledge to knowing: An inquiry into teacher learning in science.* Newton, MA: Center for the Development of Teaching, Education Development Center, Inc.

Wenger, E. (1998). *Communities of Practice: Learning, meaning, and identity.* Cambridge: Cambridge University Press.

Content Analysis of Collaboratively Constructed Knowledge Artifacts: Issues and Opportunities for Research

Abstract: New social media for collaborative knowledge construction, often associated with "Web 2.0," represent an emerging context for the research of learning and instruction. Wikis, for example, allow methods of collaborative knowledge construction that were very difficult to achieve with previous technologies. Applications of wikis and related technologies (e.g., Drupal and Django) are blooming in every corner of society, influencing the ways in which people learn and exchange with one another. They are also making their way into our research, resulting in new methodological challenges concerning the analysis of collaboratively constructed materials. This symposium will discuss new methods of content analysis in wiki-environments. The symposium includes an international set of presenters from Canada, Belgium and Norway, representing a small but growing research community that are engaged in such investigations. Each paper will present the research context and method of content analysis that was developed to evaluate collaboration in a wiki environment.

Introduction to Symposium

Across the learning sciences, wikis and other forms of collaborative knowledge construction are increasingly making their way into our classroom and informal learning environments (e.g. Harrer, Moskaliuk, Kimmerle, & Cress, 2008; Forte & Bruckman, 2007; Greenhow, Robelia, & Hughes, 2009). Wikis appeal to educators and researchers alike for several reasons: they enable students to contribute, edit, and maintain a shared document, they are relatively easy to learn, and the revision history is preserved for future reference and analyses. However, despite the growing popularity of wikis, little is known about the processes that students engage in when contributing to a wiki. What kinds of practices do they adopt when writing a wiki page? How do they interact with the content –their own and that of their peers – and how do those interactions change over time? Can we measure student learning in such task? How can we evaluate the effectiveness, or the specific dynamics of collaboration?

As observed by Jeremy Roschelle in his closing comments at the 2009 CSCL conference, the learning sciences still lack standard methods for analyzing the interactions that occur between students in a collaborative learning task. Challenges to analyzing collaborative processes include choosing an appropriate unit of analysis, segmentation, and developing a coding scheme that captures the learning goals of interest to the research (Strijbos, Martens, Prins, & Jochems, 2006). In-depth analyses of collaborative materials can also be constrained by the design of the technology environment and the kinds of analytic tools that are available to researchers. The idiosyncrasies of such research – the particular technology environments, collaborative designs, and research foci – have made it difficult to design analytic methods that can be shared or normed across the research community. A survey of the existing literature reveals little, if any, published approaches for how to analyze the conceptual content or collaborative progress within a wiki-based activity.

In the absence of established analytic methods within the academic community, researchers must design their own metrics for analyzing wiki-based collaborative knowledge construction. This symposium was conceived as a way of widening this discussion within the forum of the ICLS meeting. We have gathered four distinct research groups – two from Canada and two from Europe – who have all confronted the same challenge. We invite each of these groups to present their research paradigm as well as a specific methodological innovation or approach. Our discussant, Christine Greenhow, who is not affiliated with any of these research programs, will synthesize the ideas and advances in this work and lead a discussion amongst participants.

Paper 1: Development of a Content Analysis Approach for Collaboration in a Wiki Environment

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This paper focuses on developing a content analysis of collaboration in a wiki environment. This contribution focuses on developing a content analysis approach studying collaboration in a wiki environment. It first discusses a number of units of analysis with different level of granularity. Next, a framework for content analysis is presented, focusing on one level and distinguishing between content and presentation matter.

In order to find out what is actually happening during the creation of a wiki, we can focus on different units of analysis. One unit of analysis is the complete wiki, i.e. the complete collection of wiki pages created by students. Observations at this level can focus on how the development takes places over time: What is the first page created? What are the following pages? What is the order of page creation? Information on the priorities and the need to change pages can be revealed and linked to explicit or implicit planning issues.

Another unit of analysis is the individual wiki page. By taking a detailed look at the editing history of each page, relevant information can be retrieved: How many times is the page edited? What were the major changes in the different edits? How many people worked together on this specific page? Who edited the pages at what time? What was the pacing of the edits? Were the edits labeled as "minor edits"? However, not all the information on the page level is to be found in the page history logs. Much relevant information can be gathered by analyzing the content of the wiki page's final version. Analysis might consider how many links to other pages are included, how many external links are included, and how well the page addresses the given assignment. One might also analyze the formatting or layout of the page, as well as what types of media are included. Moreover, detailed information can be found by comparing the consecutive versions of a certain wiki page. Was information added, deleted, or moved from one version to the next? Which information was subject to change? Were specific types of media (pictures, audio, video) added (or deleted)?

In the description above, every version of the wiki page could be seen as a unit of analysis. However, since every version of the page could comprise multiple elements that are changed, some authors (e.g., Peters and Slotta, this symposium) opt to use every changed element as a unit of analysis, which they call transactions.

All of the previously discussed units of analysis can be hierarchically nested: All transactions are nested within one version. Every version is then again nested within a page. And every page is in turn nested within the overall wiki (see Figure 1 – upper portion). However, another unit of analysis, namely the user (student) does not completely fit with this hierarchically nested structure. Although transactions and versions can be hierarchically nested within users (every transaction is nested within one and only one version, and every version is edited by one and only one user), users themselves are cross-indexed with respect to wiki pages. That is, users can edit multiple pages (see Figure 1 – lower portion).

The user is an important unit of analysis when it comes to analyzing collaboration within a wiki. At this level, the following questions can be addressed: How many edits were made by a specific user? How many pages were edited by a specific user – or how many pages were edited on average by the users? How often did a user edit the wiki? Most of this information cannot be found in a log file, but must be constructed from one of the hierarchical units identified above. For instance, how many minor/major edits were done by a certain user? How many additions, figures, etc. has a user added? By combining information from the different levels, the full picture of a user's participation can be developed. Indeed, a number of interesting questions can only be answered by combining information. Moreover, users can be clustered into different groups or types, depending on their condition within the research study or their activities within the wiki-environment.

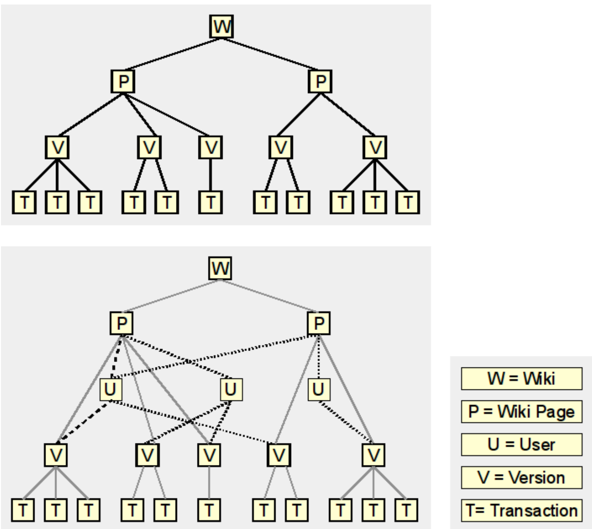

Figure 1. Four hierarchical levels within a wiki (upper figure) become more complex when a layer is added for users (lower figure).

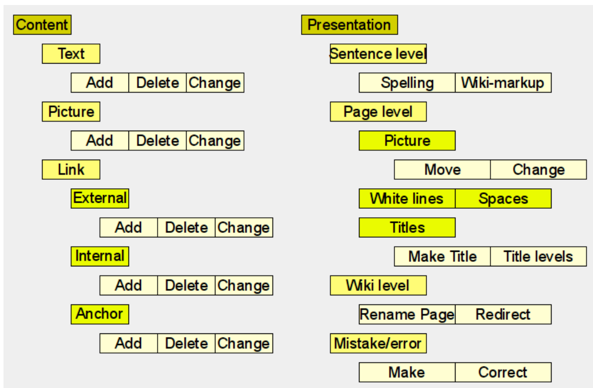

Figure 2. Coding schemes for wiki edits, including specific codes for content (left) and presentation or formatting of pages (right).

We developed a general framework for performing content analysis on collaboratively developed wiki materials. To begin, we focused on the single wiki page as our unit of analysis, which provides a basis for discussing the deeper levels framework (i.e., at the transaction level). In the proposed symposium, we will compare our approach with the methods of analyzing wiki data presented by the other participants.

Figure 2 above presents an overview of the coding scheme for each wiki page, for every version of the page. Since a version can contain different changes ("transactions"), multiple codes can be assigned to each unit of analysis. Content codes include text, pictures, and links that can be added, deleted, or changed. For links, we differentiate between external links (linking to other references on the WWW), internal links (linking to other pages within the wiki), and links to anchors (linking within the same wiki page). Other forms of media could be added to this scheme, e.g. videos, if necessary. Whereas the Add and Delete categories are straightforward, the Change category is not. Technically speaking, changing any text involves deleting some parts or adding others. Therefore, one could argue that a Change category is not needed. However, by including a specific "change" code, we focus on the fact that an existing idea is edited, which is not exactly the same as deleting an idea and adding one, where there is not necessarily a link between those two actions. Thus, when a part of a page is deleted (say in the introduction), or another part added (say in the conclusion of the page), such edits should be coded as Delete or Add, respectively. When one paragraph is rephrased, this should be coded as Change.

With regard to presentation or formatting of the wiki page, we differentiate between changes at the sentence or paragraph level, at the page level, and at more global wiki level. In addition, we include a code for revisions that involve simply correcting mistakes (e.g., typos). It is important to recognize the differences between content and presentation, and to note that some actions may be coded in both taxonomies. For instance, if somebody adds a title, this should be coded both as Text/Add in the Content scheme and Page level/Titles/Make title in the Presentation scheme, whereas simply changing some existing text to make it into a header or title would only result in the Presentation code, since the text was there beforehand.

This method of coding can permit a wide range of analyses, according to the specific needs of the research design. While we are in the beginning stages of utilizing such techniques in our own research, we are confident that it can be applied reliably, and that it can be further developed for other units of the wiki organizational scheme (Figure 1). Additionally, qualitative measures concerning the semantic content of the wiki pages themselves can be added. Thus, our present coding scheme could serve as at a first stage of analysis, to identify the versions and collaborative patterns in which content is edited (added, deleted, change). In a second stage, these versions can be studied in a more detailed way. This symposium will allow the authors to discuss such procedures with co-participants as well as with the audience.

Paper 2: Analyzing Student Collaborations in a Wiki-based Science Curriculum

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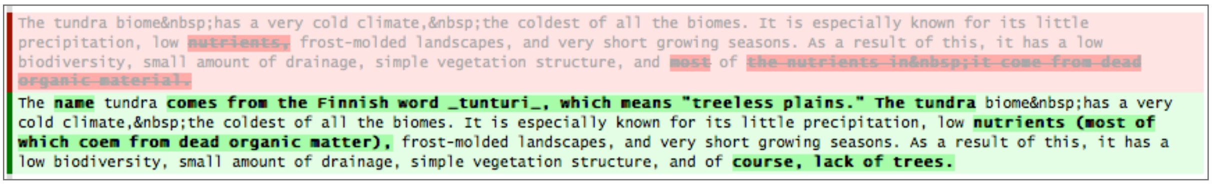
As part of a larger research study (see Peters & Slotta, 2010), we designed a collaborative wiki-based activity that engaged secondary students in co-creating a community knowledge base to serve as a resource for a subsequent inquiry activity. Over eight weeks, 112 students from four sections of a high school biology course contributed to a common wiki repository about Canadian biodiversity. A wiki provided the ideal functionality for this activity as it enabled students to easily access and edit each other's contributions, reorganize the repository, and link pages to establish connections between related themes or ideas.

While it was important to preserve the open-ended feeling of collaborative editing that typifies wikis, it was equally important to have a simple and structured way for students to create wiki pages that addressed specific science content. We therefore created a hybrid wiki environment that included a customized "Create a New Page" web form (developed using Ruby on Rails) that collects basic information about their resource page, then generates a new wiki page with pre-specified headers to help scaffold the content in students' wiki entries.

Analysis and Findings

The activity was evaluated in terms of collaborative editing, usefulness of wiki materials in later inquiry activities, and student learning outcomes. Students were actively engaged in the construction of knowledge resource within the wiki, creating 31ecozone pages with a mean word count of 2809.13 (SD = 1408.73). Each wiki page was run through Copyscape©, a web-based utility that compares web-based material to check for instances of plagiarism, with negligible results.

To analyze students' knowledge construction practices, we coded their contributions to the wiki as individual "transactions," defined as the distinct changes to a wiki page that occur during authoring. A transaction could be as simple correcting a spelling error, or it could be the revision of a paragraph that involves adding, deleting and moving text. It must be noted that, while wiki systems generally track all edits according to "versions" (i.e., where each version corresponds to one editing session), any editing session might contain multiple transactions. Thus, coding for transactions meant looking within each version edit, to see whether the author conducted multiple edits before saving the page. Transaction codes included: *move*, *add, delete* and *format*. For each of the first three codes, we then coded the object of the action: *text*, *image*, *external link*, or *internal link*. In the case of text actions, we coded whether the resulting text was *embedded* or *detached* (see Figure 1). Finally, we coded whether the text was made to one's own text, or that of a peer. This distinction was important because collaborative knowledge construction entails building on and extending the ideas of others within the learning community.



The tundra biome has a very cold climate, the coldest of all the biomes. It is especially known for its little precipitation, low ~~nutrients,~~ frost-molded landscapes, and very short growing seasons. As a result of this, it has a low biodiversity, small amount of drainage, simple vegetation structure, and ~~most~~ of ~~the nutrients in it come from dead organic material.~~

The **name** tundra **comes from the Finnish word _tunturi_, which means "treeless plains." The tundra** biome has a very cold climate, the coldest of all the biomes. It is especially known for its little precipitation, low **nutrients (most of which coem from dead organic matter),** frost-molded landscapes, and very short growing seasons. As a result of this, it has a low biodiversity, small amount of drainage, simple vegetation structure, and of **course, lack of trees.**

Figure 1. Wiki transaction showing "embedded" text that has been added and deleted.

Using the transaction as our unit of analysis, we coded the complete revision history of the wiki (i.e., the community knowledge base) to identify the kinds of contributions that students made, when they made them, and the relative frequency of contributions by different students. This coding allowed us to measure which students made substantive contributions at what points in the curriculum, whether participation was more or less equitable and whether ideas grew iteratively or simply as a piecemeal collection.

As a result of our analysis we identified several trends in terms of students' editing practices when contributing to a wiki. We also found a relationship between students' individual editing practices and their scores on their final unit exam. This presentation will provide an overview of the research and describe the methodology that was used in the study. We will detail the coding, analysis of collaboration and growth patterns within the wiki, and conclude with recommendations for educators wishing to implement a wiki technology in their classrooms.

Paper 3: Does Scale Matter: Using Different Lenses to Understand Collaborative Knowledge Building

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Web-based environments for communicating, networking and sharing information, often referred to collectively as "Web 2.0," have become ubiquitous – e.g., Wikipedia, Facebook, Flickr, or YouTube. Understanding how such technologies can promote participation, collaboration and co-construction of knowledge, and how such affordances could be used for educational purposes has become a focus of research in the Learning Science and CSCL communities (e.g., Dohn, 2009; Greenhow et al., 2009). One important mechanism is self-organization, which includes the regulation of feedback loops and the flows of information and resources within an activity system (Holland, 1996). But the study of such mechanisms calls for new ways of thinking about the unit of analysis, and the development of analytic tools that allow us to move back and forth through levels of activity systems that are designed to promote learning. Here, we propose that content analysis can focus on the flows of resources (i.e., content knowledge, scientific artifacts, epistemic beliefs) in terms of how they are established and the factors affecting whether they are taken up by members of the community.

We present our analytic approach, and some empirical data that tests out its constraints. Our approach is informed by a "systems thinking" perspective and relies on aspects of Activity Theory (Engeström, 1999) as well as distributed cognition (e.g., Salomon, 1993, Hutchins, 1995). In doing so, we attempt to look across several levels of granularity within an activity system. To start we look at the smallest unit of sense making between individuals and investigate how their contributions lead to the construction of an artifact, which is a form of interactional analysis (e.g., Zemel & Cakir, 2009). On another level, we look at how that artifact becomes a shared object, whether it is used by others in the community, and how it becomes culturally imbued (typical of socio-cultural analysis). This means that we systematically interweave the use of two units of analysis: (1) micro-scale, and (2) macro-scale. Our interest here is to determine whether the insights made by one or both levels reveal substantially different things about the system and its actors. As well, we shed light on co-regulatory mechanisms that may be at play, such as collective cognitive responsibility (Scardamalia, 2002).

We bridge these levels of granularity by producing a visualization of the discourse contributions, expanding upon earlier work by the first author (Karin, Charles & Kolodner, 2006). We demonstrate that such visualizations can facilitate the investigation of how collective states of knowledge and beliefs emerge within an activity system such as a collaboratively edited wiki.

The data we analyze is a case study of an online activity involving a class of 27 first year science students enrolled in an introductory physics course, with topics such as Newton's laws, and the basic principles of forces and motion. These data are drawn from a larger study that investigated the impact of different instructional approaches to collaborative learning, across 4 classes, at a post-secondary institution in the province of Quebec The province of Quebec, Canada, has a unique 2-year pre-university college system, equivalent to grades 12 and first-year university in other parts of the world. However, the science curriculum in our program is taught roughly at the level of an introductory university courses.

We selected this instructional case because it exemplifies collaborative knowledge building and refinement from a productive online discussion forum, which led in turn to a class wiki. This development was intriguing because it emerged from an activity system with few initial resources (i.e., weakly scaffolded) and open-ended participation goals. The teacher's instructions were simply to explore two questions following a physics lab on the topic of acceleration and its effect on weight. Participation was encouraged and monitored, though no grades were assigned. In other words, we anticipated that co-regulation would be a large factor in the success of this activity system.

We started on the micro-scale, analyzing the interactions at the level of the threaded postings. These are the tightly coupled (or chained) postings that respond to an initial idea (see Figure 4, below). Along the way to being submitted to the wiki, the idea is transformed. Sometimes it was a simple clarification (B, E, F, H). Sometimes it took on new meaning, which we consider to be a cultural artifact (C, G, I, J).

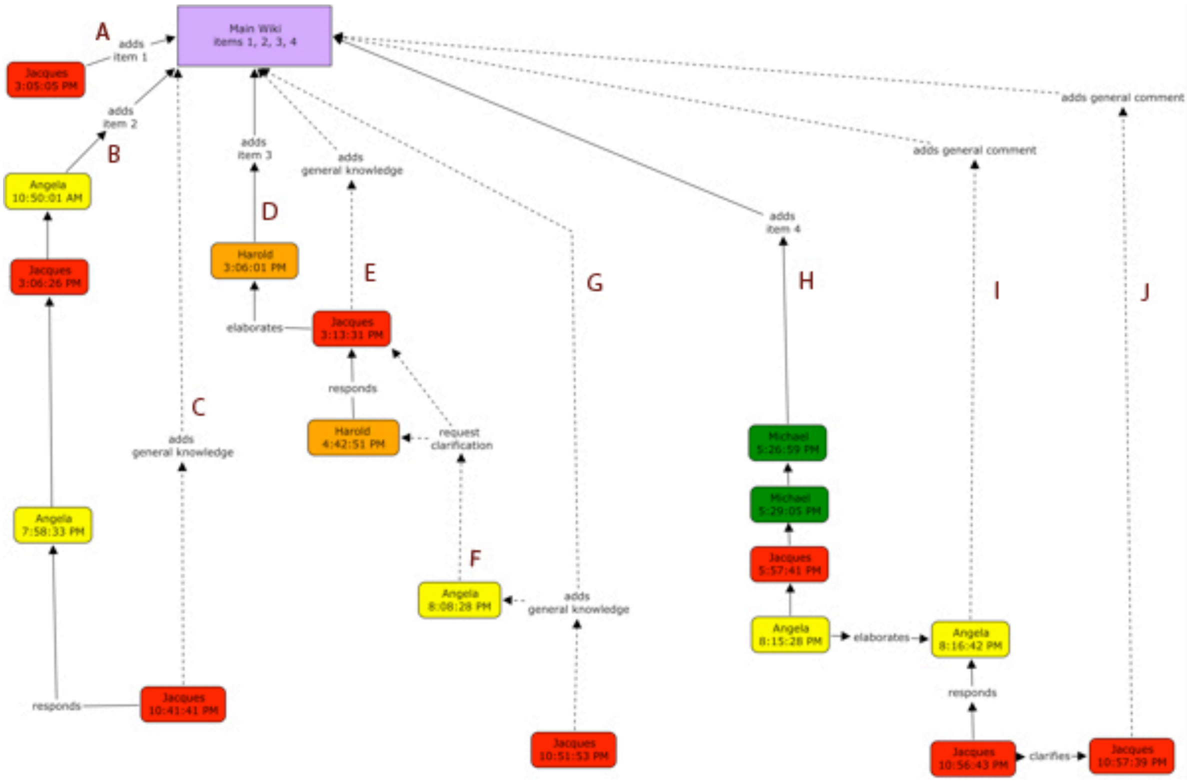

Figure 4. Micro scale representation of contributions to class wiki, deriving from previous discussions.

When there were no new artifacts being produced, we switched to the macro-scale unit of analysis (see Figure 5, below). Though not threaded, new postings instead referred to identified artifacts: (1) content knowledge (the lilac colored boxes at right) and (2) epistemic knowledge (the blue boxes on the left). Both ideas are taken up by the community and constitute their collective knowledge. This visualization thus represents these two kinds of artifacts and their flow through the activity system.

Finally, we also recorded how several of the actors continued to regulate the flow of these resources, in particular two students, Jacques and Angela (see both Figures). When viewed from the macro-scale, such repeated actions can be seen as the emergence of practice. When such practice is tightly coupled to the improvement of a shared artifact, we argue that it demonstrates the construction of a shared goal and propose this may exemplify what Scardamalia (2002) refers to as collective cognitive responsibility.

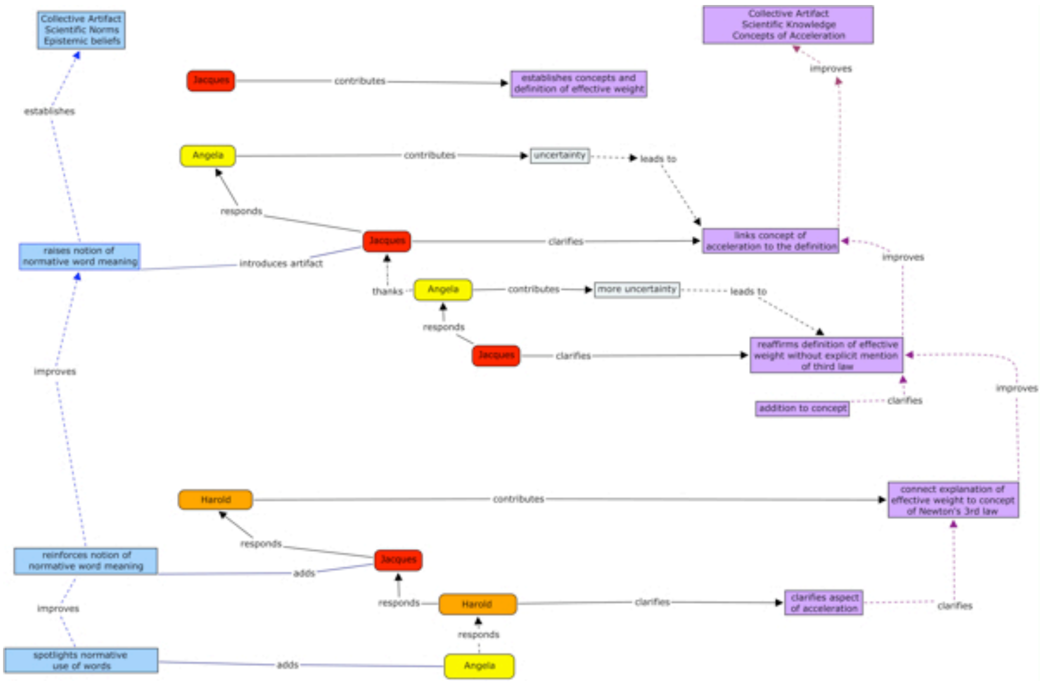

Figure 5. Macro level representation of the flow of content and epistemic knowledge in the activity system.

Paper 4: Learning Through Collaborative Creation of Shared Knowledge Objects: Technological Support and Analytic Challenges

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Recent studies of collaboration demonstrate that simply bringing people together in groups with some task, or pooling the group's knowledge, are insufficient conditions to lead to productive real collaboration (Barron, 2003; Salas, Shawn, & Burke, 2005). One recent approach to learning called Knowledge Creation (Paavola & Hakkarainen, 2005) depicts learning as a collaborative activity aimed at creating new knowledge mediated through the creation and development of shared knowledge objects (e.g., research reports, instructional material or scientific models). According to this approach, collaborative learning does not serve only individual learning or only social interaction. Rather, collaboration is seen as organized around common knowledge objects whose creation and development defines their purpose.

To design educational contexts that apply this idea involves designing new pedagogical methods and technological tools that are grounded in the knowledge creation approach to learning. One of the prominent approaches to such innovative designs is technological support of object-mediated collaboration, in the form of virtual collaboration spaces. However, such designs are often undermined by the fact that little is known about how to analyze processes of object-mediated collaboration and learning. Consequently, our study seeks to understand how learners create knowledge in a virtual environment that supports object-mediated collaborative learning. We describe an analytical framework that supports an integrative approach to analyzing how interactions between learners in the environment contribute to the progression of their knowledge objects.

The study was conducted in a collegiate institution in the Netherlands that prepares pre-service teachers for lower secondary education in the field of agricultural and animal studies. The current study involves 15 students in one of the Professional Situations a 5-month curriculum unit. Students worked in groups of 4-5 on long-term projects constructing shared knowledge objects and employing the Knowledge Practices Environment (KPE) to support their work. KPE is a virtual collaboration space offering facilities for collaboration, with peers and working with knowledge objects in shared work spaces. Each shared space encompasses a workplace which presents users with three views: a Process view (to support planning and organizing the process), a Content item view (to allow creating, sharing and collaboratively editing of documents, wiki pages, or notes) and a Community view (to enable management of the community). Each group of students worked in their own shared space, with the emphasis on using wiki or document versioning for collaborative text production and object-bound chat for supporting focused discussions around the produced material (see Figure 6).

Figure 6. Object development in wiki pages and object versions

The integrative approach described above involves combining the analysis of the interactions involved in the creation of objects with the analysis of the object up-take and progress of the objects (see also contribution by Charles, Lasry, & Whittaker, above). Based on an analysis framework for verbal and written interactions previously constructed by two of the authors (Damşa, Kirschner, Andriessen, Erkens, & Sins, in press) we distinguish between epistemic and regulative actions. Epistemic actions are those that bring about the construction and progress of the shared knowledge-object. These are actions involved in or resulting from productive interactions. They can be described qualitatively in such terms as "creating awareness," "explicating vision," "alleviating lack of knowledge," "elaborations," a" negotiations to create explanations and shared understanding" or "generative collaborative actions and problem solving." Regulative actions are concerned primarily with the processes necessary to direct, organize and support the collaborative process, and include categories of projective, coordinating and relational actions.

With respect to analyzing students' knowledge objects, two analytic perspectives are distinguished. First, the normative perspective, which involves determining the quality of the final object according to domain-specific criteria, established together with the teachers using an evaluation form. Second, the content-evolution perspective, which analyzes the progression of the contents of the constructed objects. Inspired by Suthers (2006) this analysis focuses on the epistemic content that is brought in by group members (i.e., ideas) and that evolves in terms of conceptual complexity during the period in which the object is developed. Another category of this analysis concerns the way this content was shaped, elaborated, synthesized, selected, and revised over time. These analysis categories were drawn mainly from the literature on text writing and elaboration.

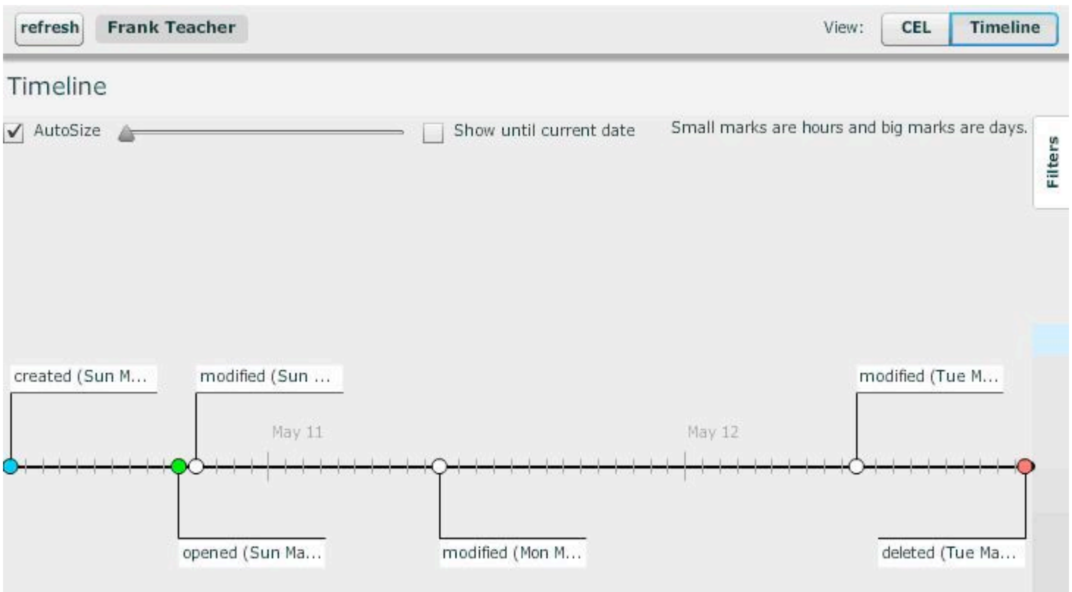

Figure 7. The object-based timeline analysis of an artefact evolution

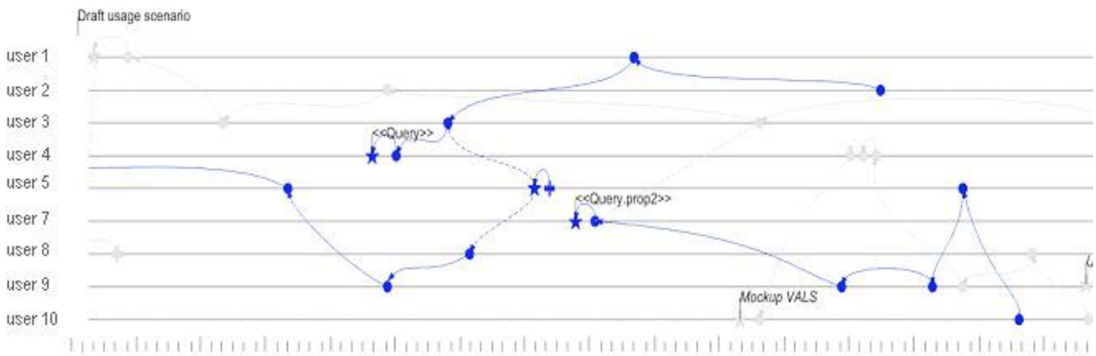

Figure 8. The user-based timeline analysis of an artefact evolution

Our analysis tool makes it possible to trace changes in the knowledge objects, by providing visualization of performed activities related to a selected object (or set of objects) or for a particular user (or group) on a timeline. (see Figure 7 and 8, above). To support the analysis of students' interactions feeding into their shared knowledge objects, the system connects the chat discussions that took place between students related to specific objects (e.g., document or versions of a wiki), serving to unveil the way in which verbal actions are taken-up and how ideas expressed are materialized in the knowledge objects.

References

Barron, B. (2003). When smart groups fail. The Journal of the Learning Sciences, 12, 307-359.

Bereiter, C., & Scardamalia, M. (1989). Intentional learning as a goal of instruction. In L. B. Resnick (Ed.) *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 361-392). Hillsdale, LEA.

Damşa, C. I., Kirschner, P. A, Andriessen, J. E. B., Erkens, G., Sins, P. H. M. (in press). Shared epistemic agency – An empirical study of an emergent concept. Journal of the Learning Sciences.

Dohn, N.B. (2009) Web 2.0: Inherent tensions and evident challenges for education. International Journal of Computer-Supported Collaborative Learning, 4(3), 1556-1607.

Engeström, Y. (1999). Activity theory and individual and social transformation. In Y.Engeström, R. Miettinen, & R. Punamaki, (Eds.), Perspectives on activity theory (pp. 19–38). Cambridge, MA: Cambridge University Press.

Greenhow, C., Robelia, B., & Hughes, J. E. (2009). Web 2.0 and classroom research: What path should we take now? Educational Researcher 38(4), 246-259.

Harrer, A., Moskaliuk, J., Kimmerle, J., & Cress, U. (2008). Visualizing wiki-supported knowledge building: Co-evolution of individual and collective knowledge. Proceedings of WikiSYm '08, Porto, Portugal.

Holland, J.H. (1995). Hidden order: How adaptation builds complexity. Reading, MA: Addisoon-Wesley Publishing Co.

Hutchins, E. (1995) Cognition in the wild. Cambridge, MA: MIT Press.

Karkin, S., Charles, E.S., & Kolodner. (2006). Visualizing Discussion by the Use of the Conversation Chain Model. Poster in proceedings of the 7th International Conference of the Learning Sciences: Bloomington, IN.

Paavola, S. & Hakkarainen, K.: The Knowledge Creation Metaphor – An Emergent Epistemological Approach to Learning. Science & Education, 14(6), 535--557 (2005)

Peters, V. L., & Slotta, J. D. (2010). Scaffolding knowledge communities in the classroom: New opportunities in the Web 2.0 era. In M. J. Jacobson & P. Reimann (Eds.), *Designs for learning environments of the future: International perspectives from the learning sciences* (p. 205-232). Secaucus, NJ: Springer.

Salas, E., Sims, S., & Burke, C. (2005). Is there a "Big Five" in teamwork? Small Group Research, 36, 555-599.

Salomon, G. (1993). Distributed cognitions. New York: Cambridge University Press.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), Liberal education in a knowledge society (pp. 67-98). Chicago: Open Court.

Strijbos, J., Martens, R., Prins, F., & Jochems, W. (2006). Content analysis: What are they talking about? Computers & Education, 46, 29-48.

Suthers, D. D. (2006). A qualitative analysis of collaborative knowledge construction through shared representations. Research and Practice in Technology Enhanced Learning, 1(2), 1-28.

Zemel, A. & Çakir, M. (2009). Student and Team Agency in VMT. In G. G. Stahl (Ed.), Studying Virtual Math Teams, (pp.). New York, NY: Springer Publishing.

A New Age in Tangible Computational Interfaces for Learning

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Abstract: Tangible computational technologies for education have evolved from research prototypes to the mainstream, led by the wide adoption of commercial kits such as the Lego Mindstorms platform. Despite their success, researchers have pointed out four main issues that have limited their adoption. First, most toolkits were marketed for a particular gender and age group. Second, they had standardized parts and proprietary connectors, which limited the types of projects that users could build. Third, they had programming environments with limited features. Lastly, they were difficulty to connect with school curricula in science and mathematics, which segregated robotics to after-school activities. In this symposium, we will: (a) investigate these limitations in light of current research in the field; (b) showcase several new designs for tangible computational artifacts for education which try to overcome these limitations; (c) discuss possible implications of the widespread use of these new computational artifacts.

Overview of Symposium Panel and Demonstrations

Over the past 15 years, tangible computational technologies for education, inspired by the constructionist tradition (Papert, 1980), have evolved from prototypes in research laboratories (for example, Martin, 1993; Resnick, et al., 1998; Resnick, Ocko, and Papert, 1991) to the mainstream, led by the wide adoption of commercial kits such as the Lego Mindstorms platform, the VEX Robotics kits, among several others. Despite the success of this first generation of digital manipulatives, particular design decisions had to be made to make them viable. First, most of these toolkits were marketed for middle-school boys (mostly robotics kits), which limited their use by young women. Second, their standardized parts and proprietary connectors made it easier for users to get started and backgrounded much of the complexity in building mechanical structures, but limited the types of projects that more advanced users could build, and made the integration with traditional materials difficult (textiles, paper, crafts, cheap electronics, scrap materials). Third, the limitations of extant programming environments and the intrinsic difficulties of mimicking complex physical behaviors with computer code also narrowed what students could accomplish, and made the activities especially hard for younger learners. Lastly, the difficulty in connecting the activities with school curricula in science and mathematics segregated the use of computational manipulatives to after-school activities.

The authors in this symposium are representative of a new generation of designers of computational tangibles for children. Each of the papers will discuss one novel emergent design framework which addresses many of current design issues in existing digital manipulatives. Michael Horn will discuss limitations of on-screen-only programming interfaces for children and show new designs in tangible programming artifacts, with which children can program using physical blocks. Paulo Blikstein will discuss the difficulties in connecting computational artifacts with scientific topics in physics and chemistry, and present the *bifocal modeling* platform, which enables learners to build their own scientific lab, collect empirical data, and match them to data from their own computer models. Leah Buechley will describe her work creating computational platforms out of paper and textiles, and how this has blurred the boundaries between traditional and computational media, and made tangibles less directed to just one gender. Finally, Hayes Raffle will show how his work with programmable-by-example computational tangibles ("Topobo") made them more approachable to younger audiences, and enabled children to program complex physical behaviors by constructing and moving robotic creatures.

These four emergent design frameworks are pointing to new directions in the use of computational tangibles in education:

1) **A wider palette of materials:** more materials and building techniques are being made available to children. In particular, low-tech materials with which students are already familiar can now be platforms for computation, as well as a wider selection of sensors, probes, and actuators.

2) **More diverse projects:** breaking away from the tradition of the gender-biased uses of robotic technologies to make robots and cars, these platforms allow children an entirely new array of expressive

possibilities, since the toolkits are composed of much more flexible and customizable parts. Projects such as interactive art, "animals" with realistic motion, sensor-enabled prototypes, scientific inquiry apparatus, and electronics sketchbooks are made possible and technically more approachable.
3) **More flexible programming modes:** traditional programming for computational tangibles has been based on text or block-based coding. The new platforms presented in the symposium enable for much more diverse modes of programming. Students can use "smart parts" that can remember motion (thus children can program a creature by example), physical smart blocks which can be combined together to create a program, or real-world sensor data for code optimization.

These three novel directions, as the individual papers will discuss, could point to a new age in the use of computational manipulatives for learning. Some of these technologies have already been tested in schools or after-school environments, but we believe that their collective presence in a symposium will enable researchers to have a more comprehensive view of where the field is going, and allow for rich discussions within the research community. In the symposium, authors will talk about their latest designs and research findings, and also do demonstrations of the actual devices and technologies.

Abstracts of Panel Participants

Topobo: programming by example to create complex behaviors

Hayes Raffle

Topobo is a 3D constructive assembly system embedded with kinetic memory—the ability to record and playback physical motion. Unique among modeling systems is Topobo's coincident physical input and output behaviors. By snapping together a combination of passive (static) and active (motorized) components, users can quickly assemble dynamic biomorphic forms like animals and skeletons with Topobo, animate those forms by pushing, pulling, and twisting them, and observe the system repeatedly play back those motions. For example, a dog can be constructed and then taught to gesture and walk by twisting its body and legs. The dog will then repeat those movements and walk repeatedly.

Figure 1. A Topobo Moose (left): to program motions, you just manipulate the toy; and Topobo pieces (right).

Topobo is a class of tools that helps people transition from simple-but-intuitive exploration to abstract-and-flexible exploration. The system is designed to facilitate cognitive transitions between different representations of ideas, and between different tools. A modular design approach, as well as an inherent grammar, helps people make such transitions. With Topobo, children use enactive knowledge, e.g. knowing how to walk, as the intellectual basis to understand a scientific domain, e.g. engineering and robot locomotion. Queens, Backpacks, Remix and Robo add various abstractions to the system, and extend the tangible interface. Children use Topobo to transition from hands-on knowledge to theories that can be tested and reformulated, employing a combination of enactive, iconic and symbolic representations of ideas.

In the past, systems for children to model behavior have been either intuitive-but-simple, (e.g. curlybot, Frei, 2000) or complex-but-abstract (e.g. LEGO Mindstorms). In order to develop a system that supports a user's transition from intuitive-but-simple constructions to constructions that are complex-but-abstract, I draw upon constructivist educational theories, particularly Bruner's theories of how learning progresses through enactive then iconic and then symbolic representations. Bruner (2004), after Piaget (1976, Cole & Cole, 2001), described a sequence of stages all people seem to progress through as they represent and acquire knowledge, moving from enactive, to iconic to symbolic representations of knowledge (Figure 2). Bruner's framework suggests that certain ideas can be made even more accessible, and at a younger age, if they can be grasped and manipulated physically. In this work, I show how tangible programming and interaction can provide an enactive mode of interacting with computers, where tangibles provide a bridge from computers' iconic and symbolic representations to enactive ones, and allow for more intuitive expression and access to certain ideas. My hypothesis is that physical, and especially spatial or 3D problems, are best approached first in the tangible domain, where simple behaviors can be prototyped and manipulated tangibly.

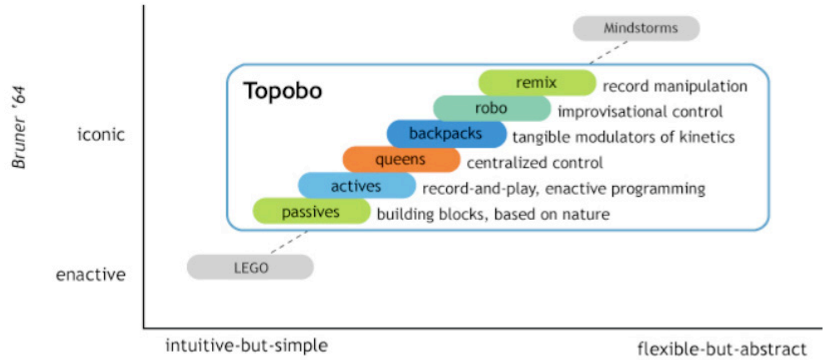

Figure 2. Sequence of stages of representation and acquisition of knowledge

In presenting the design and development of Topobo, I will talk about how more than 100,000 children have used the system through workshops and outreach, and how commercialization of the technology is putting tangibles for learning into young children's hands worldwide, helping them to climb a mountain of ideas about technology, robotics and the natural world.

LilyPad Arduino: rethinking the materials and cultures of educational technology

Leah Buechley

The LilyPad Arduino is a construction kit that enables students to construct and program tangible interactive devices (Buechley, 2008). Similar to Lego Mindstorms, it consists of a set of controllable input and output pieces like temperature sensors, light sensors, motors, and LEDs, but users of the LilyPad build interactive textiles instead of robots. Soft, wearable artifacts are made by stitching sewable components together with silver-plated, electrically conductive thread. Figure 3 shows a picture of the kit and a sample design, a jacket with turn signals on its back that was designed for cycling.

Figure 3. Components of the LilyPad Arduino (left) kit and a sample construction (right).

In an ongoing series of workshops and courses we have been using the LilyPad to engage middle and high-school students (ages 11-18) in computing and electronics. In each course students learn basic circuitry and programming and then design and construct an interactive garment that is demoed to friends and family at an exhibition/fashion show. Figure 6 shows images from a few of these sessions.

Figure 4. Images from Electronic Fashion workshops. Left: two students work on their designs. Center: a young woman models the e-textile she built, a sweatshirt with electroluminescent wire and LEDs. Right: two teenagers have fun with a touch sensitive shirt. The shirt, built by the young woman in the picture, makes sounds when someone squeezes her waist.

One of the most interesting outcomes from these experiences was our ability to attract voluntary participation from large numbers of young women, who—once they arrived in workshops—adopted engineering skills with gusto to complete functional and sophisticated designs (Buechley, 2008).

Margolis and Fisher's (2001) groundbreaking study on gender in computer science focused on "Unlocking the Clubhouse". In their report on the study they illustrate how traditional computing culture functions as a white/Asian boys' club and argue that it is crucially important to unlock this clubhouse to make it more accessible to women and minorities. Our experiences suggest a different approach, one we call "Building New Clubhouses". Instead of trying to fit people into existing computing cultures, we want to spark and support new ones. Rather than trying to recruit young women to robotics clubs and classes, we engage them in computation through electronic textile clubs and classes—venues that young women flock to with no prompting.

We believe that cultural factors, more than a lack of aptitude or intrinsic interest, make computer science inaccessible and unappealing to many students. By making computation more accessible and building computers that look and feel different from traditional ones—computers that are fuzzy, colorful, and feminine, for example—we can begin to change and broaden the culture of computation. We can begin to get a diverse range of people excited by the ways that computers can be used to build beautiful, expressive, and useful objects that are different from anything that has been built in the past.

Since the introduction of the LilyPad Arduino, a community of educational technology researchers has begun to adopt our tools and employ them in similar settings (Katterfeldt, 2009; Ngai, 2009) and we are optimistic that new real-world cultures are beginning to flourish outside of our research lab.

Connecting the science classroom and tangible interfaces: the Bifocal Modeling framework

Paulo Blikstein

Fifteen years ago, few would have predicted that children would be doing advanced robotics in middle-school. Indeed, since the seminal work by Papert, Martin, and Resnick (Martin, 1993; Resnick, et al., 1998; Resnick, Ocko, and Papert, 1991), the launch of the Lego Mindstorms platform, and the appearance of robotics competitions across the country, robotics has become a common activity in public and private schools. However, the learning revolution predicted by its proponents is still far away – such activities are oftentimes attended by males, too focused on competitions and prescribed, standardized "challenges," and disconnected from the school curriculum. In most schools, robotics teachers conduct activities regardless of what happens in the science or math classroom.

At the same time, science classrooms and laboratories are not well suited to support students for authentic scientific inquiry, developing and investigating their own scientific hypothesis. For example, a student examining an acid-base reaction in a laboratory might identify the chemical elements involved and even hypothesize as to their proportions and concentrations, but the investigation cannot dive deep into the chemical mechanisms. Later, in the classroom, he will learn about chemical equations and theories which bear little resemblance, in terms of scale and mechanism, to the phenomenon observed in the laboratory. Bifocal Modeling (Blikstein & Wilensky, 2006) is a framework to link these disconnected types of activities and environments (robotics and computational manipulatives, science laboratories, and theoretical content in science), providing continuity between observation, physical construction of artifacts, and model-building. As this modeling platform enables seamless integration of the theoretical/computational models and the physical world, allowing modelers to focus simultaneously on their 'on-' and 'off-screen' models, I termed it *bifocal modeling*.

When building a bifocal model, students have three main tasks. First, they build a computer model of the phenomenon using various computer modeling platforms (in particular, I use NetLogo (Wilensky, 1999) in my studies). This model should encapsulate students' hypotheses about a given scientific phenomenon. Second, students use electronic sensors and low-cost analog-to-digital interfaces, such as the GoGo Board (Sipitakiat, Blikstein, & Cavallo, 2004), to build their own sensor-equipped "science lab." Finally, students run both models connected in real-time as to validate, refine, and debug their hypotheses using real-world data. The computer screen becomes a display for the computer model, which is a proceduralization, through programming, of equations, text, or other representations of scientific content, and the actual phenomenon, which is discretized by means of sensors and other laboratory apparatus (see Figure 5, for a model investigating heat transfer in a copper wire, and Figure 6, for a model of acid-base reactions). Because the computer models are carefully constructed to imitate the phenomenon's visual language, the bifocal methodology minimizes interpretive challenges. That is, the seen and the hypothesized are displayed such that their perceptual differences are backgrounded and, therefore, their procedural differences are more likely to be revealed. By thus utilizing the power of computation and representation, bifocal modeling constitutes a multi-disciplinary research tool that offloads aspects of both the interpretive and menial burden of scientific practice, freeing cognitive, discursive, and material resources that can thus be allocated toward validation of the hypotheses.

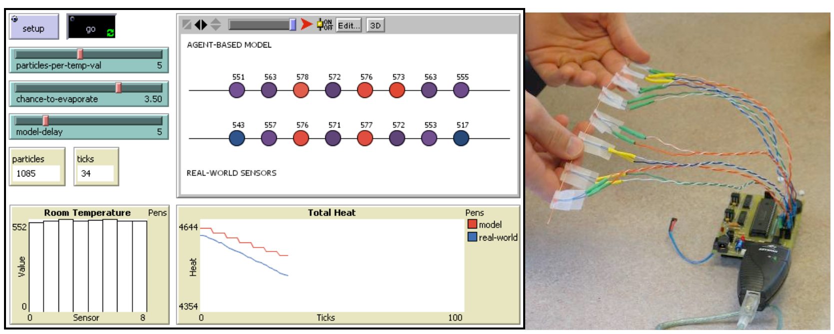

Figure 5. A computer model of heat transfer, with the side-by-side visualization (left), and the physical model (right), with a copper wire hooked to eight temperature sensors.

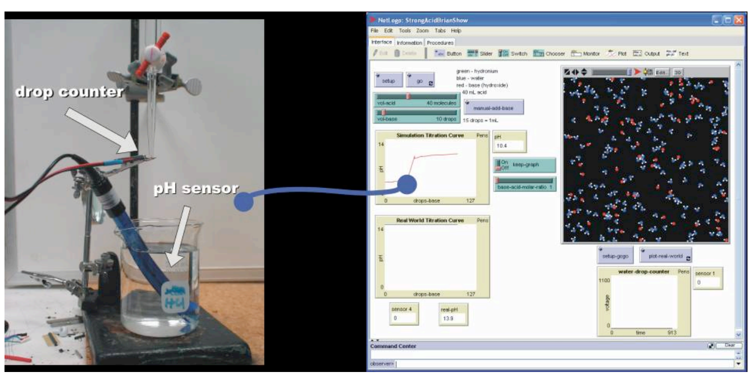

Figure 6. A model of an acid-base reaction, with the physical apparatus (left) and the NetLogo computer model (right), side-by-side.

In particular, in previous pilot studies (Blikstein & Wilensky, 2006), students who built bifocal models attended to phenomenal factors which were not mentioned by students in a second group who did on-screen-only models, such as energy loss, reversibility, synchronicity, and precision. The student who built the heat transfer model in Figure 5, for example, wanted to test how different metals would behave when heated. Coming in to the project, he had two hypotheses about the nature of each of the foci of bifocal modeling. He supposed that it should be relatively straightforward to build: (a) an artifact that enables the measurement of the target phenomenon; and (b) a computer-based procedure that emulates this phenomenon. Both hypotheses proved incorrect. The unsettling element in his model, which triggered the frustration of his expectations, was *time*. Upon completing the physical model and connecting it to the computer model, he realized that there was a fundamental (and hard) problem to be addressed: synchronicity. Sensors were sending temperature data twenty or thirty times a second, but the computer was calculating new temperatures for the virtual agents several thousands of times a second. Which “side” should be in control? Should the computer model be slowed down to match the real-world data, or should the sensor data be manipulated by software to fit into the timing scheme of the computer model? Both options have significant implications for modeling, and speak to the modeling endeavor itself. If the computer timing would prevail, the sensor data would be greatly ‘stretched’, and perhaps become meaningless. In the physical model, the inch that separated two temperature sensors contained billions of atoms. In the computer model, that same distance contained just a couple of computational agents. The nanosecond events taking place in the real material would have to be somehow converted to the model scale.

The student spent a significant part of the workshop thinking about this issue and what was, in fact, the objective phenomenon being modeled. Was it ‘what happens when you heat a wire’ or is it ‘the concept of heat flow?’ In traditional textbooks, chapter titles disclose ‘what is to be learned,’ such that learning is concept-driven, whereas his experience was phenomenon-driven (see Papert, 1996, on the ‘project-before-problem’ principle). As the seen and the hypothesized are displayed simultaneously, their perceptual differences are backgrounded and, therefore, crucial procedural differences can be revealed and problematized.

This is one of the many case studies documenting students’ experience building bifocal models. First, by connecting science content and construction of artifacts, I allow students to better transition between what is learned in the classroom and what they build with technology. Second, the construction of bifocal models, by making students connect computer models and physical sensors in real-time, introduced novel, deep issues that speak to the nature of science and the process of modeling, namely, friction/energy loss, precision, scale, time, coefficients, scale conversion, and synchronicity. Third, the motivation and engagement that is commonly observed in “hands-on” technology-rich building activities is mobilized towards creating content-driven connections with the learning of science and mathematics.

Tangible Programming in Formal and Informal Educational Environments

Michael S. Horn

Real-world learning environments are complex and often chaotic places. Teachers in classrooms must learn to balance the needs of anywhere from 15 to 30 students at a time with the demands of curriculum and the constraints of a regimented school day. In non-school environments such as science museums, the challenge is different. Program developers and exhibit designers must work without the structure and guidance provided by teachers and curriculum, devising activities and exhibits that engage a diverse audience and promote self-guided learning. For educators, the decision to incorporate computational learning activities in these setting can be fraught with risk (AAUW, 2000; Cuban, 2001). Teachers may feel a sense of loss of control and self-doubt about their own proficiency with technology (AAUW, 2000), and desktop computers, designed primarily as single-user productivity tools for businesses, can be less than ideal for many educational applications (Scott, Mandryk, & Inkpen, 2003). Likewise, in museums, although computer-based exhibits can be very engaging for individual visitors, they are often detrimental to the interactions of social groups as a whole (e.g. Hornecker & Stifter, 2006). For the past four years I have been exploring the potential of tangible interaction to address these issues. Here I briefly describe some of this work in both formal and informal educational settings. I conclude with a brief argument for a focus on creating *hybrid tangible interfaces* that combine tangible and graphical interaction into a single system, thus giving users the freedom to select an input modality to meet their current needs or preferences.

Figure 7. Tern allows children to program by connecting interlocking wooden blocks.

My research has involved a computer programming language called *Tern* (Figure 1), a tangible interface designed for children to control robotic creations. Rather than program with a mouse or keyboard, children use a collection of interlocking wooden blocks to create physical algorithmic structures. These blocks are compiled into digital code using low-cost computer vision techniques. With tradition programming languages, children are involved in the creation digital artifacts. One goal of the Tern project is to transform these digital artifacts into physical artifacts—highly visible products of student work and can become part of presentations and discussions in learning environments.

Tangible Programming in Science Museums

In 2008 I worked with colleagues at Tufts University to evaluate the use of Tern as part of a computer programming and robotics exhibit at the Boston Museum of Science (Horn, Solovey, Crouser, & Jacob, 2009). For this study, we created two interaction conditions: a graphical condition that presented museum visitors with a computer mouse and a display, and a tangible condition that presented museum visitors with a collection of wooden programming blocks. We then observed museum visitors as they interacted with the exhibit using one condition or the other on alternating weekend days (e.g. tangible on Saturday and graphical on Sunday). These observations revealed certain advantages for the tangible programming interface from the standpoint of informal science education. In particular, the tangible blocks were more inviting to visitors, and they were better at facilitating active collaboration. These findings were especially strong for children and for girls in particular. For example, roughly 33% of girls who noticed the mouse-based version of the exhibit stopped to try it. This number rose to 85% of girls in the tangible condition. For other measures there were no significant differences between conditions. This included amount of time spent interacting with the exhibit, the number of programs created, and the length and complexity of those programs.

Tangible Programming in Kindergarten

I have also been involved in research investigating the use of Tern in classrooms as part of the Tangible Kindergarten project at Tufts University. The goals of this project include (a) creating in-depth computer programming and robotics curriculum for use in kindergarten classrooms; (b) creating age-appropriate programming technology; and, (c) developing a richer understanding of young children's ability to engage powerful ideas from computer programming and robotics. As part of this project, we piloted an eight-hour curriculum with four classrooms of kindergarten children (ages 5–6) at a local elementary school. We divided these classrooms into two conditions, tangible and graphical. In the graphical classrooms, children used four desktop computers, while in the tangible classrooms, children created programs with wooden blocks.

Based on observation notes and an analysis of videotape, we found that children were able to easily manipulate the tangible blocks to form their own programs. For children in the graphical condition, however, we observed a range of capabilities in terms of being able to manipulate the computer mouse. We also found that the students were able to differentiate the blocks and discern their meanings in both the graphical and the tangible conditions. In terms of the curriculum, for certain activities and for certain children, the tangible version of Tern was clearly advantageous. For example, children could participate in whole-class discussion in a hands-on way with the tangible blocks. On the other hand, some of the most independent group work that we observed was with the graphical interface. Overall, the results of this study were mixed. Some children demonstrated surprisingly sophisticated understandings of computer programming and robotics concepts, while other children struggled throughout the curriculum unit. Since this study, the Tangible Kindergarten team has done much to improve both the curriculum and the programming technology; however, there is much to be done to refine our understanding of children's ability to participate in these types of activities in meaningful ways.

Argument for a Hybrid Approach

I conclude with a proposal that it is advantageous to combine tangible interaction with more traditional interfaces to create hybrid systems. This approach leads to several immediate advantages. The most important is that it gives actual participants in learning environments—teachers, students, museum staff, etc.—the flexibility to select the type of interaction most appropriate for a given learning situation. This flexibility is especially important in classroom settings, where teachers often determine if and when a particular technology will be used (Cuban, 2001). In addition, the use of hybrid interfaces means that not every feature of a software system need be implemented tangibly. For example, saving student work on a file system might be a feature better left to the graphical version of the interface. Beyond these immediate advantages is the potential to provide layered scaffolding as students progress toward increasingly authentic programming environments. For example, students might start with a tangible system and then transition to a graphical system with increased capabilities and complexity.

References

AAUW Educational Foundation. (2000). Tech Savvy: Educating Girls in the New Computer Age. American Association for University Women.

Blikstein, P., & Wilensky, U. (2006). *The Missing Link: A Case Study of Sensing-and-Modeling Toolkits for Constructionist Scientific Investigation.* Paper presented at the 6th IEEE International Conference on Advanced Learning Technologies (ICALT 2006), Kerkrade, The Netherlands.

Bruner, J. (2004) Towards a Theory of Instruction. Belknap Press.

Buechley, L., Eisenberg, M., Catchen, J., and Crockett, A., The LilyPad Arduino: Using Computational Textiles to Investigate Engagement, Aesthetics, and Diversity in Computer Science Education, In Proceedings of the SIGCHI conference (CHI 2008), Florence, Italy, April 2008, pp. 423-432.

Cole, M., and Cole, S. (2001) The Development of Children, Fourth Edition. New York, NY : Worth Publishers.

Cuban, L. (2001). Oversold and Underused: Computers in the Classroom. Cambridge, MA: Harvard Univ. Press.

Frei, Phil. (2000). curlybot: Designing a new class of computational toys. Master's thesis, Massachusetts Institute of Technology.

Horn, M. S., Solovey, E. T., Crouser, R. J., & Jacob, R. J.K. (2009). Comparing the use of tangible and graphical programming interfaces for informal science education. In Proc. ACM Conference on Human Factors in Computing Systems CHI'09, 975-984.

Hornecker, E., & Stifter, M. (2006). Learning from interactive museum installations about interaction design for public settings. In Proc. Australian Computer-Human Interaction Conference OZCHI'06.

Katterfeldt, E., Dittert, N., and Schelhowe, H. 2009. EduWear: smart textiles as ways of relating computing technology to everyday life. In Proceedings of the 8th international Conference on interaction Design and Children (IDC 2009), Como, Italy, June 2009, pp. 9-17.

Margolis, J. and Fisher, A. [2001] Unlocking the clubhouse. MIT Press, Cambridge, MA.

Martin, F., Resnick, M. (1993). Lego/Logo and electronic bricks: Creating a scienceland for children. In D. L. Ferguson (Ed.), *Advanced educational technologies for mathematics and science*. Berlin, Heidelberg: Springer-Verlag.

Ngai, G., Chan, S. C., Cheung, J. C., and Lau, W. W. 2009. The TeeBoard: an education-friendly construction platform for e-textiles and wearable computing. In Proceedings of the 27th international Conference on Human Factors in Computing Systems (CHI 2009). Boston, MA, USA, April 2009, pp. 249-258.

Papert, S. (1980). *Mindstorms : children, computers, and powerful ideas.* New York: Basic Books.

Papert, S. (1996). An Exploration in the Space of Mathematics Educations. *International Journal of Computers for Mathematical Learning, 1*(1), 138-142.

Piaget, J. (1976). The grasp of consciousness. Cambridge: Harvard University Press.

Raffle, Hayes (2008). Sculpting Behavior: A Taigible Language for Hands on Play and Learning. PhD Thesis, Massachusetts Institute of Technology.

Resnick, M., Martin, F., Berg, R., Borovoy, R., Colella, V., Kramer, K., et al. (1998). *Digital manipulatives: new toys to think with.* Paper presented at the Proceedings of the SIGCHI conference on Human factors in computing systems.

Resnick, M., Ocko, S., Papert, S. (1991). Lego/Logo: Learning through and about design. In I. Harel, Papert, S. (Ed.), *Constructionism*. Norwood, NJ: Ablex.

Scott, S., Mandryk, K., & Inkpen, K. (2003). Understanding children's collaborative interactions in shared environments. Journal of Computer Assisted Learning, 19, 220–228.

Sipitakiat, A., Blikstein, P., & Cavallo, D. P. (2004). *GoGo Board: Augmenting Programmable Bricks for Economically Challenged Audiences.* Paper presented at the International Conference of the Learning Sciences, Los Angeles, USA.

Wilensky, U. (1999). NetLogo. Evanston, IL: Center for Connected Learning and Computer-Based Modeling. http://ccl.northwestern.edu/netlogo.

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Leah Buechley: Mike Eisenberg, Nwanua Elumeze, Ann Eisenberg, and colleagues at the University of Colorado, Mark Gross, and colleagues at the MIT Media Lab.

Are We Managing Learning with Learning Management Systems?

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Abstract: Although Learning Management Systems (LMS) are ubiquitous in higher education, little is known about how faculty and students use them for blended learning. In this symposium, we present data from online surveys, system log data, and case studies to investigate the practice of university teaching with LMS to provide feedback about how to successfully implement these systems. We examine instructors' and students' attitudes about LMS and their use of these systems at different levels of analysis, looking across many institutions and increasingly narrowing the focus to several specific teaching vignettes. We organize our investigations of how instructors and students value the LMS by examining three types of use: Learner-Content interactions, Learner-Instructor interactions, and Learner-Learner interactions. We identify common themes and differences revealed by our analyses to make recommendations that are intended to improve teaching and learning with these systems.

Symposium Overview

Recent surveys have shown that Learning Management Systems (LMS) have become ubiquitous in higher education (Hawkins & Rudy, 2008; Smith, Salaway, & Caruso, 2009) and their use in K-12 education is growing rapidly (Picciano & Seaman, 2009). Although these systems have become basic infrastructure for learning in higher education, we know very little about using LMS to enhance teaching and learning. Few studies have looked specifically at hybrid or blended learning environments (e.g., augmenting traditional face-to-face instruction with online learning applications). Of these studies, most have been conducted by "professors and other instructors who are conducting research (on) their own courses" (Means, Toyama, Murphy, Bakai & Jones, 2009, p. 49). With so many instructors using these systems on so many campuses, we believe it is possible to generalize "lessons learned" about LMS use at a level of granularity beyond reports from individual classrooms. These lessons can help improve the practice of university teaching with LMS, as well as provide important feedback for considerations of how to successfully implement these systems with younger students.

In this symposium, we present four papers that carefully examine instructors' and students' attitudes about LMS and their reported use of these systems, beginning with a wide-angle lens looking across many institutions and increasingly narrowing the focus to several specific teaching vignettes. *Paper 1* uses a survey conducted at 11 American universities looking to examine how LMS use differs between research and non-research institutions. *Paper 2* takes a similar approach, but contrasts LMS uses between one residential campus and one commuter campus within one institution. *Paper 3* investigates qualitative survey data to analyze how the use of a LMS impacts instructors' use of in-class time. Finally, *Paper 4* describes three case studies of exemplary LMS use within the disciplines of nursing, engineering, and music. By focusing our analysis at different scales, we can better understand the ways in which LMS are being used in numerous higher education institutions, the factors that may be driving these uses (e.g., research vs. teaching emphasis, residential vs. commuter students), the ways instructors and students are choosing to use them, and the effects these systems may have on students' classroom experiences.

A typical LMS provides a number of specific tools supporting diverse functionality ranging from "materials management" to organize interactions between the student and the course content (e.g., syllabus, course readings, lecture slides), "interactive teaching" to organize interactions between the instructor and students (notifications, assignments, quizzes), and "peer learning" (peer review, group projects, student wikis) (Lonn & Teasley, 2009). With the diversity of tools available within these systems, investigations of the effects of LMS on teaching and learning must clearly specify functionalities and the particular instructional uses of those functionalities. The legacy of research on learning technology has clearly demonstrated that how a tool is used is more critical than the tool itself (Salomon, Perkins, & Globerson, 1991). Therefore, in this symposium, we organize our investigations of how instructors and students value and use LMS functionalities by examining three types of instructional uses for those functionalities: Learner-Content interactions (LC), Learner-Instructor interactions (LI), and Learner-Learner interactions (LL) (see also Moore, 1989, Bernard et al., 2009).

Paper 1: A Multi-Institutional Analysis of Interactions Supported by a LMS

Andrew E. Krumm and Steven Lonn

Introduction

Researchers of distance education conditions demonstrate that different interaction types can support different learning outcomes (e.g., Bernard et al., 2009). In this paper, we explore how instructors and students value specific uses for a LMS grouped under specific interaction types: Learner-Instructor (LI), Learner-Content (LC), and Learner-Learner (LL) interactions. For this study, we recruited 11 American universities using the same LMS, asking instructors (N=2,570) and students (N=6,980) to indicate their perceptions of LMS functionalities in an online survey. Using this large and diverse sample, we addressed four research questions: (1) Do instructors and students value interaction types differently? Do respondents value interaction types differently based on (2) their university setting, (3) the number of courses they have used a LMS, and (4) their preference for using IT in courses?

Method

To construct LC, LI, and LL interaction types, we coded participants' responses on items asking them to rate how much they value particular uses of a LMS. Using a 5-pont Likert scale, respondents rated how much they valued, for example, "Posting a lecture outline or notes before the lecture." We coded each item using Moore's (1989) and Bernard et al.'s (2009) descriptions of interaction types. After coding each item, we employed principal component analysis to extract single components for items coded under the same interaction type: LC (4 items, eigenvalue = 2.613, alpha = .817), LI (7 items, eigenvalue = 4.05, alpha = .878), and LL (4 items, eigenvalue = 3.117, alpha = .904).

Each extracted component, i.e., interaction type, served as dependent variables in three separate two-level hierarchical linear models (HLM). Survey respondents were modeled at level-1 and university effects at level-2. Within each model we included four independent variables in line with our four research questions: a research/non-research university dummy variable, an instructor/student dummy variable, a number of courses for which one has used a LMS variable, and a how much one uses/prefers IT in courses variable. We also included five control variables: perceived expertise with computers, frequency of LMS visits, general perceived value of a LMS for course activities, and perceptions of value for IT to improve teaching and learning. All non-dummy variables were grand mean centered to improve the interpretability of each model's intercept. The research/non-research dummy variable was modeled as a level-2 predictor while all other variables were modeled as level-1 predictors.

Results

In line with our four research questions, we identified differences between instructors and students for LC and LI interaction types (RQ #1), between participants in research and non-research universities for the LL interaction type (RQ #2), and among the number of courses for which one has used a LMS for LC and LL interaction types (RQ #3). Use of IT was a significant predictor across all models (RQ #4).

Students, on average, valued LC ($B = .09$, $p < .05$) and LI ($B = .208$, $p < .001$) interactions more than instructors. Number of courses for which one has used a LMS had a positive statistically significant effect for LC interactions ($B = .031$, $p < .05$) and a negative effect for LL interactions ($B = -.057$, $p < .01$). Participants in a non-research university were found to value LL interactions more than those in a research university, controlling for all other factors ($B = .39$, $p < .05$). No other research/non-research university differences were identified.

The performances of control variables were largely consistent across all models. Expertise with computers had a small but negative effect for only the LI model ($B = -.068$, $p < .05$). How often one visits a LMS was a positive predictor across all models (LC, $B = .126$, $p < .001$; LI, $B = .151$, $p < .001$; LL, $B = .105$, $p < .001$). The perceived value of a LMS for improving course activities was a strong, positive predictor across all models (LC, $B = .274$, $p < .001$; LI, $B = .269$, $p < .001$; LL, $B = .167$, $p < .001$) as was the perceived value of IT to improve teaching (LC, $B = .108$, $p < .001$; LI, $B = .143$, $p < .001$; LL, $B = .157$, $p < .001$) and learning (LC, $B = .214$, $p < .001$; LI, $B = .185$, $p < .001$; LL, $B = .134$, $p < .001$).

Discussion

In answering RQ #1, we observed that students value LC and LI interactions more highly than instructors, controlling for all other factors. Students, on average, value LC interactions only slightly more than instructors and value LI interactions to a much higher degree than instructors. These observations signal that students may value access to content but value access to their instructors more. Individuals, whether instructor or student, within non-research universities valued LL interactions .39 standard deviations more than individuals within research universities (RQ #2). Whether a respondent was located within a non-research university was the largest single determiner for how much one values LL interactions. The specific LMS uses that make up this interaction type provide few clues as to why there exist such distinct differences (e.g., Students work together on task/assignment; Students read/comment on each others' work; Students generate/share instructional materials; Students part of ad-hoc student groups or teams). These practices, in general, do not appear to favor one institutional type over another at the grain of size of research/non-research universities.

The effect of one's experience with a LMS is also interesting with respect to differences across interaction types (RQ #3). Controlling for all other factors, a one unit change in the number of courses for which one has used a LMS, which equates to approximately 3 courses, is associated with a .031 standard deviation increase in how much one values LC interactions and a .057 decrease in how much one values LL interactions. Why more experience using a LMS leads to an increase in one interaction type and a decrease in another may have to do with how much one values IT that is different from a LMS. As the number of courses for which one has used a LMS increases, he or she may value other IT for LL interactions. This conclusion is tangentially supported by the strength of the IT related questions within the LL models, and the strength of one' use/preference of IT in particular (RQ #4). Within the LL model, one's use of IT was a much stronger predictor than the same variable within the other two models, respectively. In general, examining how much instructors and students value uses for a LMS across 11 universities has provided an important wide-angle lens on issues to be explored within campuses, classrooms, and instructors.

Table 1: Statistically Significant Parameter Estimates for each Interaction Type

	LC Interaction Type		**LI Interaction Type**		**LL Interaction Type**	
	B	**Std. Error**	**B**	**Std. Error**	**B**	**Std. Error**
Level-1						
Intercept	-.162*	.065	-.37**	.113	-.308*	.102
Student[1]	.09*	.037	.208***	.05		
Num. courses use LMS	.031*	.015			-.057**	.02
Use/Preference of IT	.059**	.02	.13***	.023	.163***	.024
How often visit LMS	.126***	.013	.151***	.015	.105***	.017
Expertise with comp.			-.068*	.028		
Value LMS	.274***	.016	.269***	.02	.167***	.021
IT valuable teaching	.108***	.02	.143***	.025	.157***	.028
IT valuable learning	.214***	.023	.185***	.028	.134***	.031
Level-2						
Non-Research Univers.[2]					.39*	.147

*p < .05, **p < .01, ***p < .001; Reference category = (1) Instructor, (2) Research University

Paper 2: Commuter vs. Residential: LMS Perceptions & Use on Two Campuses

Steven Lonn and Andrew E. Krumm

Introduction

In this study, we used the same survey described in Paper 1 to specifically explore differences in respondents' attitudes about LMS use and actual experience with a LMS between instructors and students at two campuses of a Midwestern university: a large residential campus and a smaller commuter campus. We also analyzed aggregated log data from the LMS to see if students' system use was consistent with their beliefs. Although there have been some multi-campus studies of LMS (e.g., Harrington et al., 2004), none have focused on the possible differences between residential and commuter institutions. Online technologies have been found to significantly affect the nature of interactions between commuter students and with their instructors (Krause, 2007). The specific research questions we address in this paper are: (1) Do instructors and students at the two campuses differ in their perceptions of different types of interactions supported by LMS? (2) When other factors, such as number of courses using the LMS, are taken into account, do differences between campuses still exist? (3) How does actual LMS use compare to survey attitudes and perceptions?

Method

The sample for the online survey included instructors (residential n=612, 16% response rate (r.r.); commuter n=64, 19% r.r.) and undergraduate students (residential n=1182, 22% r.r.; commuter n=805, 19% r.r.) who taught or were enrolled in at least one course with a LMS site. We then used the system's event logs to create an aggregated data set representing the activity in the sites in which the student respondents were enrolled (residential n=1,565; commuter n=287).

As in Paper 1, the survey data was categorized as LC, LI, or LL interactions. We analyzed the results using three HLM models. We identified five factors of interest: (1) differences between campuses and (2) between instructors and students, (3) number of courses for which the LMS has been used (4) how often the respondent visits LMS course sites and (5) how much one uses/prefers IT for course activities. We included four control variables: perceived expertise with computers, perceived value of a LMS for course activities, and perceived value of IT to improve teaching and learning.

Results

The first phase of our analysis investigated individual survey items, grouped by interaction type. In general, instructors rated nearly all survey items at a 4.0 or above on a 5-point Likert scale, meaning that they "agreed" or "strongly agreed" that all of these activities within LMS were valuable. When first investigating differences between residential and commuter campus respondents, there were no significant differences between instructors for Learner-Content, Learner-Instructor, or Learner-Learner interactions. Student respondents, however, significantly differed on several survey items. The students' ratings of the survey items were also generally high at a 4.0 or above for most LC and LI items, but somewhat lower for LL items (means between 3.37-3.83). Compared to the commuter students, the residential students rated all four of the LC items higher, five of the seven LI items lower, and all four of the LL items lower. Many of these differences were significant (see Table 1).

Table 1: Significant Differences Between Campuses in Students' Ratings of LMS Activities

Learner-Content Items	Residential	Commuter	Mean Difference
Access online readings / supp. materials	4.57 (n=951)	4.39 (n=641)	.18***
Access lecture outline before lecture	4.34 (n=920)	4.21 (n=568)	.13**
Access lecture outline after lecture	4.48 (n=947)	4.32 (n=598)	.16***
Learner-Instructor Items			
Students ask questions before lecture	3.63 (n=669)	3.93 (n=493)	.30***
Students ask questions after lecture	3.83 (n=742)	4.03 (n=527)	.20***
Take online exams and quizzes	3.35 (n=666)	3.71 (n=477)	.36***
Learner-Learner Items			
Students work together on task / assignment	3.51 (n=712)	3.70 (n=492)	.19**
Students read / comment on each others' work	3.37 (n=610)	3.81 (n=489)	.44***
Students generate / share instructional materials	3.55 (n=665)	3.83 (n=501)	.28***
Students part of ad-hoc student groups or teams	3.22 (n=511)	3.54 (n=384)	.32***

**p<.01, ***p<.001

We also ran 3 HLMs in order to identify factors that might affect how much a survey respondent values a particular interaction type. On average, respondents from the commuter campus valued LI ($B = .428$, $p < .001$) and LL ($B = .363$, $p. < .01$) interactions more than their residential counterparts, controlling for all other factors. Also, students more favorably rated LI interactions more than instructors.

Finally, we calculated the average percentage of total events for each LMS tool by aggregating the events for the LMS course sites. The respondents on the residential campus used three of the four LC-oriented tools more than their commuter campus counterparts while the commuter campus users used four of the eight LI-oriented tools, and all five of the LL-oriented tools more, by percentage, than the residential campus users. The specific differences that were significant are shown in Table 2.

Table 2: Significant Differences Between Campuses in Percentage of Use of LMS Tools

Category	Tool	Residential Campus (n=1565 sites)	Commuter Campus (n=287 sites)	Mean Difference
Learner-Content	Content Sharing	57.74%	52.43%	5.31*
	Drop Box	4.83%	2.55%	2.28***
Learner-Instructor	Email Archive	0.52%	0.08%	0.44***
Learner-Learner	Chat	0.75%	1.65%	0.90*
	Discussion	1.26%	2.97%	1.71**
	Forums	0.56%	2.92%	2.36**
	Messages	2.93%	6.18%	3.25***

*p<.05, **p<.01, ***p<.001

Discussion

When we examined the reasons underlying the overall positive ratings of the LMS activities, a distinctive pattern emerged: residential students rated Learner-Content survey items more highly than commuter students and commuter students rated Learner-Learner items more highly than residential students. Ratings for the Learner-Instructor activities were mixed. The log data supported these findings showing higher activity in the most heavily used LC-oriented tools for the residential campus and higher activity in the LL-oriented tools for the commuter campus. Taking other factors (e.g., frequency of LMS use) into account, the differences between the residential and commuter campus remain significant for LI and LL interaction, but not for LC-related uses.

Commuter students may have relied on LMS interactive tools to communicate with instructors and students with whom they do not otherwise have opportunities to do so face-to-face (Pascarella, 2006). Furthermore, commuter campus instructors may structure their courses to include more student interaction through the LMS as a consequence of diminished face-to-face time that is likely to be more easily accomplished at the residential campus. Further study is needed to better understand exactly how residential and commuter instructors structure the use of the LMS for course-related activities in order to help instructors and students at both types of campuses use this technology to its fullest potential.

Paper 3: How Does LMS Use Affect Instructional Time?

Tanya Cleveland Solomon and Kara Makara

Introduction

In recent years, the ubiquitous use of online learning environments in American higher education has increased the need to understand their effectiveness as pedagogical tools (e.g., Apedoe, 2005). This pervasive use also necessitates understanding their influence on the *quality* of students' experiences and interactions in online and blended learning environments (e.g., Bernard et al., 2009). Chickering and Gamson (1987) posit seven principles for good teaching practice in undergraduate education that have been used extensively to evaluate and improve face-to-face pedagogy in higher education. In this paper, we employed four principles most relevant to understanding the nature of interactions between students and instructors in the context of blended learning. The first principle relates to instructors' and students' perceptions of the form and quality of LI interactions. The second principle relates to interactions and cooperation among students. The third principle relates to the expectations that are communicated in courses using LMS as perceived by both instructors and students. The fourth principle relates to ways that use of LMS tools structure and influence instructors' and students' time inside and outside of class.

This paper utilizes data from the online survey discussed in Paper 2 to investigate how the "blended" use of a learning management system (LMS) affects instructors' use of in-class time, comparing instructors and students at the residential and commuter campuses. We explore the issues survey respondents raise regarding how LMS influences Learner-Instructor (LI), Learner-Learner (LL), and Learner-Content (LC) interactions. The specific research questions that we address in this paper are: (1) In what ways does the use of LMS affect the way instructors use in-class time in the higher education classroom? (2) How does the use of LMS in these classrooms influence the Learner-Instructor and Learner-Content interactions? and (3) What are the effects of LMS on Learner-Learner interaction during class time?

Methods

We analyzed an open-ended survey item about the instructors' use of in-class time from the survey described in Paper 2. This item asks: "Do you think using the LMS has affected you/your instructors' use of in-class time? If so, how?" From the residential campus, 57.0% of students (n=1,101) and 55.3% of instructors (n=602) responded about the effects of LMS use on in-class time. From the commuter campus, we received a 63.6% student response rate (n=682) and a 72.4% instructor response rate (n=55).

To categorize the survey answers, we made note of common themes and issues encountered, and used these to collapse redundant categories. We arrived at a rubric with 12 codes for both the instructor and student responses, and used up to three codes to describe each response (see Table 1). The rubric accounted for both positive and negative responses concerning the affect of using LMS on instructors' in-class time. Inter-rater reliability produced kappa statistics between 0.8 and 0.93.

Results

The majority of responses by students and instructors indicated that the LMS positively influenced instructors' use of in-class time (see Table 1), where the most common responses were about facilitating logistics and providing access to materials (Learner-Content interactions). More residential students (21.7%) than commuter students (15.2%) mentioned improved efficiency and logistics. The differences between instructors were not as pronounced (19.4% residential; 21.8% commuter). Almost twice as many commuter instructors replied that the

LMS affected in-class time by providing access to materials compared to the other three populations. However, a significant portion of the sample indicated no change in their in-class time due to the LMS, slightly higher for the residential campus respondents than the commuter campus respondents.

Few respondents provided answers that suggested the LMS affected pedagogy or improved Learner-Learner or Learner-Instructor interaction. However, we did find that students at both campuses (7.3% residential; 11.6% commuter) perceived that instructors change the content or pace of instruction in classrooms due to the LMS. Few instructors responded that there was a change in content or pace (3.5% residential; 1.8% commuter). These data suggest that instructors and students at both campuses have different perceptions of how LMS use affects in-class time. Last, many instructors' negative responses reflected their criticism of students and technology while others mentioned a desire to improve the incorporation of LMS in their teaching. Students' negative responses also spoke to instructors' use of LMS and included somewhat sophisticated views of how technology could be better integrated into instructors' pedagogy.

Table 1: Frequency of Most Common Student & Instructor Responses to "In-Class" Qualitative Survey Item

Code	Residential Campus		Commuter Campus	
	Students	Instructors	Students	Instructors
Facilitates logistics	**21.7%**	**19.4%**	15.2%	21.8%
Provides access to materials	18.1%	16.8%	**15.8%**	**29.1%**
General positive response	8.5%	7.1%	12.2%	10.9%
Changes the content/pace of instruction	7.3%	3.5%	11.6%	1.8%
Facilitates discussion in class or online	2.1%	3.3%	3.1%	5.5%
Preparation for class – students	1.0%	1.7%	2.5%	1.8%
Limited / non-user	1.1%	1.3%	3.1%	0.0%
Does not change	34.0%	39.7%	27.1%	25.5%
Changes negatively	2.7%	1.8%	4.1%	1.8%

Discussion

Overall, the majority of respondents indicated that LMS had a positive effect on instructors' use of in-class time. Instructors and students generally gave similar reports about the nature of this change, although their perceptions differed regarding the degree to which LMS use facilitated logistics, provided access to materials, and changed the pace of instruction. There were far fewer negative responses but these were eye-opening. Some residential instructors suggested that the LMS was beneficial only for out-of-class time, but they also talked about their own lack of familiarity and how students were using LMS instead of coming to class. A few residential students and commuter students, to a lesser degree, complained that instructors were completing lessons too quickly or not covering material in sufficient depth in class because they posted materials online.

From these data we can conclude that changes in the use of class time are mostly due to the increases in Learner-Content (LC) interactions supported by the LMS. Log data from the LMS confirm that LC interaction is the primary use of LMS at the residential and commuter campuses (see Paper 2). We found few responses about changes in Learner-Instructor (LI) and Learner-Learner interactions as a result of LMS use. Also, there were higher percentages from commuter students than residential students mentioning LI and LL discussions. Perhaps the capacity of the LMS to support LL and LI interaction is not needed as deeply at a residential campus, where students and instructors may have more opportunities to interact face-to-face.

We also see evidence that LMS can support the four principles of best practices for higher education that we examined (Chickering & Gamson, 1987). First, the efficient availability of course material and announcements support LC interactions. Second, discussion boards within LMS support LL interaction. Third, course expectations are communicated through various resources, such as a syllabus, assignment instructions, grades, and other materials, although students disagree on the extent to which this occurs. Finally, we found that the LMS is particularly useful for structuring instructors' and students' time inside and outside of class through improved logistics and organization of course materials. Responses across campuses revealed an implicit assumption that students learn material independently outside of class when LMS is used, and the reaction to this assumption was mixed: Instructors thought this was a good thing and students did not. Therefore, we recommend that future studies explore students' ability for self-regulated learning. We also recommend further exploration for how LMS can better support LI and LL interaction more broadly across campus types.

Paper 4: The Gifts We Give Ourselves: Embedding Disciplinary Tools in LMS

Diana Perpich

Introduction
It would be pleasant to think of Learning Management Systems (LMS) as the perfect gift we gave ourselves to celebrate the coming of age of higher education in the 21st century. A *System* to manage *Learning,* packaging up the whole messy business of teaching and learning into a collection of neat, authenticated boxes wrapped in the school colors and tied with a bow. That's what we ordered, and that's what typical LMS have delivered onto our virtual doorstep, a stack of well-bundled packages. As we open up the boxes we are somewhat surprised, albeit pleasantly, to find simple gifts: the typical LMS includes functionality to manage materials, view and assess student work, and support communication. However, following the gift metaphor, faculty are left asking themselves, "Socks? Just socks?" Wanting more are the educators dedicated to exploring the seemingly infinite possibilities poised by new technologies. "These users are more interested in support for their need to experiment with new ideas in their teaching and learning environments and then evolve/improve those ideas as they go along" (Severance, Hardin, & Whyte, 2008). Educators, and the organizations that support them, can go shopping for themselves to seek out innovative, discipline-specific tools wherever they may be found.

In this paper, I present vignettes of three instructors at a large Midwestern university teaching in the Fall 2009 term who returned these gifts to themselves in concert with the local LMS. These instructors successfully leverage the basic functionality of the system to frame and to extend their coveted discipline-specific elements and to engage students in new ways with the course material, with the instructor, and with each other.

Vignette 1
The Community Health Nursing course provides an example of an instructor leveraging the local LMS to enhance students' interactions with course materials (LC). This theory and clinical course requires students to "think critically about the role and core competencies of community health nursing … within diverse population and ecological contexts" (quote from the online course description). In planning this course, the instructor sought out materials that not only presented data and policy about community health, but also presented the stories of those being served. Specifically, she integrated materials from "The Neighborhood," an innovative, virtual case-based learning strategy centered on interactions between the household and community agency characters developed by a professor at another university. The interrelated stories unfold in weekly installments and include photos, biographical information, medical records, and video clips.

Even though "The Neighborhood" represents innovative, well-conceived, discipline-specific content, it's not the whole course package. When the instructor presents the discipline-specific content of "The Neighborhood" within the structure of the university's LMS, she adds context by linking more traditional articles and local community stories, often drawing from the daily headlines. She also facilitates workflow by posting notifications and reminders within the LMS and she uses the LMS assessment tools to deliver rapid feedback on graded activities. She is not using the novel, discipline-specific course material in place of the standard LMS; she is using outside online materials in combination with the LMS.

Vignette 2
Jazz Arranging is a composition class where the instructor utilizes the LMS as a platform for students to share their original work with each other, as well as submit it for credit. Historically, students would compose and turn in their scores to the instructor for critique. Students could share their work with each other, but the arrangements needed to be heard to be properly evaluated. This practice posed significant challenges as students had to perform their compositions for each other in class or record them outside of class for sharing later.

The instructor experimented with and eventually adopted Sibelius, a leading musical notation software package. In Sibelius, compositions can be archived digitally and the files play themselves so the focus is squarely on the composition and not the performer. This instructor's integration of Sibelius with the LMS benefits not only himself, but also his students. Now students are required to arrange their scores in Sibelius, and the class meets in a computer lab where students can see and hear each other's arrangements by accessing them via the LMS. The instructor uses the Assignments tool to collect and grade privately (LI), and then he shares and discusses each student's work with the class. Facilitated by the LMS, each student-arranger has the entire class as audience (LL). The instructor also uses several other LMS tools to manage class logistics, freeing up class time to listen to students' music and to engage in discussion.

Vignette 3
In Principles of Engineering Materials, the instructor leverages the local LMS to enhance students' Learner-Instructor interactions (LI). This is an introductory Engineering course with both a weekly lecture presented by the faculty-instructor and a weekly discussion session led by a teaching assistant. Typically with this arrangement, student-instructor interaction is limited to well-timed nods and courtesy smiles passed back and

forth during the lecture. In this class, however, the instructor sought a way to engage students by directly exposing and sharing his approach to weekly problem-solving assignments.

In preparation for Fall 2009, the instructor purchased a LiveScribe system. He now records himself solving key homework problems by hand every week. He clicks Record on his smartpen and then he starts working through the solutions, talking through each step. Students access the resulting "pencasts" via the standard LMS. Because students hear his voice and watch his pen draw the diagrams and formulas; because they hear and see his scribbles and missteps; because they can start, stop, jump, and replay his recordings; *because these are personal recordings,* the students have more interaction with the instructor, albeit one-way interaction. The expectation is that this process provides not only a model of problem-solving but also a sense of familiarity with the instructor that pays forward to provide opportunities for richer engagement with the instructor during lectures and office hours.

What does the LMS offer this arrangement beyond a place to access the recordings? For one, the instructor encourages students to bring laptops to lecture (supplying them when appropriate) and encourages student use of the Chat tool during the lecture. The instructor can also use the Chat transcripts to assess student comprehension and follow up with a specific student when appropriate. The LMS is flexible enough for him to personalize the look, feel, and organization of his syllabus and schedule, drawing students into the LMS even though he has the technical skills and resources to work outside it. In this regard, he meets students on familiar ground, in the LMS, while in the same space offering them uncommon access to their professor and a window into his problem solving processes.

Discussion

These instructors accept the basic tools that the LMS offers and employ them as the functional foundation for students' interactions with the course materials, with each other, and with the instructor. It is worth noting that the innovative and independent elements portrayed in each vignette all engage students with multimedia artifacts via learner-driven navigation. The LMS supports these multimodal and personalized engagements by enveloping them, not only structurally but also programmatically into the domain content. The LMS can be the constant in the evolution of new learning models within and across specialized disciplines. To return to the metaphor of gifts, innovative instructors in higher education know what they need: bring on the socks but don't forget to tuck a gift certificate in with them. Some things, you just have to pick out for yourself.

References

Apedoe, X. (2005). The interplay between teaching conceptions and course management system design. In P. McGee, C. Carmean & A. Jafari (Eds.), *Course management systems for learning: Beyond accidental pedagogy* (p. 57-68). Hershey, PA: Idea Group Inc.

Bernard, R. M., Abrami, P. C., Borokhovski, E., Wade, C. A., Tamin, R. M., Siurkes, M. A., et al. (2009). A meta-analysis of three types of interaction treatments in distance education. *Review of Educational Research*, *79*(3), 1243-1289.

Chickering, A.W., & Gamson, Z.F. (1987, March). Seven principles for good practice in undergraduate education. *AAHE Bulletin*, *40*, 3-7.

Harrington, C. F., Gordon, S. A., & Schibik, T. J. (2004). Course management system utilization and implications for practice: A national survey of department chairpersons. *Online Journal of Distance Learning Administration, 7*(4) http://www.westga.edu/~distance/ojdla/winter74/harrington74.htm

Krause, K-L.D. (2007). Social involvement and commuter students: The first-year student voice. *Journal of the First-Year Experience & Students in Transition*, *19*(1), 27-45.

Lonn, S. & Teasley, S. D. (2009). Saving Time or Innovating Practice: Investigating Perceptions and Uses of Learning Management Systems. *Computers & Education*, *53*(3), 686-694.

Means, B., Toyama, Y, Murphy, R., Bakia, M., & Jones, K. (2009). *Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies*. Report for the US Department of Education.http://www.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf

Moore, M. G. (1989). Three types of interaction. *American Journal of Distance Education*, *3*(2), 1-6.

Pascarella, E. (2006). How college affects students: Ten directions for future research. *Journal of College Student Development*, *47*(5), 508-520.

Picciano, A. G., & Seaman, J. (2007). *K-12 online learning: A survey of U.S. school district administrators*. Boston, MA: Sloan Consortium. Available: http://www.sloan-c.org/publications/survey/K-12_06.asp

Salomon, G., Perkins, D. N. & Globerson, T. (1991). Partners is cognition: Extending human intelligence with intelligent technologies. *Educational Researcher, 20*(3), 2-9.

Severance, C, Hardin, J., & Whyte, A. (2008). The coming functionality mash-up in Personal Learning Environments. *Interactive Learning Environments, 16*(1), 9–14.

Smith, S. D., Salaway, G., & Caruso, J. B. (2009). *The ECAR Study of Undergraduate Students and Information Technology, 2009*. Boulder, CO: EDUCAUSE.

Understanding Families' Educational Decision-Making Along Extended Learning Pathways

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Abstract: This paper explores the socio-cultural-historical influences on educational decisions made by a sample of families from an urban community in the northwestern United States. We report on three analyses of the everyday cultural and social contexts in which parents' and their children's ideas about formal and informal education are developed and applied through educational choices. The research employs a family-centered analytical focus and a cognitive ethnography of learning to examine educational decisions and knowledge about learning opportunities that families use in their homes, at school, and in their communities. Our analyses foreground the role of choice and values in families' everyday lives, their lived histories, and their educational decisions. Implications for better coordinating in-and-out of school learning experiences in light of extended learning pathways are discussed.

This paper explores the socio-cultural-historical factors that influence families' consequential decisions related to learning and educational opportunities. We report on three analyses of the everyday cultural and social contexts in which parents' and their children's ideas about formal and informal education are developed and applied, both in the United States and in other countries. The research employs a family-centered focus and a cognitive ethnographic approach to educational decisions and knowledge of opportunities that families use in their homes, schools, and communities. Research focuses on how families learn to navigate school and select and/or create out-of-school activities, with implications for theories that examine the coordination (or not) of home and school learning experiences.

After an overview of the cognitive ethnography from which these three case studies stem and an overview of our conceptual framework, the *first case analysis* examines the influence of Vietnamese immigrant parents' social and educational histories on the ways in which they view and construct academic identities for their children. The *second analysis* examines the parent-child interactions between three mothers and daughters around science and math learning experiences. The *third analysis* examines how two families negotiate decisions about in and out-of-school learning experiences as influenced by education ideologies formulated in Africa, Vietnam, and the United States.

Learning Ethnography of Educational Choices: Methodological Approach

These analyses share a learner-centered focus and a cognitive ethnographic approach, deeply exploring how families' personal histories interact with the educational choices they make relative to a myriad of available learning opportunities, including school, afterschool, and summer time activities. The data utilized in these analyses were collected as part of a three-year team ethnography. Researchers followed the same youth across the settings of their lives to study how these youth learn about science and technology specifically, as well as how they develop expertise in personally consequential domains (Bell, et al., 2006; Bricker and Bell, 2008). The majority of the observations of the focal participants have taken place in school and at home. However, focal participants have also been observed in a multitude of additional settings, such as religious institutions, after school clubs, museums, sporting events, camping excursions/vacations, neighborhoods, and parks.

Across all settings, data collection methods included: (a) observation and participant observation; (b) interviews (both ethnographic and clinical); (c) self-documentation techniques, in which focal participants were given digital cameras and asked to document various objects and phenomena (e.g., use of technology) and then interviewed about their photographs; and (d) document collection. Two surveys, designed to gather information about socioeconomic status, ethnic identity, and participation in science were administered. Researchers also conducted analyses of public census tract data for the neighborhoods in which families lived. Data sources include: (a) *field notes* of all observations, interviews, participant self-documentation, and documents collected; (b) *video- and audio-recordings* of all observations and interviews (when in settings that allow video and/or audio taping); (c) *digital photographs* taken during observations and interviews; (d) *video and/or digital photographs* taken by participants as part of their self documentation assignments; (e) *documents* collected during family visits (e.g., magazines, school work, writing samples from clinical interviews); and (f) *survey results*.

Study Design and Participants

In the spring of 2005, researchers formed a partnership with an elementary school in a large metropolitan area of the Pacific Northwest (pseudonym Granite Elementary). Granite caters to a diverse student body with respect to ethnicity, nationality, languages spoken, and socioeconomic status. Approximately 65% of the students are of Asian or Pacific Islander descent, 16% are of Hispanic descent, 12% are African American, and 5% are Caucasian. Many of the children are from first-generation immigrant families. During the 2004-2005 school year, 60% of the students qualified for free or reduced price lunch.

In the fall of 2005, researchers began recruiting families into the ethnographic study. Thirteen families agreed to participate, and the sample of focal participants from each of those families was balanced for age (six children in fourth grade and seven in fifth grade at the beginning of the study) and gender (seven boys and six girls). Study participants were chosen to reflect the school's diversity in racial/ethnic make-up and socioeconomic status. Currently, 128 people are consented into the ethnography, including the focal participants and their immediate family members, extended family members (e.g., grandmothers, cousins), teachers, and peers. In these papers, we focus on five of the thirteen focal families.

The Development of Everyday Expertise: How Significant Learning is Accomplished Socially and Culturally in Everyday Life

In this paper, we consider the influence of social, cultural, and historical factors on families' educational perspectives and decisions. One way in which scholars have investigated individual and social perspectives is through the lens of ideology. Ideologies mediate people's understanding and learning processes in profoundly important yet unconscious ways (Althusser, 1971; Bakhtin, 1983) through complex social processes (Thompson, 1984). The social dynamics around educational ideologies are particularly complex given that significant learning is constituted across settings, groups, and pursuits over extended timescales. Learners routinely navigate a range of diverse social, material, and discursive contexts every day—from the classroom to home, afterschool programs, informal education institutions, and out into their communities—with a variety of purposes and value systems in place (Banks et al., 2007). Learning is accomplished across these diverse pathways of participation in activity and affiliation with cultural groups in ways we do not fully account for in the literature. Consequently, the field needs empirically-informed theoretical models that fully reflect the complexity of everyday life and everyday learning. These models can be used to understand how and why learning is accomplished—or impeded—across sociocultural contexts throughout diverse social niches and networks in relation to enacted ideologies. Even as U.S. communities become increasingly diverse in terms of ethnic and racial group membership, immigrant histories, and linguistic variation, few teachers or university professors are equipped to work effectively with all students in their classrooms. Cultural and ecological perspectives are increasingly understood to be central in the scientific understanding of learning and development, and they have strong implications for educational practice (Lee, 2008; Banks et al., 2007; Bell, Lewenstein, Shouse & Feder, 2009).

Together our analyses answer two driving questions: *How do socio-cultural-historical factors influence families' consequential decisions related to learning and education*? *What role do individual family members have in the choices made?* Educational ideologies play a profound role in these learning processes. Our theoretical framework seeks to account for the social and material dimensions of sophisticated domain learning as it relates to the interests and practices of specific cultural groups (Bell, et al., 2006). The ultimate explanatory goal is to better understand the extended learning pathways (e.g., related to the accomplishment of expertise development in science and technology) that are culturally architected through complex sequences of contingent interaction and activity that occur across the breadth of everyday life. Our theoretical stance on sophisticated learning and expertise development builds upon the social, cultural, and material perspectives associated with situated perspectives on learning (c.f., distributed cognition [Hutchins, 1995], situated learning [Lave & Wenger, 1991], the agency-identity framework [Holland et al., 1998], and critical feminist perspectives [Barton et al., 2003; Suchman, 2007]). These perspectives allow us to develop a theoretical and empirical understanding of the social and material influences on what is taken to be sophisticated learning and activity that occurs within and across figured cultural worlds. Such figured worlds exhibit significant cultural variation, are often contested among social actors, and are inequitably available to individuals and groups.

Key to our analyses of these cases is the assumption is that educational choices and educational values are co-constituted. Families make choices building on what they value, and valuing develops through choices made in social and cultural settings. Researchers have documented that the development of learner's interest, reputation, and identification with forms of expertise and practice have a strong influence on what they choose to learn and to value (Barron, et al. 2009; Esmonde et al., 2009; Pea et al., 2007; Stevens, O'Connor, et al., 2008; Zimmerman, Reeve & Bell, 2008).

This work is part of the broader efforts of the Learning in Informal and Formal Environments (LIFE) Center to answer questions about the social genesis and expression of learning choices and the *socio-cultural-historical* values that drive them. Learners develop competencies and dispositions that contribute to their choosing and valuing of learning opportunities. This includes social learning processes put in place between experts and novices (Bransford & Schwartz, 2009), choices and values that drive specialized learning interests (Barron et al., 2009; Reeve & Bell, 2009), preferred learning arrangements, such as seeking help or working alone (Stevens et al., 2008), social positioning of individuals in ways that support or constrain learning (Harré, 2008; Holland et al., 1998), as well as features of social cognitive development, such as strategies associated with learning through imitation (Meltzoff et al., 2009). In these analyses, we use ethnographic and interview data to document both choices families made and the values behind these decisions.

Paper 1: Negotiating Identity and Expertise in a Vietnamese Immigrant Family

Children of families who have immigrated to the United States must often negotiate different systems of values and ideas across home, school, and community settings. Even within the home setting, parents' and children's differing educational experiences, language abilities, and perspectives on the dominant culture can make for a complex network of influences through which young people must find their way. Though some scholars have begun to investigate these challenges (e.g., Lee, 2008; Orellana, Reynolds, Dorner & Meza, 2003; Phelan, Davidson & Cao, 1991; Suarez-Orozco & Suarez-Orozco & Todorova, 2008), the ways in which young people's learning is affected by the disparate worlds they traverse are still poorly understood.This paper discusses the experiences of one Vietnamese boy (pseudonym Luke Vuong) and how he is positioned differently by his mother in the domain of school learning and in his home-based expertise with technology (cf. Harré, 2008). It focuses on the question, *how do immigrant parents' educational life histories and value systems affect how they construct learner identities for their children in school and home-based pursuits?*

Findings

Luke Vuong (age 13) and his younger sister Anna (age 10) were born in the Philippines to Vietnamese parents, mother Agnes and father Sinh (all names are pseudonyms). The Vuong family immigrated to the United States from the Philippines in 2002, when Luke and Anna were young children. The family speaks Vietnamese at home, although both children are bilingual in Vietnamese and English.

Over the course of our team's acquaintance with the Vuongs, Luke's mother Agnes expressed deep and repeated concerns that Luke did not study hard enough or do well enough in school. Her concern about his academic performance caused her serious distress, and resulted in changing Luke's school enrollment, requesting standardized testing to test his cognitive abilities, and multiple efforts to support out of school learning opportunities including after school clubs, individual reading, and educational software. Agnes frequently described Luke as being "lazy" and needing constant "pushing" to complete and turn in his schoolwork.

As we continued working with the Vuongs, it became clear that the way in which Agnes positioned Luke academically was heavily informed by her experiences growing up in South Vietnam. Agnes's formative years were spent in a home and a national environment where economic and educational opportunities were both limited and often unequally distributed. Agnes often expressed to us that Vietnamese students were expected to study long hours and prepare intensively for admission to a limited number of university possibilities. She related her own experience of being unable to pursue a university education, and the subsequent great importance she placed on the educational opportunities of her children. Agnes' values, derived largely from her social and cultural histories, have clearly impacted the family's decisions related to Luke's learning.

At the same time as Agnes and other family members positioned Luke negatively with respect to his school performance, however, Luke had a developing identity within his family as someone who is knowledgeable and skilled in a home-based pursuit - operating and maintaining a variety of technological tools. When our research team first met the Vuongs, they did not own a computer, but Luke reported helping his father, Sinh, use the Internet in their apartment complex's computer room. The Vuongs bought their first computer in part with proceeds from participating in our study, and since then, they have owned a series of desktop and laptop computers, as well as other technological systems (e.g., televisions, speaker systems, handheld and console video games). Agnes reported multiple times that she calls on Luke for help with the family computer, including installing software and operating various programs. She also related that Luke was one of the main participants in putting together a new television and speaker system, and that the family calls on him to troubleshoot technological problems. While she continues to express concern that Luke's studying and academic performance are below her expectations, Agnes increasingly praises Luke's mechanical abilities and his understanding of technology.

The ways in which Luke is positioned in school- and home-based pursuits have been informed by family members' educational experiences and cultural values. Each of these factors can have multiple and complex influences on how learner identities are formed and sustained. For example, one reason Luke's parents (especially his mother) look to him for technological expertise at home is because of his comparatively stronger abilities in speaking and reading English. At the same time, however, one likely factor behind Luke's difficulties in school is his challenge in developing academic English at the necessary level of sophistication.

This work sheds light on how families' sociocultural histories play important roles in educational identity formation. It also has relevance for understanding learning pathways among the growing population of immigrant and bicultural youth in the United States. As ethnic and cultural diversity continues to increase in the nation's schools, educators must take a complex view of the students in their classrooms and of the myriad of social and material influences on who these young people are and will become.

Paper 2: Orienting Children Towards Science: Influences of Parental Values and Family History on How Parents Arrange Children's Educational Experiences

This paper looks at the role of mothers in supporting and arranging for educational experiences related to science and math—both in school and out of school—for their daughters. Ethnographic methods are used to create three mother-daughter case studies. In each case study, the mother's family histories are analyzed in relationship to science and math learning experiences that they plan for and decide about with their daughters. This work identified four key areas of educational decision making: 1) middle school selection, (2) afterschool programs, (3) summer learning activities, and (4) the at-home structure created for homework, hobbies or other pursuits. The research question that guides this study is: *What is the influence of family histories and parental values on how parents arrange and encourage educational experiences related to science and math for their daughters?* The focus is on the four themes above as the girls transitioned from elementary school into middle school.

Work in developmental psychology focuses on parental educational beliefs—especially in the areas of academic stereotypes and achievement (e.g., Bhanot & Jovanovic, 2005; Raty & Kasanen, 2007). This work explores the psychological mechanisms underlying the under-representation of females in math, science and engineering fields. A related line of work adds social interactions to its psychological analysis of how parents foster disciplinary affiliations. Researchers (Crowley, Callanan, Tenenbaum, & Allen, 2001; Tenenbaum & Leaper, 2003) studied parent-child interactions and found that parents differentially orient their children towards subject matter learning—spending more time with boys on science. Other work analyzed how children engage in school science in comparison to their reported home experiences. Researchers (Brickhouse, Lowery, & Schultz, 2000) found that home activities and social networks were important in determining science identities. Barron et al. (2009) found that youth with more sophisticated STEM expertise had benefited from a greater variety of parental supports for their learning.

This paper adds on this literature in three ways. First, the majority of prior work analyzes large data sets, assessment protocols, and/or interviews. Observations of activities in family settings are added. Second, many studies compare the beliefs of the children to the beliefs of the parent. This comparison ignores the social processes by which the beliefs are shared. Here, the analysis is on parents' beliefs and values embedded in family practices to understand how the processes by which the daughters take up or resist their parents' ideas. Finally, much of the research looks to understand if mothers or fathers give more support to their sons or daughters. Instead, here the focus is on the experiences of girls and women.

Findings

This analysis focuses on three mothers and three girls—Raven, Wendy, and Penelope (pseudonyms)—when they discussed or reflected on decisions related to learning experiences or when they crafted learning arrangements. Overall, Wendy's, Raven's, and Penelope's mothers were active *learning advocates*. As advocates, the mothers were involved and involved others in helping their children. The mother arranged for or assisted with homework, helped with searches for relevant information, sought out learning activities for their child, and provided access to artifacts and tools. Mothers set up physical spaces for academic success in the home—including access to computers and materials needed for homework. These mothers also arranged for trips to extend learning (e.g., Raven to the library and Wendy to an organic garden).

The mothers' experiences with their own parents were often articulated as influencing their activities with their daughters. For example, Eve Smith, Penelope's mother, was born, raised, and schooled in the Philippines; where she received a bachelor's degree in management. Eve expressed that while education was valued in her family, higher education was not necessarily valued *for women* by her father. Eve told us her father "didn't want to waste his money sending her to school; she should just stay home and get married. – *Smith home, November 14, 2006"*. Unlike her father, Eve often encouraged Penelope in math and science—and school more generally. Eve determined Penelope was going to college, sharing with the research team that she was already saving money. During multiple visits, Penelope teased the research team that she did not want to attend college at our institution—she commented instead about liking another local university and its mascot. While teasing was a communication genre common in the Smith household, it also revealed Penelope's awareness at 5th grade of multiple colleges in her immediate area and her goal to attend one. In this way, Eve's views advocating for Penelope's educational experiences and Penelope's goals for herself were shaped from Eve's father's talk around schooling.

Raven's mother Cyndi also used her life experiences to navigate suggesting college. Cyndi cited her love of school and her own lack of success in getting her bachelor's degree as motivation for Raven. Wendy's mother Grace was more immediately focused on her daughter's success in middle and high school through joining the gifted and talented program, and Wendy's college was not such a primary focus for Grace.

The mothers worked to make their homes environments where scholarship was encouraged, high standards were achieved, and academics were balanced with recreational and social times. At the same time, mothers created home environments that were resources for learning the knowledge and practices valued by the families' communities. For example, the mothers set up homework spaces and/or resources, arranged with tools (i.e., Internet, rulers, books, etc.) for the children to use. They created social networks to support learning from cultural groups, from neighbors, from golfing partners, from family, and from religious groups. The social networks were used for science and math learning, and they were also used in support of hobbies and other interests.

In the case of Eve and Penelope, Eve encouraged Penelope to work on her homework and to participate in academically-related afterschool programs, like the science afterschool program. When the transition to middle school happened, Eve thought about how she could change her life to be more helpful to Penelope academically, as illustrated by this fieldnote excerpt: "Eve and I talk about her new schedule—she wants to be more help with Penelope and her middle school homework. She is trying to adjust her [work] schedule to help Penelope study math and science. – *Smith family home, 2006-11-14"*. Eve relied not only on the school but herself to support Penelope's continued academic success. Eve did this through buying commercial books, arranging for one of Penelope's godmothers to tutor Penelope in math concepts, and encouraging her to participate in a science afterschool program as well as a church-centered music afterschool program.

Grace also created an academic environment for her three daughters including Wendy—often maintaining a library-like quiet during study times. During the academic year, Grace planned an afterschool schedule for Wendy that included homework time, music practice, a 30-minute television break, and a snack. In one case, when Grace was not home, she created instead an afterschool work-play schedule for Wendy on a Post-It™ note. Grace also encouraged her children to participate in supplemental activities. Cyndi was observed to give similar assistance through spending time on the Internet looking up help for math and related subjects and by taking Raven to the library.

Conclusion

One of the main findings is that the children's family life was a rich collection of learning resources to support science and math as well as cultural activities (music, religion, and cooking). Mothers acted as learning advocates to craft learning experiences for their daughters that they believed to be the most useful (based on their own histories and cultural experiences) is not readily available. Families tapped social networks to provide their daughters the kinds of science and math related experiences are believed (based on parental histories and cultural experiences) will provide the daughters the best experiences, and parents gave their daughters choice, in varying degrees, about their educational decisions. Additionally, families were thoughtful when selecting educational opportunities for their children—to balance academic and social needs. Parents are not commonly studied in the learning as resources that provide science-related help, yet these cases show how parents, and mothers in specific, have a huge impact in helping a child learn science-related knowledge and skills related to both school work and out-of-school pursuits. This analysis argues that mothers need to be more considered in their role as learning partners when trying to understand the development of their daughters' disciplinary affiliation and identity.

Paper 3: Examining the Complex Ecologies Associated with Immigrant Youth and Family Educational Decision Making

Youth from immigrant families make up a large percentage of youth in the United States and the percentage is steadily increasing (e.g., Fuligni, 1997). Yet, little is understood about their lives (Suárez-Orozco, Suárez-Orozco, and Todorova, 2008). Many scholars studying immigration and education have focused on bilingual education (cf. Suárez-Orozco, Suárez-Orozco, and Qin, 2005) and academic achievement once youth from immigrant families become participants in the United States' educational system (e.g., Suárez-Orozco, Suárez-Orozco, and Todorova, 2008). In addition to these important areas of scholarship, we propose a focus on how immigrant youth and families *learn* what it means to "do" school in the United States, which we argue is a form of expertise (cf. Bricker and Bell, 2008; Ericsson, Charness, Feltovich, and Hoffman, 2006). Given the importance of prior experience relative to acts of learning (e.g., Bransford, Brown, and Cocking, 2000), our analysis hinges on emic (Harris, 1987; Pike, 1954) and place-based (e.g., Holloway and Valentine, 2000) accounts of lived educational histories.

We wish to examine what meanings immigrant youth and families associate with the concept of schooling given their lived educational histories, which include educational experiences (both formal and informal) in countries of origin, as well as those along migratory paths. We examine the everyday spaces associated with schooling that immigrant youth and/or their parents inhabit over time, including the spatial discourses used in these everyday spaces (cf. Holloway and Valentine, 2000). Our *research question* for this analysis is: What ideologies and lived experience undergird educational decisions made by immigrant youth and families?

Findings

To investigate our research question, we utilize data from two case studies of Biqila Gamada and Ka-zee Cheung respectively. Biqila and Ka-zee are focal participants in the aforementioned ethnographic research. Biqila and his family arrived from Kenya two years before enrolling in the ethnography. Ka-zee was born in the United States but her parents came to the United States from Vietnam. As part of our analysis, we map both Biqila and Ka-zee's educational patterns, which are influenced by parental educational ideologies and experiences.

In Biqila's case, he understands the educational choices made by his family in the larger context of his and his families' lived schooling experiences in Africa (namely Ethiopia and Kenya). His father attended only a few years of elementary school in Ethiopia. Biqila's sister reports her father telling all of his children that without an education, everyone will "…use you as a napkin" (i.e., wipe their hands on you). All decisions are made in Biqila's household based on furthering one's education because Biqila's father wants his children to "…be somebody like he wants to see." In this analysis, we show how in one instance a particular educational decision becomes contested space (Low and Lawrence-Zúñiga, 2003) and threatens to pit obtaining an education against the development of significant expertise development in a sport (which if continues has a high probability of culminating in a higher education scholarship). We also use an interdiscursive analysis (e.g., Bricker and Bell, in preparation; Silverstein, 2005) to highlight the various spatial and temporal aspects of Biqila's lived educational history and choices as they unfold along extended learning pathways.

In Ka-zee's case, we note that all educational decisions are made by Ka-zee's father Mau. Ka-zee has been tracked into special education programs and classes since early elementary school. Mau makes educational decisions for Ka-zee based on his educational ideology that in Vietnam, only the top tiered students have a chance to compete for employment that confers economic advantages, while in the United States, even those who are mediocre can still "make it." Using interaction analysis to find patterns in discourse and behavior, we map Mau's educational behaviors and ideologies of what it means to "do" school to his own educational experiences in Vietnam. We also report on how Mau 'learned' what it means to make educational choices for one's offspring in the United States; learning that is situated in a space undergirded by racial and socioeconomic influences.

Conclusion

These cases show the influence of educational ideology and lived experience in educational practices and decision-making. Through geographic, linguistic, and interaction analyses, we uncover and explore these educational ideologies and patterns and show how they travel through space and time to influence educational decisions. In addition, we show that educational decisions, although made to offer youth the best education possible, can conflict with other possible decisions and experiences that might lead to the very educational opportunities that parents want for their children.

References

Althusser, L. (1971). Ideology and the ideological state apparatus. In *Lenin and philosophy*. New York: Monthly Review Press.

Bakhtin, M. (1983). *Rabelais and his world*. Bloomington: Indiana University Press.

Banks, J. A., Au, K. H., Ball, A. F., Bell, P., Gordon, E. W., Gutierrez, K., et al. (2007). *Learning in and out of school in diverse environments: Life-Long, Life-Wide, Life-Deep*. Seattle, WA: UW Center for Multicultural Education.

Barron, B., Martin, C., Takeuchi, L., & Fithian, R. (2009). Parents as learning partners and the development of technological fluency. *International Journal of Learning and Media, 1*(2).

Barton, A. C., Ermer, J. L., & Burkett, T. A. (2003). *Teaching science for social justice*. New York, NY: Teachers College Press.

Bell, P., Bricker, L.A., Lee, T.R., Reeve, S., & Zimmerman, H.T. (2006). Understanding the cultural foundations of children's biological knowledge: Insights from everyday cognition research.

Proceedings of the Seventh International Conference of the Learning Sciences (ICLS), pp. 1029-1035. Mahwah, NJ: Erlbaum.

Bell, P., Lewenstein, B., Shouse, A.W. & Feder, M.A. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits*. Committee on Learning Science in Informal Environments, Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education, National Research Council. Washington, DC: The National Academies Press.

Bhanot, R., & Jovanovic, J. (2005). Do parents' academic gender stereotypes influence whether they intrude on their children's homework? *Sex Roles, 52*(9/10), 597-607.

Bransford, J.D., Brown, A.L., & Cocking, R.R. (Eds.) (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Bransford, J., & Schwartz, D. (2009). It Takes Expertise to Make Expertise: Some Thoughts about Why and How. In K. A. Ericsson (Ed.), *Development of professional expertise: Toward measurement of expert performance and design of optimal learning environments*. New York, NY: Cambidge University Press.

Bricker, L. A., & Bell, P. (2008). Mapping the learning pathways and processes associated with the development of expertise and learner identities. In P. A. Kirschner, J. van Merriënboer & T. de Jong (Eds.), *Proceedings of the Eighth International Conference of the Learning Sciences.*

Bricker, L.A., & Bell, P. (in preparation). Linguistic markers as evidence of interdiscursive learning in youth talk across encounters.

Brickhouse, N., Lowery, P., & Schultz, K. (2000). What kind of a girl does science?: The construction of a school science identity. *Journal of Research in Science Teaching*, *37*(5), 441-458.

Crowley, K., Callanan, M. A., Tenenbaum, H. R., & Allen, E. (2001). Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science, 12*(3), 258-261.

Delgado-Gaitan, C., & Trueba, H. (1991). *Crossing cultural borders: Education for immigrant families in America*. London, UK: The Falmer Press.

Dreier, O. (2009). Persons in structures of social practice. *Theory & Psychology, 19*(2), 193-212.

Ericsson, K.A., Charness, N., Feltovich, P.J., & Hoffman, R.R. (Eds.). (2006). *The Cambridge handbook of expertise and expert performance.* Cambridge, UK: Cambridge University Press.

Erickson, K., & Stull, D. (1998). *Doing team ethnography: Warnings and advice.* Thousand Oaks, CA: Sage Publications.

Esmonde, I., Blair, K., Goldman, S., Martin, L., Jimenez, O., & Pea, R. D. (in press). Math I am: What we learn from stories that people tell about math in their lives. In B. Bevan, P. Bell & R. Stevens (Eds.), *Learning outside school time*. New York: Springer.

Fuligni, A.J. (1997). The academic achievement of adolescents from immigrant families: The roles of family background, attitudes, and behavior. *Child Development, 68*(2), 351-363.

Harré, R. (2008). Positioning Theory. *Self-care, Dependent Care & Nursing*, *16*(1), 28-32.

Harris, M. (1987). *Cultural anthropology* (2nd ed.). New York, NY: Harper & Row Publishers.

Holland, D., Lachiocotte, W., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press.

Holloway, S.L., & Valentine, G. (2000). *Children's geographies: Playing, living, learning.* London, UK: Routledge.

Horton, J., & Kraftl, P. (2006). What else? Some more ways of thinking and doing 'children's geographies.' *Children's Geographies, 4*(1), 69-95.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: The MIT Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, MA: Cambridge University Press.

Lee, C.D. (2008). The centrality of culture to the scientific study of learning and development: How an ecological framework in education research facilitates civic responsibility. *Educational Researcher, 37*(5), 267-279.

Low, S.M., & Lawrence-Zúñiga, D. (2003). *The anthropology of space and place: Locating culture.* Malden, MA: Blackwell Publishing.

Meltzoff, A., Kuhl, P., Movellan, J., & Sejnowski, T. (2009). Foundations for a new science of learning. *Science*, *325*(5938), 284-288.

Moll, L.C., & González, N. (2004). Engaging life: A funds of knowledge approach to multicultural education. In J. Banks & C. McGee Banks (Eds.), *Handbook of research on multicultural education* (Second edition) (pp. 699-715). New York: Jossey-Bass.

Olneck, M.R. (2004). Immigrants and education in the United States. In J. Banks & C. McGee Banks (Eds.), *Handbook of research on multicultural education* (Second edition) (pp. 381-403). New York: Jossey-Bass.

Orellana, M.F., Reynolds, J, Dorner, L. & Meza, M. (2003). In other words: Translating or "para-phrasing" as a family literacy practice in immigrant households. *Reading Research Quarterly, 38*(1), 12-34.

Pea, R. D., Goldman, S., Martin, L., Blair, K. P., Booker, A., Esmonde, I., et al. (2007, July). Situations and values in family mathematics. *In Proceedings of CSCL-2007 (Computer-Supported Collaborative Learning*) (pp. 26-35). Rutgers, Mahwah, NJ: Erlbaum Associates.

Phelan, P., Davidson, A.L. & Cao, H.T. (1991). Students' multiple worlds: Negotiating the boundaries of family, peer, and school cultures. *Anthropology & Education Quarterly*, 22(3), 224-250.

Pike, K.L. (1954). *Language in relation to a unified theory of the structure of human behavior*. Ann Arbor, MI: Braun-Brumfield, Inc.

Räty, H & K Kasanen, K. (2007) Gendered views of ability in parents' perceptions of their children's academic competencies. *Sex Roles,* 56(1-2), 117-124.

Reeve, S. & Bell, P. (2009). Children's self-documentation and understanding of the concepts "healthy" and "unhealthy." *International Journal of Science Education, 31*(14), 1953-1974.

Silverstein, M. (2005). Axes of evals: Token versus type interdiscursivity. *Journal of Linguistic Anthropology, 15*(1), 6-22.

Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D.M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education*, *97*, 355-368.

Suárez-Orozco, M.M, Suárez-Orozco, C., & Qin, D.B. (Eds.) (2005). *The new immigration: An interdisciplinary reader*. New York, NY: Routledge.

Suárez-Orozco, C., Suárez-Orozco, M.M., & Todorova, I. (2008). *Learning a new land: Immigrant students in American society.* Cambridge, MA: The Belknap Press of Harvard University Press.

Suchman, L. (2007). Agencies in technology design: Feminist reconfigurations. In *Human-machine reconfigurations: plans and situated actions*. New York: Cambridge University Press.

Tenenbaum, H. R. & Leaper, C. (2003). Parent-child conversations about science: The socialization of gender inequities? *Developmental Psychology*, 39(1), 34-47.

Thompson, J. B. (1984). *Studies in the theory of ideology*. Berkeley: University of California Press.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Waters, J.L. (2006). Geographies of cultural capital: Education, international migration and family strategies between Hong Kong and Canada. *Transactions of the Institute of British Geographers, New Series, 31*, 179-192.

Zimmerman, H. T., Reeve, S., & Bell, P. (2008). Distributed expertise in a science center: Social and intellectual role-taking by families. *Journal of Museum Education*, *33*, 143-152.

Adaptive human guidance of computer-mediated group work

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Symposium overview

Many studies have shown that small-group work can have positive effects on student achievement, especially compared to other forms of instruction that involve less peer interaction (e.g., O'Donnell, 2006). However, learners may not benefit as much as they could, because they often fail to spontaneously engage in productive forms of interaction and dialogue (Fischer, Kollar, Haake & Mandl, 2007). An expert teacher or tutor monitoring group progress and providing support in real time has been found to significantly improve group productivity (see Webb, 2009, for a recent review on guidance of collaborative group work). In this symposium, we focus on human guidance directly provided by a teacher during (1) small group discussion, and (2) scripted through assigning the role of tutor and tutee in dyadic collaboration (also called *peer tutoring*). For example, in teacher-guided, small-group discussion, Chiu (2004) has shown that the explicitness of teacher's content-specific help was negatively related to students being on task immediately after the teacher's intervention, and to group's performance on that problem. Providing low levels of help content, and issuing few directives seemed to benefit student performance. Chiu showed that beyond the kinds of interventions teachers undertook, a key element in determining the effectiveness of teacher interventions is whether the teacher's help is tied to students' ideas (see also Meloth and Deering, 1999 for similar insights). As claimed by Yackel (2002), however, such an adaptive behavior task is extremely complex for teachers, especially since they have to closely monitor group and individual progress.

Peer tutoring has also been found as productive. For example, in *reciprocal teaching* (Brown & Palincsar, 1989; Palincsar & Herrenkohl, 1999), students were trained to carry out certain strategies designed to their improve comprehension of their texts. Fuchs and colleagues (Fuchs et al, 1997) studied tutors-students trained to give highly elaborated conceptual rather than algorithmic explanations helped in promoting high-level discourse. Reflecting on the important activity of the help receiver, King (1999) trained tutors to ask questions designed to encourage the tutee to provide explanations, to ask further questions to push the tutee to elaborate upon or justify their explanations as well as to correct incomplete or incorrect explanations. All these experiments led to overall beneficial effects but the contingency of the help given by the tutor to the tutee, its adaptive character, is crucial but not easily reached.

On-line learning environments open new perspectives for guiding both small-group discussion and peer tutoring. The tools embedded in computer software may enable the teacher/tutor to monitor and evaluate group and individual processes more accurately, and as a result provide support that is contingent upon the learners' needs. However, it is questionable whether the positive results obtained in face-to-face settings are transferable in the guidance of small groups or individuals in on-line environments. On-line guidance of individuals or small groups is then a new enterprise.

The four presentations in this symposium focus on the effectiveness of guided small group discussion and peer tutoring and on their adaptive character. We will describe moderation and tutoring strategies, the unfolding interaction between moderator and group (members), the effectiveness of certain prompts and strategies over others, and, for on-line group work, ways to support the teacher or tutor. The first presentation focuses on face-to-face peer tutoring. It proposes a new quantitative methodology to study the *reciprocal* relation between the actions of the tutor/teacher/moderator, on the one hand, and of the tutee/small-group, on the other. They show how this new methodology may be used to gain new insights into the way both sides of the interaction mutually influence each other's actions. The three other presentations concern on-line group work and show indeed that peer tutors can be effectively supported by computer software to become more adaptive to their peer tutees' needs (Walker, Koedinger & Rummel), that moderators can adaptively moderate multiple synchronous discussions (Schwarz & Asterhan), and that teachers can cope with students' heteroglossia in e-discussions on socio-scientific issues (Baker).

Statistical Discourse Analysis of Young Children's Peer Tutoring at Computers

Christine Wang, Ming Ming Chiu & Cynthia Carter Ching

Past studies have shown that active participation is essential for peer tutoring and collaboration that successfully yields subsequent individual learning gains (e.g., Mackie, 1983; Gauvain & Rogoff, 1989). Yet these studies are lacking in two ways: (1) excessive focus on tutor actions can limit our understanding of the tutees' contributions (Chi, Siler, & Jeong, 2004); and (2) understudied sequential mechanisms between early actions and later actions of tutors and tutees within and across peer tutoring sessions may limit our understanding of moment-by-moment tutoring dynamics (Ellis & Gauvain, 1992). These challenges become compounded when we look at young children as a peer tutoring population, because, compared to studies of older populations, the limited indicators of participation (often verbal expression of new ideas or disagreement, Roscoe & Chi, in press) are not sensitive enough to capture younger children's emerging (and sometimes effective) tutoring processes (Cooper, Ayers-Lopez, & Marquis, 1982).

The purposes of this study are to address these limitations in the existing literature, to understand young tutors and tutees' mutual and sequential influence on each other's participation while engaged in computer tasks, and to investigate what other kinds of non-verbal indicators of engagement would be effective for this population. We focused on two one-on-one tutoring sessions, one for each of two groups consisting of a first-grader one kindergartner. The task was for the first grader to teach the kindergarteners to use the *SimpleText* computer program. Using statistical discourse analysis (SDA, Chiu & Khoo, 2005), we analyzed the videotaped behavior sequences of a first-grader (Nancy) teaching two kindergartners (Calvin, Ellen) to use the *SimpleText* program during 469 transcript conversation turns. Each conversation turn was coded for the variables used in the model (see Figures 1 and 2), which showed high inter-coder reliability (Krippendorff's α [2004]).

Unlike ordinary least squares regressions, SDA addresses the difficulties of nested data, discrete outcomes, and serial correlation during analysis of group processes at the conversation turn level. SDA identifies watersheds (breakpoints) and models discrete outcomes, time period differences, serial correlation, and direct and indirect effects.

$\mathbf{P}_{yij}=p(\mathbf{Y}_{yij}=1|Calvin,b_{01})=F(b_{y00}+f_{y0j}+b_{y01}Calvin)$ (1)

The probability ($\mathbf{P}_{yij}$) that the vector of y tutee outcome variables $\mathbf{Y}_{yij}$ occurs at turn i of time period j is the expected value of $\mathbf{Y}_{yij}$ via the Logit link function (F) of the overall mean b_{y00}, the time period deviations (f_{y0j}), and each variable (e.g., *Calvin*).

$\mathbf{P}_{yij}=F(b_{y00}+f_{y0j}+b_{y01}Calvin+b_{yuj}\mathbf{U}_{yij}+b_{yvj}\mathbf{V}_{y(i-1)j}+\gamma_{yvj}\mathbf{V}_{y(i-2)j})$ (2)

Current (**U**) and previous speaker variables ($\mathbf{V}_{y(i-1)j}$, $\mathbf{V}_{y(i-2)j}$) were entered via a vector autoregression (see Figures; Kennedy, 2004). These analyses were then applied to the parallel tutor outcome variables.

Results

The tutor and the tutees generally gazed on-task (89%; 80%, respectively) and were active (81%, 61%). Being "active" was defined as talking, using the computer, or pointing. The tutor contributed more ideas (53% vs. 17%) and displayed positive emotion more often (10% vs. 5%). Locations of artifacts (mouse, keyboard), tutor behaviors, and tutee behaviors all influenced one another's participation (see Figures). The tutees were more active when the mouse or keyboard was closer to them. While tutor commands increased tutee activity, tutor disagreement stifled it. However, the explanatory models differed substantially for each tutee. Results also suggest that tutor actions might have stronger effects and be more important when tutees are less engaged or more passive. More important, tutee differences altered interaction dynamics, even with the same tutor on the same task. The keyboard location and tutee behaviors had similar effects on the tutor's behaviors such as disagreement, on-task gaze, actions and emotional displays.

Sequential effects were also noted. For example, tutee disagreements sharply increased tutor disagreements. After the tutee gazed on-task (–1), the tutor was more likely to express a new idea, suggesting that the tutor checked for joint attention before expressing a new idea. This result suggests that young tutors attend to one another's engagement more subtly than shown in previous research. Tutee new ideas did not immediately beget further new ideas, suggesting that the tutor might have spent time processing the tutee's new ideas.

There are several contributions that we see from this early exploratory work. First, the multidimensional indicators of active participation (verbal, non-verbal, computer-related actions, emotions) provided many ways to study interaction during peer tutoring. Second, we expanded the tutoring explanatory mechanism by showing how tutees influence tutors and how they mutually interact. The tutor's different tutoring dynamics with different tutees highlight how tutoring mechanisms can differ across working pairs. Future research can illuminate how tutor differences influence tutoring dynamics. Third, the statistical discourse analysis systematically shows how recent actions affect subsequent actions at the micro-level and suggests future applications at the macro-level to address temporal issues. This study suggests that online moderators and online students would likewise mutually influence one another, and that online artifacts can also play a substantial role in directing attention and influencing participation. Specifically, online moderators can benefit from access to online students' computer actions and video displays of their non-verbal behaviors to adapt to their needs accordingly.

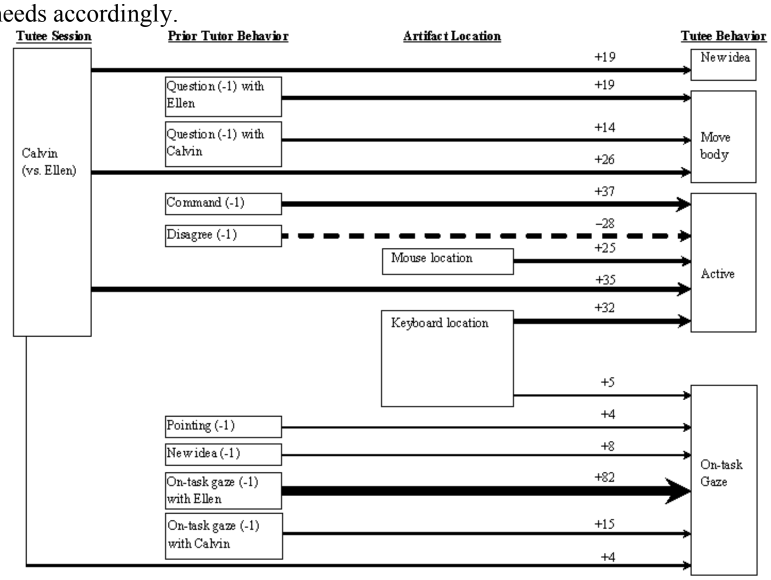


Figure 1. Model predicting 4 types of tutee participation behaviors. All arrows indicate significant effects Solid arrows indicate positive effects and dashed lines indicate negative effects. Thick arrows indicate larger effects.

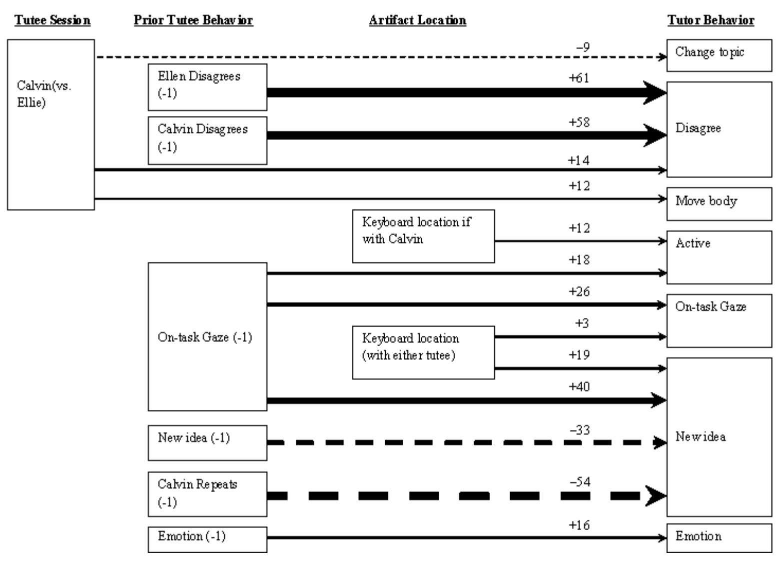


Figure 2. Model predicting 7 types of tutor behaviors. All arrows indicate significant effects Solid arrows indicate positive effects, dashed lines, negative effects. Thick arrows indicate larger effects.

Automated Adaptive Support for Peer Tutoring in High-School Mathematics

Erin Walker, Nikol Rummel and Kenneth R. Koedinger

Reciprocal peer tutoring is a type of small-group work where two students of similar abilities take turns tutoring each other. It has been shown to improve domain learning of students involved (Fantuzzo, Riggio, Connelly & Dimeff, 1989), most likely because students who tutor other students benefit from the reflective and elaborative processes involved in observing problem-solving steps and providing explanations (Roscoe & Chi, 2007). However, for students to benefit from the tutee role they must receive help that is conceptual (Fuchs et al., 1997) and that gives the tutee correct information about the domain (Webb, 1989). Many previous efforts at assisting peer tutoring have focused on structuring the tutoring process. For example, King, Staffieri, and Adelgais (1998) attempt to increase the conceptual content of the interaction by having students ask each other a series of questions at different levels of depth, and Fantuzzo et al. (1989) support the correctness of the interaction by having students compare tutee problem-solving steps to problem solutions. While these approaches have been successful, adaptive support for the peer tutor may be an improvement over fixed support in two ways. First, it would be able to provide individually tailored *interaction* support, for example by detecting when peer tutor help was not conceptual enough, and giving relevant feedback. Second, it would be able to provide context-sensitive *domain* support, adaptively alerting peer tutors to tutee errors rather than simply providing a resource for peer tutors to consult.

We have developed adaptive support for peer tutoring by augmenting the Cognitive Tutor Algebra (Koedinger, Anderson, Hadley, & Mark, 1997), a successful intelligent tutoring system for individual learning, with peer tutoring activities. In our extended system, students work on literal equation solving problems, where they are given a prompt like, "Solve for x" and an equation like "$ax + by = c$". Each student gets the opportunity to tutor a partner by observing the tutee solve problems, marking problem steps, and giving help in a chat window. We provided peer tutors with two types of adaptive support: one which assisted the peer tutor in giving correct help (*domain* component), and one which assisted the peer tutor in giving conceptual help (*interaction* component). For the domain component, we adapted the hints and feedback already present in the Cognitive Tutor Algebra for a collaborative context. As tutees took steps in the problem, peer tutors were asked to mark the tutees' steps as correct or incorrect. If peer tutors made an error (e.g., marked a "correct" step "incorrect"), the system indicated the error by highlighting it in the interface, and then gave peer tutors the domain feedback students would typically receive if they were solving the problem individually, along with a prompt to communicate it to the tutee (see Figure 1a). As tutees solved the problem, the peer tutor could request a domain hint from the computer tutor at any time. While this domain help provided peer tutors with information on which problem-solving steps were correct and why, it did not provide explicit guidance or feedback on how students should help their partner, and thus we added an additional *interaction* component to the assistance. Prior to composing a chat message, students were asked to select a sentence classifier labeling their message as a prompt ("Ask Why"), error feedback ("Explain Why Wrong"), hint ("Give Hint"), or explanation ("Explain What Next"). Upon submitting the help, an intelligent tutor for collaboration used a combination of the self-classification, an automated assessment of the help quality, and the domain context (whether tutees had just made an error or not) to make an estimate of the level of student help-giving skills. Based on this assessment, the computer gave context-sensitive reflective prompts in the chat window that were seen by both the peer tutor and the tutee (see Figure 1b). We expected that the adaptive support would lead peer tutors to give more correct help by alerting them to the domain errors that they made, and lead peer tutors to give more conceptual help by alerting them when more conceptual help would be necessary.

We conducted a classroom study with 77 participants comparing two conditions: adaptive assistance (40 participants) and fixed assistance (37 participants). In the fixed condition, students had access to problem solutions and tips for good collaboration. The support contained the same content as the assistance in the adaptive condition but did not vary based on student actions. We found that adaptive support did indeed have a positive effect on student help. When peer tutors made marking errors, they corrected their error significantly more often in the adaptive than in the fixed condition (adaptive $M = 65.8\%$, $SD = 26.6\%$; fixed $M = 7.5\%$, $SD = 14.6\%$; $F(1,69 = 127.6)$, $p < 0.001$). Further, students gave significantly more conceptual help in the adaptive than in the fixed condition (adaptive $M = 2.58$, $SD = 2.75$; fixed $M = 1.38$, $SD = 2.14$; Mann-Whitney $U = 525.5$; $p = 0.05$). Overall, it appeared that adaptive support was more effective than fixed support at improving student interaction.

We further examined why the adaptive support may have had a positive effect on student interaction using qualitative observations. Interestingly, when students received reflective prompts they would rarely acknowledge them, and often would not appear to incorporate the advice into their next utterance. This behavior was in stark contrast to their use of domain hints given by the computer, which were often immediately repeated to tutees in a form stripped of conceptual content (e.g., tutors might receive the hint "subtract x to get it to the other side", and simply say "subtract x"). This pattern of behaviors suggested either that students perceived domain help as more integral to the task than interaction help, or that they perceived it as easier to implement than interaction help. Further, it seemed that students felt free to ignore advice from a computer in a way that they would not from a human being, potentially because our computer agent was not as responsive to specific student utterances as a human would be. Given these observations, it is interesting that student behavior improved in the adaptive condition compared to the fixed condition. One factor that qualitatively appeared to mediate this process was student feelings of accountability for their partner's learning. It is possible that even the limited responsiveness of the computer to the peer tutor behavior, in combination with the reflective prompts being posted publicly (i.e., in view of the peer tutee), triggered feelings of social responsibility which led peer tutors to give help more thoughtfully. Accountability also played a role in how peer tutors attributed the help they give tutees. Peer tutors would occasionally frame their help as coming from the computer (e.g., "it wants you to subtract *x*"), placing peer tutors and tutees in the position of interpreting the help together. Allowing peer tutors to take on a novice role compared to the computer may be a secondary advantage of the assistance provided. In future work, we hope to explore why adaptive support has a beneficial effect on student interaction, and what features of adaptive support augment this effect.

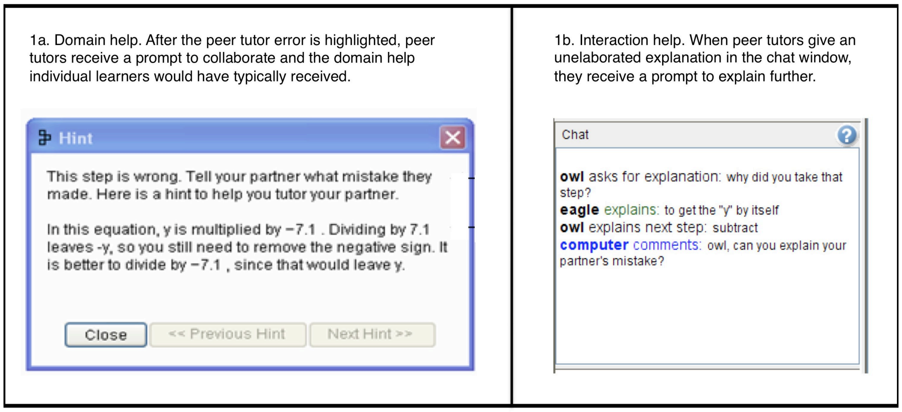


Figure 1. The adaptive domain support and adaptive interaction support given to collaborating students.

Human guidance of synchronous discussions: A nascent school practice

Baruch Schwarz and Christa Asterhan

Although small group methods have been shown to have positive effects on student achievement (e.g., O'Donnell, 2006; Slavin, 1995), simply placing students in small groups does not guarantee learning gains which depend on the quality and depth of discussions, such as the extent to which students give/receive help, share knowledge, build on each others' ideas and justify their own, and the extent to which students recognize and resolve contradictions between their own and others' perspectives (Asterhan & Schwarz, 2009; Webb & Palincsar, 1996). Teachers should then help to avoid detrimental practices and to facilitate beneficial ones. However, little is known about how the teacher can foster small group learning. Influencing student interaction through teacher's discourse is particularly underrepresented in research (Webb, 2009). Several studies (e.g., Chiu, 2004; Webb, 2009) have found that beyond the question of what *type* of teacher prompts are more effective (direct or indirect, explicit or implicit) , a key element in determining the effectiveness of teacher interventions is whether the teacher's help is tied to students' ideas.

Due to the complexity of this task (Yackel, 2002), some researchers have preferred to adopt a phenomenological approach to observe how extraordinary teachers facilitate group learning in specific contexts (e.g., Hmelo and Barrows, 2006, 2008 in a PBL context; and Zhan, Scardamalia, Reeve and Messina, 2009, for long-term classroom learning in small groups with Knowledge Forum). These studies show that small-group facilitation is complex but possible and open new research directions: (a) How can 'normal' teachers face the challenge of ascertaining student thinking during small group work to base their interventions? (b) How can 'regular' teachers successfully monitor and support several discussion groups at the same time? Our goal is to show that it is possible to provide a suitable environment that tackles these challenges in the context of a program for fostering critical thinking through collective argumentation.

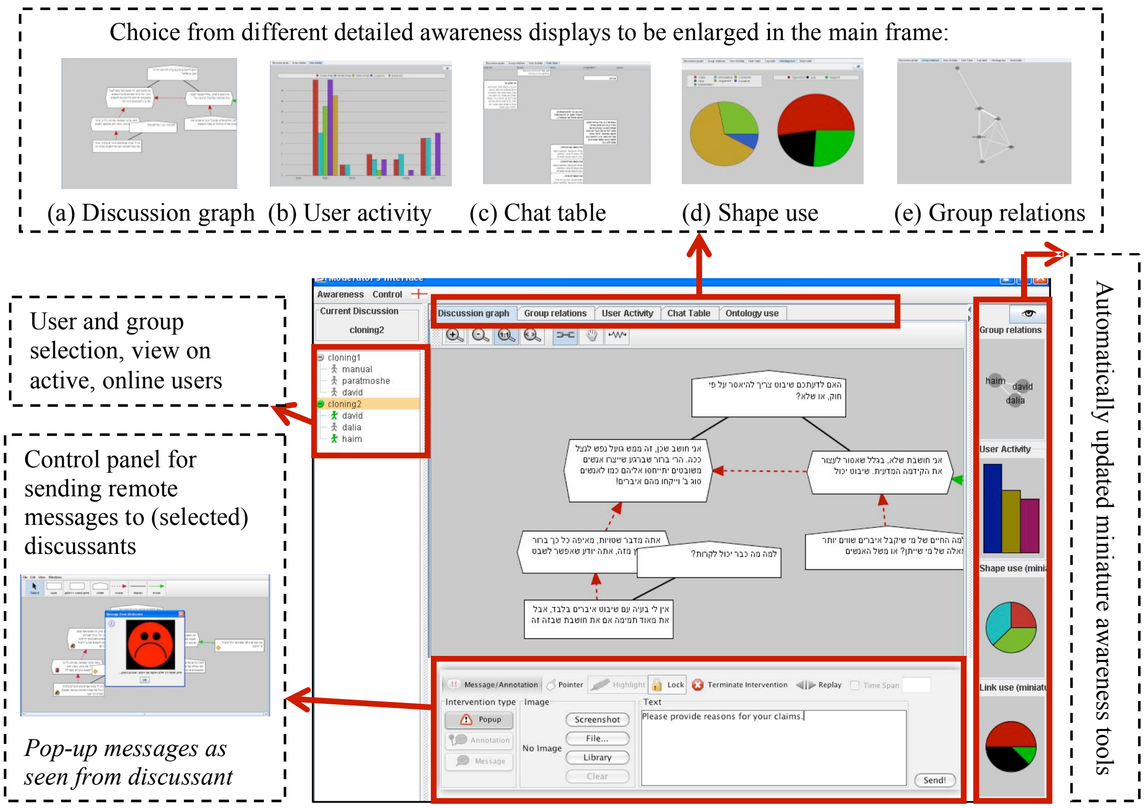
Overall, software tools have limited ability to provide adaptive scaffolding (Puntambekar & Hübscher, 2005). Collaborative scripts are not adaptive either. In the context of a-synchronous discussions in on-line group work in post-secondary e-courses, guidance has been studied and referred to as *e-moderation* (e.g., Salmon (2004). Human guidance of synchronous group discussions seems to be more appropriate, but has not been sufficiently studied yet. Studying guidance of synchronous discussions is then a new adventure but two ideas of e-moderation of e-courses should be retained:

Moderators should not be *intrusive* but be *caring* about their students. The balance between *non-intrusiveness* and *care* is difficult to find, since moderation should be based on ascertaining current group thinking.

Design research for enabling e-moderation of multiple synchronous discussions

As our goal concerns facilitating critical reasoning through synchronous group interaction, the moderator is committed (a) to participation, (b) to argumentation, and (c) to the other. Moderating commitment to argumentation is particularly demanding since it means both monitoring argumentative moves and following the ideas developed along with these argumentative moves, especially in classes, that is, in <u>multiple</u> synchronous discussions. We undertook a design research program that led to the construction of the *Moderator's Interface*, placed within a multifunctional environment called *Argunaut*. Figure 1 shows some of the most important functionalities of the Argunaut Moderator's Interface (AMI).

Figure 1. Argunaut's Moderator's Interface and its main features.



In this presentation, we will report on a case study in which one teacher, Rhonna, moderated four groups of three university students discussing societal dilemmas. We will answer three questions. The two first are: *(1) What are the strategies of e-moderation in parallel synchronous discussions?* and (2) *what are the AMI's functionalities that mediate the enactment of these functionalities?* The AMI, is central in all the strategies deployed by Rhonna in her multiple discussions. It enables passing from one group to another one instantaneously. This possibility combined with the persistence of previous contributions confers to AMI the potentiality to navigate across multiple synchronous discussions. Rhonna begins by (a) observing contributions without intervening though hovering over postings to quickly read their content in the Discussion Graph tab, or scrolling up and down the Chat Table tab, help grasping the development of ideas. This observation leads her to identify the development of ideas and the contribution of students in this development. Also, the role of each participant could be made salient through selecting a discussant in the participant list made his/her contribution visible in the Discussion Graph or in the Table Chat. The Ontology Use and the Group relations tab were mostly used to get an impression about overall group functioning.

An interesting strategy developed by Rhonna is (b) to include students in their group discussion through private care, that is, without the other discussants being aware of that private care:

she first notices that one student did not participate, and then in her successive visits to the group of this student, to monitor her participation. Rhonna uses private channels of communication with annotations attached to specific contributions. She finally convinces her to participate because two channels, public and private are open at the same time. A third general strategy is to encourage groups to open new perspectives through generic interventions. This is made possible because Rhonna is able to monitor the development of one discussion at a glance with the help of awareness tools through the Ontology use tab that shows the distribution of connecting links, and suggests for example that there is too much agreement in a particular discussion. The Remote Control Panel enables Rhonna to send pop-up messages to the group as whole to prompt them to consider additional perspectives. She also (d) progressively helps in deepening the discussion space either by using generic interventions or through specific hints. These monitoring actions are once more achieved through the Discussion Graph and the Chat Table. The Chat Table is particularly handy to check ideas with dexterity. Rhonna also uses the distribution of links to see that links are almost uniformly black, indicating a lack of distinctive and different standpoints. She uses the remote control panel through alternation and combination of highlighting, using pop-ups and annotations to encourage the deepening of the discussion space. She draw the discussants' attention to specific contributions or groups of contributions (through highlighting); she refers to a specific contribution through a question or a challenge (with annotations); and she points at a general lack of the discussion (with the pop-ups). She also (e) socializes students that include themselves in discussions, of course in the public sphere, without patronizing but rather in indirect ways: After having identified that one student is willing to participate in the discussion but that the others have not referred to her so far, Rhonna initializes private communication with her to encourage her and public communication to encourage the discussants to refer to each other. This combination enables the socialization of an out-group discussant into the discussion, in a delicate way and by avoiding any patronizing. Rhonna also (f) puts public focus on specific issues (substantial or problematic). The power of this strategy depends on the possibility to advertise it. The Remote Control Panel enables an array of moderator's interventions to catch the eye of the group persistently, until discussants catch the bait.

In the presentation we will also answer a third and central question*: Do e-moderation actions have some impact on the flow of synchronous discussions?* We will show that to some extent, the moderator could capitalize on the tools provided by the system and use them to evaluate the effectiveness of her past actions. We will conclude that the adaptive facilitation of multiple synchronous discussions is possible in classrooms. We will show then that this nascent practice with help in the organization of learning settings in classrooms that preserve group collaboration but give to the teacher a central role in moderating multiple discussions towards productive interactions.

Buds, flowers and fruit: potentialities for guidance in collaborative argumentation-based learning

Michael Baker

The title of this presentation is inspired from the following passage of Vygotsky's works, justly famous for the power of its imagery: "The zone of proximal development defines those functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in an embryonic state. These functions could be termed the "buds" or "flowers" of development rather than the "fruits" of development." (Vygotsky, 1935/1978, p. 86). Bruner's seminal work (Wood, Bruner & Ross, 1976) defined types of tutorial interventions that could guide (or "scaffold") and facilitate the processes whereby such buds could come to fruition. The relevant use of scaffolding strategies required the adult to be able to identify features of the individual learners' problem-solving behavior, such as focusing on the problem, progression towards the solution, motivation and emotion. The growing emphasis in the Learning Sciences research community on the study of collaborative learning in small groups raises problems for adaptive guidance of such groups of a quite different order of complexity from those encountered in individual learning. Whilst teachers guiding individual learning need to pay attention to problem-solving in specific domains, and individuals' emotional states, in group interactions, if there genuinely is collaboration, then problem solutions emerge from the interaction via processes that in some sense go beyond the sum of individual contributions. In many countries, teachers are simply not trained to be aware of and to identify the "buds" of potentially productive and constructive forms of interaction (Miyake, 1986; Baker, 1999).

In this paper, I begin by discussing potentially constructive forms of interaction, for a specific genre: argumentative interactions, arising during collaborative problem-solving in science, and pedagogically-oriented debates concerning societal questions. This focus is motivated by an extensive and growing literature on the role of argumentative interactions in the co-construction of knowledge (e.g. Coirier & Andriessen, 1999; Kuhn & Udell, 2003; Leitão, 2000; Andriessen, Baker & Suthers, 2003; Schwarz & Glassner, 2003; Muller-Mirza & Perret-Clermont, 2009). Within this research, three main families of such processes have been described. The first set of potentially constructive processes concerns changes in students' degrees of epistemic commitment ("change in view", Harman, 1986) towards the problem solutions that are proposed (for example, changes in belief and/or acceptance). The way that students' views change turns out to be radically different according to whether they 'care' or not about what is being discussed; in other words, whether the topic involves their value and idea systems (such as in the case of discussing human cloning) or does not (such as in working on the concept of energy in physics). In one case, students are often led to strengthen and deepen their views, as a result of argumentation; in the other, they proceed by elimination of flawed proposals (Baker, 2003). The second set of processes involves knowledge negotiation, building or co-construction of new solutions, during argumentation itself, or as a means of building new compromises. The third set involves cognitive-linguistic operations performed on fundamental concepts at stake in the debate, distinguishing concepts from each other (by "argument by dissociation"), and deepening the meaning of the questions being debated (Baker, 2002).

Such complex and subtle potentially constructive interactive processes are difficult for teachers — as for researchers — to identify. Indeed, teachers may need to set their understanding of students' interactive learning processes within a broader understanding of collaborative learning, whereby their guidance interventions as moderators of students' debates operate on at least three dimensions: effective *collaboration* (such as degree of shared participation, listening and uptake), *moderation of the debate* itself (adhesion to debate ground rules, coherence, progression towards a clear outcome) and providing or verifying *taught knowledge*. The problem of teachers' identification of dialogical learning potentials is further compounded by the prevalent *heteroglossia* (Bakhtine, 1929/1977) of students' discourses, which combine elements of school-based and everyday genres (Wertsch, 1991). This means that (to take an authentic example), although students' discussion of wearing makeup and doing body-piercing may not at first glance appear to provide an opportunity for adaptive guidance, it may do so if it is seen in the context of a discussion of what Nature is, in a debate about human cloning or genetically-modified organisms (Baker, 2009).

In the second part of the presentation, I shall present analyses of guidance interventions of teachers who are moderating students' synchronous on-line pedagogical debates (in the domains of physics problem-solving, and water preservation policies), together with the precise interactive contexts in which the interventions are produced. These will then be compared with the buds that could have been identified, had the teachers been aware of them. The presentation will conclude with reflections on how to train teachers to identify opportunities for adaptive guidance of students' pedagogical debates.

Selected References

Baker, M. J. (2003). Computer-mediated Argumentative interactions for the co-elaboration of scientific notions. In J. Andriessen, M.J. Baker & D. Suthers (Eds.) *Arguing to Learn: Confronting Cognitions in Computer-Supported Collaborative Learning environments*, pp. 47-78. Dordrecht, The Netherlands : Kluwer Academic Publishers.

Baker, M.J. (2009). Argumentative interactions and the social construction of knowledge. In N. Muller Mirza & A.-N. Perret-Clermont (Eds.) *Argumentation and Education: Theoretical Foundations and Practices*, pp. 127-144. New York: Springer.

Chiu, M. M., & Khoo, L. (2005). A new method for analyzing sequential processes. *Small Group Research*, *36*, 600-631.

Hmelo, C. & Barrows, H. S. (2008). Facilitating collaborative knowledge building. *The Journal of the Learning Sciences, 26*, 48-94.

Koedinger, K., Anderson, J., Hadley, W., & Mark, M. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education, 8*, 30-43.

Roscoe, R. D. & Chi, M. (2007). Understanding tutor learning: Knowledge-building and knowledge-telling in peer tutors' explanations and questions. *Review of Educational Research, 77*(4), 534-574.

Schwarz, B. & Glassner, A. (2003). The blind and the paralytic: fostering argumentation in social and scientific domains. In J. Andriessen, M. Baker, and D. Suthers (Eds.) *Arguing to Learn: Confronting Cognitions in Computer-Supported Collaborative Learning environments*, pp. 227-260. Dordrecht : Kluwer Academic Publishers.

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of child psychology and psychiatry*, 17, 89-100.

Scaling Practices of Spatial Analysis and Modeling

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Symposium Description

In this symposium we present recent research on spatial analysis and modeling as these forms of spatial thinking are practiced in the professions, and in interactions between professionals and public stakeholders. Our objective is to provide descriptive and comparative analysis of learning in this new socio-technical domain. Authors of a recent survey of research on learning and use of spatial thinking (NRC, 2006) argue that a wide variety of advances in science and technology made over the past century would have been unlikely or even impossible without innovations in ways of representing, analyzing, and thinking about spatial structure. Despite steady progress in basic cognitive research on how spatial thinking develops and is learned (Newcombe & Huttenlocher, 2000), there are many open questions about how people learn to think spatially across different domains (Liben, 2003), and equally, how forms of spatial analysis might contribute to what is taught in K-12 schools (Edelson, Gordin & Pea, 1999; Enyedy & Mukhopadhyay, 2007). Moreover, while there is some speculation about how new technologies might change spatial thinking (e.g., Uttal, 2000), there has been little research in this area.

Comparative case studies of doing and learning spatial analysis and modeling in professional work settings can provide new insights into how people learn spatial thinking, outside the psychological laboratory and in settings where spatial technologies and work practices are rapidly changing. In three case study papers, we ask on how professionals change scale and modality, strategically, while at work in different practices: physical anthropology, urban planning, and emergency medical communications. In each case, we ask how changes in scale and modality both extend the body over time and space, and bring disparate aspects of the world into the body as proximal, modality-specific experiences (Barsalou, 2008; Gallese & Lakoff, 2007). In each case, we consider problems of coordination (how are different scales and modalities layered together in practice), of learning (how are newcomers inducted into practice), and of innovation (how are new technical practices developed and incorporated into existing work practice).

Comparative case studies reported in this symposium use a common set of methods that focus on learning as changes in interaction, biography, and group history (Scribner, 1985). In each case, we engage in three study phases. In the first phase, we identify a project work group and collect ethnographic data, including semi-structured biographical interviews with central participants. In the second phase, we capture detailed video recordings of naturally occurring work sessions, and we index these by topics and events for further study. Selected episodes are transcribed for detailed interaction analysis. In the third phase, we conduct video-elicited interviews with central participants, asking for their (separate) understandings of episodes we have selected as critical in our analysis of their work and learning. Video recordings and video-elicited interviews provide material for our analysis of learning as changes in interaction, while biographical interviews and participant observation provide material for our analysis of learning as movement along professional trajectories.

Our analysis of professional practice follows from our recognition that abstractions such as 'scale' are made meaningful as situated constructs:

> 'scale' is rendered most meaningful in its development as an empirical generalization—a concept made real by building up an understanding of complex and dynamic relationships and processes in context.
> (Howitt, 2003, p. 151)

Moreover, our comparative analysis across cases allows our approach to develop and test theoretical constructs of scale-in-practice. Of particular focus in this symposium are the relationships of scale to the modalities of the body. In his examination of undergraduate physics students, Nespor (1994) considers how students, as physicists in training, "move out of everyday bodily space-time and into the textual space-time of the discipline" (p. 78). A progression from scales and modalities of the body to scales and modalities of representation is also generally supported in Actor Network accounts of scientific work (e.g., Latour's (1988) account of the circulation of textual "immutable mobiles").

However, across the present cases of professional practice we pursue a contrasting argument that asserts the significance of scales and modalities of the body across three forms of genesis of professional practice. In the microgenesis of routine professional practice, experienced or more 'full' (Lave & Wenger,

1991) members of practice engage in scale coordination and assembly that involve specific disciplinary relations of embodied scales/modalities with representational scales/modalities. In other terms, our spatio-temporal analysis makes evident how 'full' members of professional practices are "variably scaled" (Nespor, 2004) within particular practices of the body and coordinated practices of representation. In the ontogenesis of new members to practice, newcomers become "rescaled" through practice, by bringing particularly scaled histories to present practice and by learning new practices of scale coordination and assembly. Innovations to practice—the sociogenesis of new ways of working—also involve new relations among scales and modalities of the body and of representations. Resources and models from other disciplines or practices—differently scaled and with different modal relations—are often the engines of such transformation. Thus, our account across these diverse cases is not an argument concerning the replacement or loss of the body in representational practice; rather, we argue that the particular relations between embodied scales and modalities and representational scales and modalities, and the variable and extensibility of the "professional body" in these relations, provides an important and understudied account of professional practice.

Shifting Between Person, Structure and Settlement Scales in Anthropological Field Work

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In this paper we report from a study of a group of physical anthropologists, focusing on joint activity by the group's faculty leader (Tom) and one of his advanced graduate students (Wanda) as they worked to "ground truth" a model of colonial succession by walking through a settlement they were excavating in the highlands of Peru. In this and other work activities of this scientific group, researchers deliberately moved between different spatial scales and representational modalities, in support of analysis, modeling, and research management. Newcomers to the group tended to work on individual dwellings (structures) within the colonial settlement, restricting their contributions to excavation and digital stratigraphy of particular features. Over time, their work expanded in scale to include work across structures, and with full group membership, to model changes in related structures over time. As part of a modeling innovation, underway during our case study, new ways of showing cultural behavior at the settlement scale provided group members with new, embodied resources for making explanatory inferences about colonial succession.

Tom's research investigated changes in the built environment of an Incan settlement in 16th Century Peru as an instrument of Franciscan colonization. For Tom, a major disciplinary objective was to model relations between phenomena at structure-scale and settlement-scale for a group of people who lived centuries ago during a transition between Incan and Franciscan rule. His group studied the settlement for four years, excavating structures in the summer and organizing and analyzing data during the academic year. In typical work, students focused on one or two particular structures, digging, collecting, and documenting while in the field, and creating digital stratigraphic representations back at the university. At a national conference where the group presented, students reporting on their structure excavations, while Tom used their findings for his analysis at the level of the whole settlement.

In the most recent field season, the group returned to Peru for a variety of tasks, one of which was to "ground truth" paths between structures in the settlement. Their earlier maps of the settlement, derived from aerial photographs and field surveys, were not precise enough to support a modeling innovation under development by Tom as the lead investigator. Using methods borrowed from network analysis, Tom modeled movement through the settlement into a central plaza, keeping track of what residents of each structure could observe as their neighbors passed along least-effort paths to the plaza. This measure of "observational power" was calculated for each structure (household) in the settlement, and could be compared before and after architectural changes undertaken by the Franciscans. Not only were new buildings constructed and old buildings renovated under Spanish colonization, but a new plaza was also built. Tom conjectured that changes in the built environment had drastic effects on the daily lives of residents, changing their social status and relations of power within the settlement. However, to establish this new kind of modeling within the discipline, Tom had to insure that his maps correctly represented the location and orientation of each structure's doorway and paths between structures and the central plaza.

Tom and Wanda visited each structure and walked these paths in an effort to "ground truth" the settlement model. For one of the structures they visited, building that Tom and Wanda noticed that the original door, shown in their existing settlement model, had been blocked by a terrace for another building, and converted to a window. Tom reasoned that the terraced building must have been built later, blocking the original door, so a new doorway would have been built after architectural changes accompanying Franciscan rule. Wanda, standing at the remodeled door/window, immediately picked up on Tom's train of thought:

Wanda: So, I mean this would be a good one to look at changes from,=
Tom: [right
Wanda: [like earlier use, versus later [use
Tom: [yeah, yeah. Yeah=we could model this [as a doorway,
Wanda: [Model this one, and the [other one.
Tom: [and that one. Yeah. Yeah there's a doorway here.
Wanda: Uh huh. A::and, [that o::one,
Tom: [this is, one side and then this is the other side here.

Wanda related modeling the doorway and path for this particular building to the larger goal of the analysis, comparing the everyday experience of residents of the settlement before and after Franciscan colonial rule. As he listened to Wanda, Tom got increasingly excited, and evaluated (positively) her move into modeling at settlement scale ("yeah, yeah. Yeah"). They began to finish each other's sentences in overlapping talk, describing how to model earlier versus later use. The two then attempted to walk the path to the colonial plaza. After several starts and stops and consultations with a settlement map Tom was carrying on his laptop, Wanda exclaimed, out of breath, "When they rerouted it, in the colonial part? They like, you know, it was a pain in the ass for those people!"

As to the microgenesis of routine professional practice, this episode highlights the problem of coordinating representations of architectural structure and cultural behavior at different scales. While guided by a planimetric view of the settlement on his tough book computer, Tom and Wanda still struggled to find structures, paths, and architectural features at a (much needed) scale of walking between structures. On finding unexpected architectural features as impediments to their own mobility (a blocked door, paths interrupted by a terrace), Tom and Wanda rapidly expanded their analytical scale to that of the whole settlement (relationships between buildings) over a time period of colonial succession. The existing, flawed representation (in Tom's laptop) was coordinated with on the ground experience to repair the model and to imagine a new line of analysis.

As to the ontogenesis of members of the practice, Wanda's reasoning here operated at a scale larger than the individual structures she had excavated during previous field seasons. As the summer progressed, Wanda was well on her way to becoming a full participant in the discipline, exhibiting facility with shifting scales to reason about relations between structure and settlement scales. Also during the summer season, she found a new settlement in the highlands, which had not yet been excavated, and began to create settlement-scale maps that would support a dissertation project during subsequent summer fieldwork.

As to the sociogenesis of new ways of working, in this episode we see Tom and Wanda struggling to provide accurate architectonic data for a new, network modeling technique. Whereas earlier field work and analysis was devoted to finding architectural changes to individual structures, the "observational power" network analysis demanded that Tom strengthen his modeling of architectural features of individual structures (doorways) as well as the paths connecting these structures to the central plaza as part of the settlement's daily life under two administrative orders (Incan, Franciscan). Tom and Wanda used their bodies at walking, human scale, They walked among structures at the site, locating themselves in relation to other structures and within the map representation in the laptop, repeatedly shifting between structure and settlement scales to imagine changes in daily life for past-time residents. As both of their bodies stumbled through uneven and steep terrain and their breathing became labored, Wanda made a significant observation about a result Franciscan renovation, that it resulted in "a pain in the ass" for people who lived in parts of the settlement that lost more direct access to the plaza.

Changing the Structure of Planning Participation by Moving Across Scales

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This paper discusses how urban planners seek out and borrow innovative ways of coordinating scales from other planning departments across the nation to more successfully induct public participants into the planning process. Planners routinely imagine possible changes for communities and urban areas, but in an age of participatory planning, need public backing to leverage support from other governmental agencies involved in implementing change. Incorporating local residents and business owners into the planning process necessitates a new kind of scale coordination so that participants can eventually "see" their community as a planner. While maps at the planimetric scale are commonly used in public meetings and provide a visual of a large area that is not within reach of the body, some planners promote "charettes," or workshops, where residents and other stakeholders experience their community at a walking-scale, accompanied by a planner. Becoming intrinsic to the space under consideration is talked about by planners as having considerable advantages over extrinsically dominating the area as one does when viewing a map. This innovative technique of regaining the body at a walking-scale, and coordinating it with a representational scale in community workshops, is an effort to simultaneously instruct and construct a participating public in the "professional vision" (Goodwin, 1994) of urban planners.

The data for this paper is taken from a professional workgroup meeting occurring in a governmental planning department located in a medium-sized, mid-South city (Gotham). The purpose of the meeting is to discuss innovative ways in which other cities' planning departments have facilitated public participation in "community update" or "visioning" workshops. Currently in Gotham, these workshops have residents, business owners, and other stakeholders seated around a table-sized map that represents the community under review. Facilitated by a planner, each group of participants is urged to imagine possible changes for the community, and to point out aspects that should remain the same. Participants are encouraged to draw or write on the map with a permanent marker to make desires for their community visible for the duration of the meeting. Unfortunately, public participants spend a considerable amount of time in these visioning workshops trying to understand the model before them, asking about colors, symbols, and the locations of places that bear personal import.

While relying on maps and scaled representations of an area is commonplace in the practice of planners, these models tend to breakdown for newcomers and create more hurdles than supports for design. In response, five Gotham planners in a workgroup meeting were discussing ways to guide residents and business owners *into* the model, in the hope that conceptualizing space and imagining possibilities for that space might be easier. One innovation from a West Coast planning department was arranging a visioning workshop (or "charette") so as to feel more like running a shopping errand— entering a store, running into familiar faces, and having a chat. In this scenario, the planning workshop would take place in a local storefront, rather than in a church basement, and involve planners, business owners, and residents more informally discussing ideas for community change. A map of the community was close-by for referencing. Once a few ideas came to the fore, a planner would escort the participants into the street space for a stroll, also called a "site tour." The Gotham planner who first mentioned this idea, Tanya, states, "I always thought it would be interesting to take people out to the environment we're trying to change." It is during this site tour that planners could highlight for public participants the community characteristics of which they take notice, and vice versa. Another Gotham planner described the walking-scale charette as a way to "really be out there."

As to the microgenesis of routine professional practice, this episode demonstrates how incorporating a walk along a community's business corridor into the usual design review can coordinate embodied scale (the pace of walking, what can be seen) with much larger representational scales. Taking a walk down a familiar street with a planner might allow community stakeholders to insert their own experiences into the planner-created, representational view of that space. While coordination of embodied (intrinsic) views with planimetric (extrinsic) views comes naturally to planners, public participants in the planning process often struggle with this coordination. From the perspective of professional planners, providing public participants with a chance to experience proposed developments at a walking scale may help to convey planners' proposals. And because urban planning increasingly requires public input and support, providing these forms of coordination is increasingly important. In response, the planning department in our case was searching for techniques of scale coordination to invite new forms of public participation in urban planning.

In terms of the ontogenesis for members of the practice, Tanya's site tour idea (borrowed from another planning department) was quickly taken up by the other four planners. In interview she reported making "good" proposals for neighborhood developments, only to face staunch opposition from community residents who gave little evidence of understanding the proposal. Tanya's search for how other departments managed this problem identified a strategy that promised, at a personal level, to give Tanya a new way of working. She described her desire to transport members of a neighborhood association to another part of town where they could walk through and around a novel kind of development, as opposed to experiencing only pictures and maps. "Sometimes [residents] really have to see it to get the idea," she reported.

Regarding sociogenesis, or changes in the collective practice of planning, planners in Gotham already realized that the daily, embodied experience of residents living in a particular place, on a particular street, next to a particular house, was not well represented in the maps and models that they designed. As a proposed innovation in their practice, borrowed during a systematic search of other cities' visioning techniques, the storefront charrette promised to offer public participants a new way to experience the contrast between existing and proposed urban space. By partnering with local businesses to host street level activities in which planners and members of the public move between neighborhood scale maps and walking tours, these planners began to organize for a different way of constructing/instructing public input and political support for departmental initiatives. This new form of charrette extended to public participants many of the same changes in scale that planners typically rely on in their own work—shifts between an extrinsic perspective in plan views and an intrinsic perspective while walking through neighborhoods to imagine changes in the built environment.

Modality and Scale at AirMed

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In this paper, we report on findings from a study of the uses of multiple resources available for conducting time-sensitive and complex spatial navigational work in a technology-intensive environment. The site of our study is the flight communications center (FlightCom) at a large hospital (Hampton Hospital). We call the flight program at this hospital AirMed. FlightCom personnel coordinate the operations of four AirMed helicopters, one fixed-wing aircraft, and neonatal ground ambulances, creating what Suchman (1997) called a center of coordination. These modes of medical transportation service an area within 900 miles of the hospital.

Staffed around-the-clock by up to four communicators, FlightCom gives us an opportunity to study how spatial analysis relies on established routines, models, and technical infrastructure while also being conducted on the fly. Spatial problems at FlightCom, which must be approached in a time-sensitive manner, include making precise determinations about where to send a helicopter using a range of resources (e.g., geographic information system (GIS) databases and on-the-ground information from medical crews, which is often unreliable), using multiple modalities to coordinate communications among several helicopters sharing the same airspace, and coordinating communications among medical personnel at various locations and across time and distance.

Cases of spatial analysis and modeling typically emerge at FlightCom when calls come in from area emergency dispatchers requesting that a patient be transported as quickly as possible from one location (e.g., the scene of an accident, a referring hospital) to another location (e.g., Hampton Hospital, another local hospital). Flight communicators regularly solve the spatial problems presented to them within each case by coordinating available resources to ensure that the helicopter flies safely to the scene, locates a landing zone, and returns with the patient. At FlightCom, the three forms of genesis of professional practice that form the foundation of our symposium are evident in the scale coordinations and assembly of experienced flight communicators, the way that newcomers' practices are rescaled across their work histories, and innovations to the practices of flight communication involving new practices of the body and representation.

As to the microgenesis of routine professional practice, experienced flight communicators perform complex scale coordination and assembly work across each case they encounter, expertly varying practices of coordination and assembly across embodied and representational resources according to the demands of the case. In one case of "routine trouble," Dennis, one of the flight communicators, received a phone call informing him that an AirMed helicopter was needed at a regional hospital with known GPS coordinates. After Dennis relayed this information to one of the AirMed helicopter teams and they were in the air, the dispatcher called back to request that the helicopter land at the scene of the emergency, an ATV accident in a rural area. Based on street names supplied by the dispatcher, Dennis used an off-the-shelf location-finding software to locate the landing zone (LZ) and determine GPS coordinates, which were then relayed to the helicopter and punched into a computer-aided dispatch software tool that follows the helicopter in flight. Within a few minutes, the helicopter pilot reported back that they had been in communication via radio with the ambulance crew on the ground at the scene of the accident and received a different set of coordinates for the LZ. Dennis got on the phone again with dispatch, confirmed his coordinates by checking the cross-street information again and then asked the dispatcher, "Is any uh significant uh ground features or anything that I need to look for out there?" Receiving this information, Dennis reported back to the helicopter pilot, who was able to locate the scene of the accident.

In this episode, Dennis worked across multiple scales and modalities to assemble the landing zone—across, for example, multiple communication channels (i.e., phone and radio) and representational resources (i.e., off-the-shelf location finding software, GPS coordinates, specialty helicopter-following software) at various scales (e.g., street-level, level of ground features visible from a helicopter a thousand feet in the air, 900-mile radius of AirMed flight coverage). This work exemplifies scaling processes that extend the body and incorporate the world, showing the complexity of routine work of spatial analysis and modeling by experts in this professional setting.

As to the ontogenesis of new members to practice, the practices of newcomers are rescaled from their previous work histories to perform flight communication practices at FlightCom. Flight communicators are required to have at least two years of emergency medicine experience on the ground (e.g., as an EMT or a dispatcher for a local ambulance operation) prior to working for AirMed. Thus, over time as a flight communicator moves from on-the-ground medicine to an overhead view coordinating flights, practice is rescaled from on-the-ground scales to more expansive scales: navigational practices for finding sites of emergencies along local road networks in an ambulance shift to an overhead regional perspective of a 900-mile airspace and ground radius. This overhead perspective consists of an assembly of representational resources including paper and digital maps, communication resources for contacting helicopter pilots and nurses in flight as well as on-the-ground emergency dispatchers near the site of the emergency, and real-time tracking of helicopters in flight. Although flight communicators have at their disposal an array of representational resources, they continue to draw on their embodied knowledge gained from years on the ground as well as the embodied knowledge of other flight communicators in the room. For example, as flight communicators like Dennis work through episodes of routine trouble in assembling sometimes shifting landing zones, they often rely on embodied knowledge of local roadways, names, and routes gained from driving and riding in ambulances prior to coming to FlightCom. Over the course of work histories, flight communicators are cultivated as teams of professionals who can flexibly operate at multiple scales to complete their work. Embodied scales maintain their importance as a resource-to-be-called-upon in the complex practices of scaling at FlightCom.

As to the sociogenesis of new ways of working, we have observed innovations to the practice of flight communication involving new practices of the body and representation. At FlightCom, communicators not only track AirMed helicopters, but also those owned and operated by other companies that fly in and out of Hampton Hospital. These other helicopters are not equipped to be tracked in real time at FlightCom and so communicators have created innovative practices that aid in keeping all aircraft coming in and out of the hospital and in surrounding flight space safe. One of these innovations is the recent addition of a physical map zoomed in to the downtown Langdon area. The map is located under plexiglass on a table that sits between two communicators. On top of the plexiglass are small tokens that represent helicopters and can be moved as these helicopters move around Langdon. The communicators also use a grease pencil to mark the path of these helicopters as their locations are reported by their pilots (e.g., from a neighboring hospital to the airport to fuel up). This embodied resource is coordinated with other innovations that utilize representational resources and operate at other scales (e.g., the "shadowing" of non-AirMed helicopters on flight-following software by approximating their arrival times and flight paths).

References

Barsalou, L. W., Simmons, W. K., Barbey, A. K. & Wilson, C. D. (2003). Grounding conceptual knowledge in modality-specific systems. *Trends in Cognitive Sciences, 7*(2), 84-91.

Edelson, D.C., Gordin, D.N., & Pea, R.D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences, 8*(3/4), 391-450.

Enyedy, N., & Mukhopadhyay, S. (2007). They don't show nothing I didn't know: Emergent tensions between culturally relevant pedagogy and mathematics pedagogy. *Journal of the Learning Sciences, 16*(2), 139-174.

Gallese, V. & Lakoff, G. (2005). The brain's concepts: The role of the sensory-motor system in conceptual knowledge. *Cognitive Neuropsychology, 22*(3/4), 455-479.

Goodwin, C. (1994). Professional vision. *American Anthropologist, 96*(3), 606-633.

Howitt, R. (2003). Scale. In Agnew, J., Mitchell, K., & Toal, E. (Eds.), *A companion to political geography* (pp. 138-157). Malden, MA: Blackwell.

Latour, B. (1988). Drawing things together. In M. Lynch & S. Woolgar (Eds.), *Representation in scientific practice.* Cambridge, MA: MIT Press.

Liben, L. S. (2003). Extending space: Exploring the territory of spatial development. *Human Development*, *46*(1), 61-68.

National Research Council of the National Academies (2006). *Learning to think spatially: GIS as a support system in the K-12 curriculum.* Washington, DC: The National Academies Press.

Nespor, J. (1994). *Knowledge in motion: Space, time, curriculum in undergraduate physics and management.* London: The Falmer Press.

Nespor, J. (2004). Educational scale-making. *Pedagogy, Culture, and Society, 12*(3), 309-326.

Newcomb, N. S., & Huttenlocher, J. (2000). *Making space: The development of spatial representation and reasoning.* Cambridge, MA: MIT Press.

Scribner, S. (1985). Vygotsky's uses of history. In J. V. Wertsch (Ed.), *Culture, communication, and cognition: Vygotskian perspectives* (pp. 119-145). Cambridge, UK: Cambridge University Press.

Suchman, L. (1997). Centers of coordination: A case and some themes. In L.B. Resnick, R. Säljö, C. Pontecorvo, & B. Burge (Eds.), *Discourse, tools, and reasoning: Essays on situated cognition* (pp. 41-62). Berlin: Springer.

Uttal, D. H. (2000) Seeing the big picture: Map use and the development of spatial cognition. *Developmental Science, 3*(3), 247-286.

Learning about Dynamic Systems by Drawing

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Abstract: The act of drawing as a means of publicly presenting one's ideas is not *cognitively neutral*. Drawing, perhaps in a way that is somewhat like self-explanation, influences knowing and learning. It can help learners evaluate and transform their understanding, help them communicate their ideas, and be a motivating and highly engaging way to process and express scientific concepts. Asking learners to draw when they are exploring dynamic systems can be highly beneficial. Yet analyses of drawings may depend on learners' accompanying speech and gestures. Learners also benefit from pedagogical and technological support in making drawings that support modeling. This symposium draws together research on how people use drawings when learning about dynamic systems. It explores different theoretical frameworks for analyzing drawings, their impact, interactions with prior knowledge, and the different roles drawing can play in learning and asks how learning by drawing can be enhanced.

Introduction

Asking learners to draw when they are exploring complex ideas is not cognitive neutral. In fact, previous work (e.g. Gobert & Clement, 1999; Kress, Jewitt, Ogborn, & Tsatsarelis, 2001; Prangsma, Van Boxtel, & Kanselaar, 2008; Van Meter & Garner, 2005) as well as some of the papers presented in this symposium suggest the act of drawing can be highly beneficial. Yet, compared to our knowledge of how people learn by interpreting text (reading) and pictures (viewing), or by constructing text (writing) or speech (verbal reporting) we know relatively little about how drawing affects learning. Consequently, the focus of this symposium aims to redress this balance a little by increasing our understanding of how knowledge and learning about dynamic systems is influenced by drawing.

Dynamics systems such as the workings of the circulatory system, the process of chemical reactions or the thermodynamics of the earth are an ideal arena in which to explore how drawing shapes learning. Such topics are complex for students to understand and there is much evidence to suggest that learners need support to develop deep knowledge of these systems. Researchers have therefore explored how different forms of representation can help learners develop this knowledge. Rather than a simple textual presentation, learners have been provided with pictures, animations, interactive simulations and even augmented reality environments to help them understand dynamic systems (e.g. de Jong & Ban Joolingen, 1999; Hegarty, Kriz & Cate, 2003; Ohlson, Moher & Johnson, 2002). In contrast, in this symposium we have focused not on the representations that are provided for the learner but on the graphical representations that learners construct for themselves.

The paper by Zhang and Linn addresses how learners can be helped to understand the processes involved in chemical reactions by interacting with a dynamic visualization of atomic interactions in hydrogen combustion. Subsequently, learners either drew four intermediates phases of hydrogen combustion or selected four appropriate pictures. Whilst both techniques supported learning, the relative effectiveness of the strategies was dependent on student's prior understanding. Zhang and Linn suggest that drawing helped learners to distinguish their ideas about chemical reactions, helping those with low knowledge realize this lack and prompt them to overcome it whereas selecting existing pictures prompts students with some higher knowledge of develop and extend their ideas.

Ainsworth explores how learners can be helped to draw more effectively. She reports on a series of small experiments whereby students learn about the structure and the functions of the cardio-vascular system by drawing after reading texts. Two different approaches have been trialed: a) encouraging constructive processing of the text by self-explanation prior to drawing; and b) altering the audience and function of the intended drawing by asking learners to draw for themselves, a peer or draw a self-explanation.. Analysis of these studies is on-going but so far shows that these approaches alter the drawings that students make and this may further impact on learning.

Nathan & Johnson also ask learners to draw the human circulatory system. However, the focus of their work is on exploring the limits of drawing as a mode of expression, especially when learners need to convey a dynamic, three dimensional process in a static two dimensional form. They show that our understanding of learners' drawings in enhanced if we treat them as instances in a multimodal system and that the gestures and speech that accompany a drawing are a crucial part of this system.

The last paper in the symposium is by Van Joolingen and colleagues. They focus on learning dynamic systems through modelling. Drawing is shown to be valuable in two ways. Firstly, it can help learners prepare for the modelling task by requiring them to be explicit about the variables in their model activating prior knowledge and acting as a constraint on the solution. Secondly, a drawing, if constructed using specific formalisms, can act as the model without further transformation.

The papers in this symposium were selected to address a number of major issues in the area of drawing to learn. The first issue explored is the varied roles drawing plays in learning. Across the papers, we see drawing used as preparation for learning new ideas, during reading about new concepts, as a way of reflecting on presented material, and for communication and assessment. Secondly, the researchers highlight the cognitive processes that drawing supports. Properties of drawing as a medium itself as well as the socially compelling drive to be understood by other interlocutors shape the process and outcomes of drawing. Taken together, the papers suggest that drawing helps learners make their ideas explicit, perhaps in a way that is analogous to self-explanation, so that they are able to overcome gaps in the material or generate new inferences. A third important unifying theme is the way that the papers do not treat drawing as a 'black box'. Rather than asking "Does drawing support learning?" they explore questions such as "What ideas are conveyed by a drawing?" and "How does drawing support learning?" by analysing the characteristics of learners who benefit from learning, how the nature of the representations reveal learners' conceptualization of the domain, how learners' transform their understanding across modes of representation, whether that transformation predicts learning, and how drawings can be understood as part of a multi-modal construction.

There are, however, important differences between the approaches described in the papers. Drawing has been conducted either free hand with pen and papers or with computer-based tools. It has been done solely for the purposes of a learners' own understanding, to communicate with other people, or to provide input for a computer model. Implicitly, there are differences in the theoretical frameworks the authors use to situate their work that should contribute to a lively interaction among presenters and members of the audience. These common threads and divergent points of view will inform the discussion offered by Peggy van Meter.

Interest in research on the nature of drawing and evidence of learning by drawing is growing in the Learning Sciences. This symposium offers a timely opportunity to reflect upon a research agenda for learning by drawing. By contrasting these four diverse perspectives we can explore which theoretical approaches/models should inform our understanding of learning by drawing, such as characteristics of learners, tasks and the social and technological environments within which drawings are constructed and explained. We can also gain purchase about broad concerns about how to analyze drawings, as well as questions such as how drawing shapes and is in turn shaped by cognitive structures that mediate drawing to learn and communicate. As a consequence we will be in a better position to understand how we should support learners as they draw to learn, and researches interested in analyzing data from drawing tasks.

How can selection and drawing support learning from dynamic visualizations?

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When students generate drawings it helps them learn from expository text (Van Meter & Garner, 2005) and from scientific visualizations (Zhang & Linn, 2008). Generating a drawing requires students to select information, to distinguish this information from their existing views, and to represent connections among the selected elements. Dynamic visualizations support chemistry learning because they illustrate interactions at the molecular level (Ardac & Akaygun, 2004; Kozma, 2003; Williamson & Abraham, 1995). Yet students often find them difficult to follow and neglect nuanced information such as bond breaking and formation. Learners need guidance to help integrate ideas about molecular interactions and link with observable and symbolic ideas. Our previous study demonstrated that students who generated drawings when using dynamic visualizations can integrate more ideas than those who learned only with visualizations. To further clarify the mechanism of drawing, this study compares selection among drawings and generating drawings to help students learn chemistry with dynamic visualizations.

Students studied chemical reactions using the WISE (Web-Based Inquiry Science Environment) *Hydrogen Fuel Cell Cars* project designed following the Knowledge Integration framework (Linn & Hsi, 2000). Students interact with a dynamic visualization showing atomic interactions during hydrogen combustion (see Figure 1) for a screenshot of the visualizations) and integrate symbolic, molecular, and observable ideas to understand hydrogen fuel cell cars. Drawing and selection occur after the visualization step. The drawing activity requires students to generate four pictures to represent intermediate phases of hydrogen combustion using the WISE drawing tool. In selection, students select four drawings among twelve to model the reaction processes. We hypothesized that drawing helps students learn from the visualization because it encourages them to distinguish among ideas and enables them to realize flaws in their previous interpretations. The selection activity also requires distinguishing among ideas.

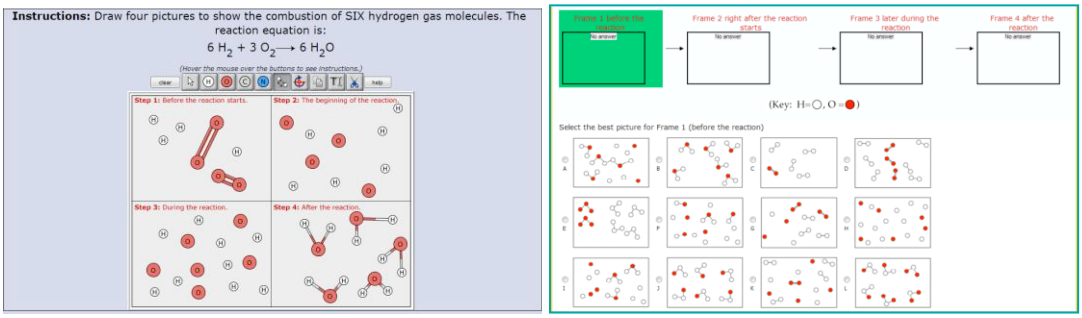


Figure 1 Left: a screenshot of the online drawing tool. Students create four pictures to represent four intermediate phases during hydrogen combustion; Right: a screenshot of the selection activity. Students select four pictures from twelve to represent four intermediate phases during hydrogen combustion.

Eighth graders (N=172, six classes) in a public middle school were assigned to either drawing (n=83) or selection (n=89) conditions. Students in both conditions spent 40 minutes interacting with the visualization and working on the drawing or selection tasks as part of the week-long project. Comparing student performance on the posttest with pretest as covariate shows that both groups gained understanding [$t(171)=21.45$, $p<.0001$, effect size=1.64] and performed equally well [$F\ (1,\ 169)=1.72$, $p=.19$]. This suggests that both drawing and selection support student learning.

Using pretest drawing performance, we grouped students based on knowledge integration rubrics (Figure 2). We found that selection and drawing have similar impact on students with high [$t(16)=.36$, $p=.73$] and low [$t(80)=.78$, $p=.44$] levels of integrated ideas before the project. For students with partially integrated ideas (medium level), drawing is less effective than selection [$t(71)=2.25$, $p<.05$].

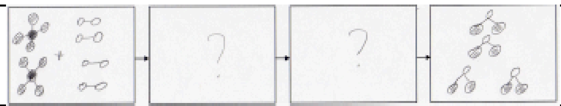
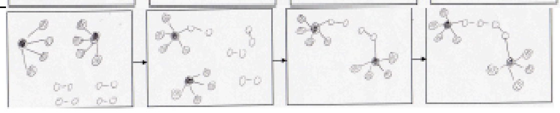
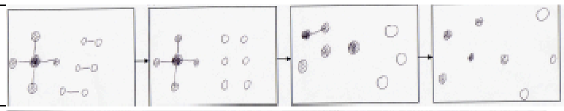
KI Levels	Student ideas	Descriptions	Student sample answers
Low	No/Wrong ideas	Incorrect ideas about reactants & products, no idea about the reaction process.	Leave all boxes blank, or draw reactants and products incorrectly
	Instantaneous view	Represent reactants and products correctly, but no ideas about the reaction process.	
Medium	Big Molecular view	Have the idea of bond formation but explain the reaction as all molecules and atoms forming into one big molecule as the end products.	
	Breaking view	Have the idea of bond breaking but represent the reaction as all molecules try to break bonds and the end products are separated atoms moving freely.	
	Exchanging view	Have the idea of molecular rearrangement but represent the process as exchanging atoms between molecules.	
High	No conserve	Have the ideas of bond breaking and formation, and represent them correctly. But the drawings don't show conservation of matter.	
	Correct	Correctly represent bond breaking and formation using molecular representations. All drawings follow the conservation of matter law.	

Figure 2. Categorization of students' ideas about chemical reaction processes on the pretest. The sample answers are collected from students' answers to a question asking to draw 4 pictures to represent how methane combustion occurs at the molecular level.

Overall this study reveals that it is crucial to encourage students to distinguish among ideas when learning with visualizations. Drawing prompts learners to distinguish among ideas currently in their repertoire. For students who started with incorrect or no ideas about chemical reactions, drawing enables them to realize the insufficiency of their previous understanding and prompts them to revisit the visualization for new ideas. For students who had some correct ideas, selection requires them to analyze new ideas represented in the choices and distinguish among their own ideas and new views. Compared to drawing, selection may add ideas and enable students to develop criteria for distinguishing ideas.

Improving learning by drawing

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Drawing to learn can be a very successful way to help learners engage with complex concepts. For example, it can help people observe, plan writing, improve memory, reduce anxiety, increase motivation, *etc* (Van Meter & Garner, 2005). However, Leutner, Leopold & Sumfleth (2009) found that drawing after reading significantly decreased performance. Moreover, research shows that learners benefit from support during drawing. The form this support has taken includes task instruction to focus on specific aspects of the task (Alesandrini, 1981), providing pre-existing materials such as scenes and cut-outs (Lesgold, Levin, Shimron, & Guttman, 1975) or complete drawings for learners to compare with their own (Van Meter, 2001). This often leads to improved outcomes. For example, Van Meter, Aleksic, Schwartz, & Garner, (2006) compared children learning from a science text when they either read an illustrated text, read then drew, read, drew and then saw illustrations or finally read, drew and saw illustration combined with prompts to compare to their own drawings. Sixth grade children how received support in the drawing process outperformed students in the other conditions on tests of problem solving knowledge. However, studies such as these are unclear as to the extent to which the benefits come from active interpretation of multiple representations (itself often associated with improved learning, . Ainsworth, 2006). Consequently, this paper summarises studies which have explored whether learning by drawing from written text which describe the structure and function of the cardio-vascular system can be improved without providing additional pictures. Two different approaches have been trialed: a) encouraging active processing of the text prior to drawing; and b) altering the audience of the intended drawing.

There are many ways to improve text comprehension but one strategy that has been found to be particularly effective is that of self-explanation (e.g. Chi, 2000). When learners self explain, they go beyond the information in the written text to generate inferences that help them construct new knowledge. Self explanation thus helps learners to overcome gaps in the presented material or helps them build more accurate and complete mental models. A drawing of self-explained text may then reflect this new knowledge in an external and consequently inspectable visualisation, leveraging graphical representations known benefits of computational offloading (e.g. Scaife & Rogers, 1996) which could in turn prompt new self-explanations (e.g. Ainsworth & Loizou, 2003). Additionally, drawings due to their specificity and perceptual advantages may provide learners with complementary insights to those provide by the self-explanation process. Examples from a pilot study are shown below which suggest that self-explanation may indeed support drawing as those constructed after self-explanation are typically and contain more transformations of the original text .

a b c D

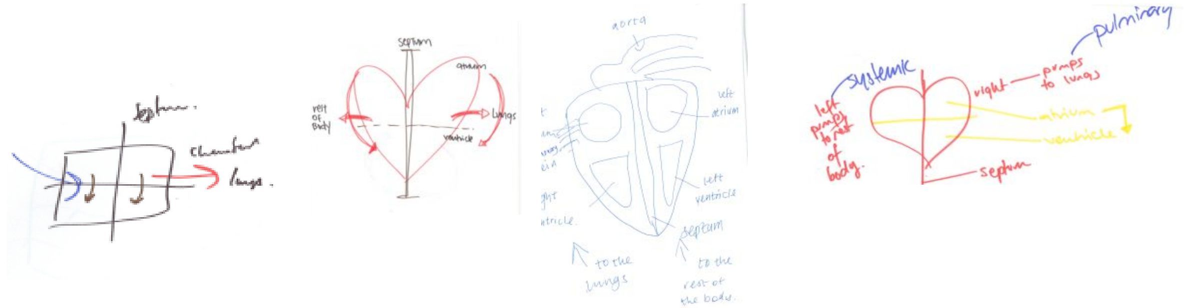

Figure 3. Drawings created by 4 participants a & b) drawing and c & d) SE + drawing conditions after reading "*The septum divides the heart lengthwise into two sides. The right side pumps blood to the lungs, and the left side pumps blood to other part of the body. Each side of the heart is divided into an upper and a lower chamber. Each lower chamber is called a ventricle. Each upper chamber is called an atrium. In each side of the heart blood flows from the atrium to the ventricle*"

The second series of studies have taken their inspiration from researchers who have studied writing as they have long recognised that the social context of the writing (including a writer's collaborators and their intended audience) will shape the process and outcomes of writing (Flower & Hayes, 1981). However, in the context of drawing this has received relatively little attention to date (although see Schwartz (1995) for an exception whereby drawers who worked in dyads created more abstract visualisations than those who worked alone). My research has asked learners to draw an explanation for themselves, for a peer or has asked them to draw a 'self explanation' for themselves (a self-explanation diagram follows a similar protocol to a verbal self-explanation in that it asks learners to go beyond the text to generate new inferences).

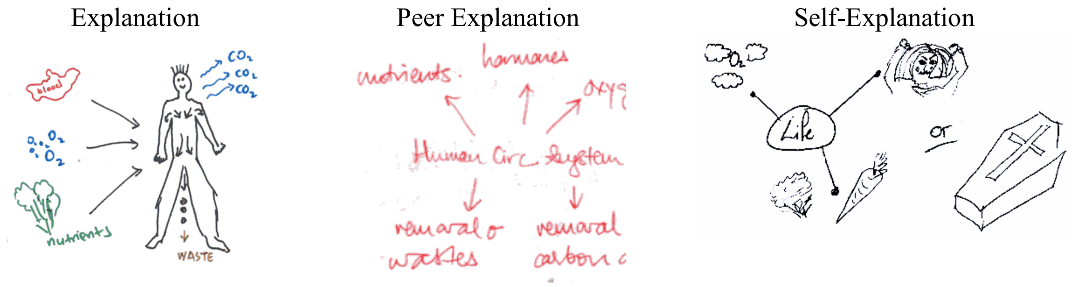

Figure 4. *Shows three drawings created after students read "Human life depends on the distribution of oxygen, hormones and nutrients to the cells in all parts of the body & the removal of carbon dioxide and other waste".*

Analysis of the pilot studies suggest that all three forms of instruction help students learn (although as they were conducted with slightly different materials and tests no direct comparisons can be made as to their relative effectiveness). It also suggests that distinctly different drawings emerge in the three different conditions. Explanations created for peers (rather than for oneself) tend to be judged as clearer and contain both more content and more words. Explanations created as 'self explanations' whilst not necessarily representing more content, do include more inferences and even indications of monitoring (ticks and question marks added to the diagram. Typically, learners who create self-explanation diagrams first directly translate the text content to the diagram and then either annotate or amend the diagram to contain these inferences.

These preliminary studies suggest that learning by drawing can be supported by strategies that encourage learners to actively process the material and then reflect their new understanding in the drawing. Current research is now extending these studies by gathering systematic evidence on the relation between different forms of support for drawing, the process of drawing and learning outcomes.

Drawing Inferences about Students' Mental Models of Dynamic Processes Depicted in Scientific Drawings: The Role of Gestures and Speech

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Drawings are commonly used in the assessment (e.g., Magnusson, Krajcik & Borko, 1999) or spontaneous articulation of scientific knowledge (e.g., Kinfield, 1993). As an activity, drawing has been shown to enhance some forms of learning and comprehension (Ainsworth et al., 2007; Gobert & Clement, 1999; Van Meter & Garner, 2005; Zhang & Linn, 2008). Yet learners regularly bump up against inherent constraints of the static, two-dimensional medium for conveying three-dimensional information and time-varying, dynamic processes, and of the producer's performance level for veridically depicting one's ideas. For example, in order to establish common ground, interlocutors may insist on modifications and standardizations to drawings used during collaborative problem solving (e.g., rules of linear perspective; Nathan, Eilam & Kim, 2007).

We were explicitly interested in the ways that college students learning about a scientific system of moderate complexity, the circulatory system, used drawings to depict their understandings after a self-guided (approx. 25 minutes), computer-based tutorial (following Butcher, 2005). Our analysis here focuses on how gesture and speech were employed in the service of the drawings as students explained them to an observer. We report here on the findings from two participants (supplemented by video in the presentations.)

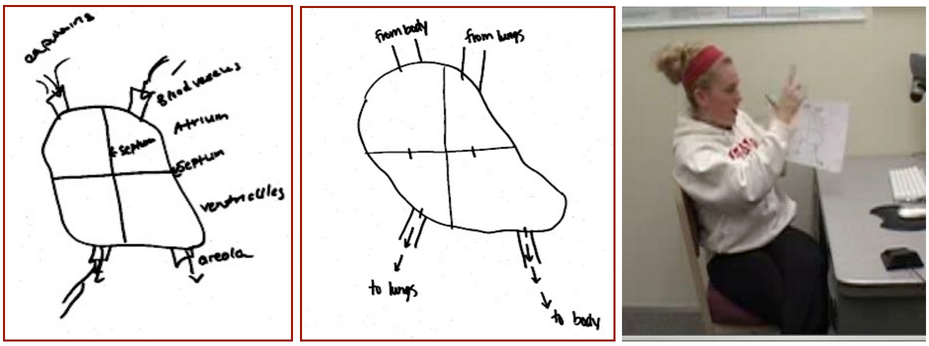

Figure 4. (a) A simple drawing with no dynamic processes conveyed by gesture. (b) A simple drawing that a student uses to provide (c) a simulation of the intended flow of blood to the body using gesture and speech ("And then this blood that from the right ventricle goes to the lungs. And then back into the heart from the lungs through this vein.")

Students may produce simple drawings that are similar in appearance (Figure 4) but mask wildly different mental models of the circulatory system. Figure 4a (Student A27) shows arrows entering the right and left atria at the top and arrows exiting the ventricles at the bottom. While pointing gestures index drawn and labeled elements such as the chambers and walls, no explanation of a time-varying process is provided, resulting in a very low score for the model (2 points out of 6). In contrast, Figure 4b (Student A14) shows a very similar drawing, with less detail (no labels) but through gesture and speech provides a rich account of the blood flow following two distinct pathways (from heart to lungs and back, and from heart to body and back) that receives a high score (6 out of 6 points). As Figure 4c shows, A14's gestures dynamically simulate blood flow to components of the system (e.g., lungs, body) that are not present in the drawing, but are invoked by gestures that move beyond the boundaries of the page.

Several insights emerge from the analysis of students' drawings and explanations. Methodologically, drawings are only a part of a student's rich, multimodal construction and must therefore be assayed in the context of the associated verbal and nonverbal information. Other examples show that even elaborate diagrams with arrows and labels suggesting the occurrence and direction of dynamic processes have limited assessment value without co-expressive gestures and utterances. As part of an emerging theory of the nature and functions of drawings for knowledge assessment, we find that these multimodal constructions (*psychological units* to Vygotsky, 1986; *growth points* to McNeill, 1992; *composite signals* to Engle, 1998; and *semiotic nodes* to Radford et al., 2003) are particularly evident when conveying time-varying phenomenon and causal relations.

Interactive drawing tools to support modeling of dynamic systems

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Dynamic computer modelling is a valuable way to learn about complex dynamic systems (Löhner, van Joolingen, Savelsbergh, & van Hout-Wolters, 2005; Spector, 2000). In a modelling task, students create an executable model in order to build and express their understanding of scientific phenomenona. Once the model is built, the data it produces can be compared to the expected or observed behaviour. The model can be modified depending on the outcome of this evaluation (Penner, 2001). Despite its benefits modelling is often experienced as difficult for students. For instance, students often fail at successful modelling behavior, because they do not use their prior knowledge while working on an inquiry modelling task (Sins, Savelsbergh, & Van Joolingen, 2005). Such observations highlight the need to support the modelling process. In the present paper, descriptions of drawing sketches of the modelled system as a means to support modelling are presented. Two approaches can be distinguished: drawing to prepare the model and drawing the model itself.

When drawing to prepare the model, a sketch serves a supporting and assisting role prior to "real" modelling. A sketch can be used to identify relevant variables and relations between variables. Figure 5 displays a sketch of a water tank that is then converted into a System Dynamics model. The drawing helps the learner to identify the relevant variables in the system, such as water level and outflow. These variables can then be converted into variables in the model. The drawing helps in this way with activating prior knowledge, and in constraining the model, based on the drawn elements. A sketch-based modelling tool can provide support in transforming a sketch into a model for instance by labelling model elements in the drawing.

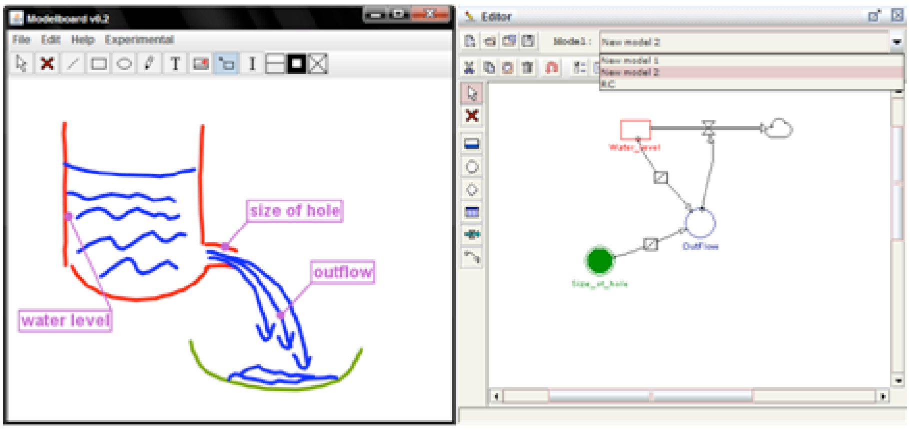

Figure 5. A sketch as a preparation for a (System Dynamics) model.

In order to investigate the suitability of this approach, we asked 68 students in upper secondary school to create drawings about the thermodynamics of the Earth: the earth is heated by the sun, making the earth radiate heat that is absorbed by the atmosphere, resulting in an equilibrium temperature. Close analysis of these drawings, identifying drawing elements and using principle component analysis shows that drawings give clear indications of learners' main views on heat and temperature, diverging into a radiation view and a heat transport view (Kenbeek, Van Joolingen, & De Jong, submitted), yielding complementary sets of variables to include in the model. Apparently drawing guide learners in making their views on the domain more explicit.

Alternatively, the learner-created sketch can be regarded as a model in itself. The drawing will not be transformed into another representation, but it is fully qualified as a learner's external representation of a phenomenon. In this case the drawing must adhere to some formal aspects, such as clear identification of objects in the drawing and their properties. Forbus and Usher (2002) put the burden of doing this with the learner who needs to identify the start and end of drawing and object (glyph in their terminology) and select a term from an ontology to describe the object. The approach presented here automates object identification by clustering strokes based on time, position, color and weight. A 95% agreement with human raters is reached using this method based on a set of drawings created by 37 students on two domains, a toy car (e.g. Figure 6) and a heating system (Leenaars, Bollen, & Van Joolingen, submitted). Sketch recognition techniques (Paulson & Hammond, 2008) can then assist object identification which can result in a formal model.

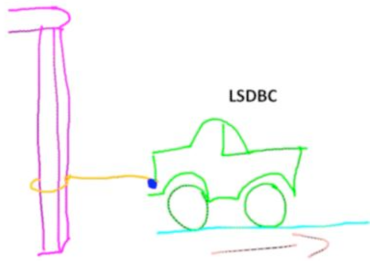

Figure 6. Drawing of the toy car system. Colors indicate automatic clustering results.

These two approaches provide a promising outlook on the use of drawings to support the complex task of modelling. The drawings collected in the two studies – for different purposes and in different domains, show that they are interpretable and give insight in learners' ideas about the domain modelled. Together the two approaches form a set of stepping stones that can be used to support the development of a modelling competency by novice modellers.

References

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. Learning and Instruction, 16(3), 183-198.

Ainsworth, S. E., & Loizou, A. T. (2003). The effects of self-explaining when learning with text or diagrams. Cognitive Science, 27(4), 669-681.

Alesandrini, K. L. (1981). Pictorial—verbal and analytic—holistic learning strategies in science learning. *Journal of Educational Psychology, 73*, 358-368.

Ardac, D., & Akaygun, S. (2004). Effectiveness of multimedia-based instruction that emphasizes molecular representations on students' understanding of chemical change. *Journal of Research in Science Teaching, 41*(4), 317-337.

de Jong, T., & van Joolingen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research, 68(2)*, 179-201.

Chi, M. T. H. (2000). Self-explaining expository texts: The dual processes of generating inferences and repairing mental models. In R. Glaser (Ed.), *Advances in instructional psychology* (Vol. 25, pp. 161-238). Mahwah, NJ: LEA.

Engle, R. A. (1998). Not channels but composite signals: Speech, gesture, diagrams and object demonstrations are integrated in multimodal explanations. In M. A. Gernsbacher & S. J. Derry (Eds.), *Proceedings of the Twentieth Annual Conference of the Cognitive Science Society* (pp. 321-326). Mahwah, NJ: Erlbaum.

Flower, L., & Hayes, J. R. (1981). A cognitive process theory of writing. College composition and communication, 365-387.

Forbus, K. D., & Usher, J. (2002). *Sketching for knowledge capture: A progress report.* IU'02, San Francisco.

Gobert, J., & Clement, J. (1999). Effects of student-generated diagrams versus student-generated summaries on conceptual understanding of causal and dynamic knowledge in plate tectonics. *Journal of Research in Science Teaching, 36*(1), 39-53.

Hegarty, M., Kriz, S., & Cate, C. (2003). The roles of mental animations and external animations in understanding mechanical systems. *Cognition and Instruction,, 21*, 325-360.

Leenaars, F., Bollen, L., & Van Joolingen, W. R. (submitted). Facilitating model construction during inquiry learning with self-generated drawings.
Lesgold, A. M., Levin, J. R., Shimron, J., & Guttman, J. (1975). Pictures and young children's learning from oral prose. *Journal of Educational Psychology, 67*, 636-642.
Leutner, D., Leopold, C., & Sumfleth, E. (2009). Cognitive load and science text comprehension: Effects of drawing and mentally imagining text content. Computers in Human Behavior, 25(2), 284-289.
Linn, M. C., & Hsi, S. (2000). *Computers, Teachers, Peers: Science Learning Partners*. Mahwah, NJ: LEA.
Löhner, S., van Joolingen, W. R., Savelsbergh, E. R., & van Hout-Wolters, B. (2005). Students' reasoning during modeling in an inquiry learning environment. *Computers in Human Behavior, 21*, 441-461.
Kenbeek, W. K., Van Joolingen, W. R., & De Jong, T. (submitted). Representational drawings as a scaffold for dynamic computer modelling.
Kindfield, A. (1993/1994). Biology diagrams: Tools to think with. *The Journal of the Learning. Sciences, 3*, 1–36.
Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learning and Instruction, 13*(2), 205-226.
Kress, G., Jewitt, C., Ogborn, J., & Tsatsarelis, C. (2001). *Multimodal Teaching and Learning: the rhetorics of the science classroom (London, Continuum).* London: Continuum International Publishing Group.
Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. Lederman (Eds.) *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-132). Dordrecht: Kluwer Academic Publishers.
McNeill, D. (1992). *Hand and mind: What gestures reveal about thought*. Chicago: University of Chicago Press. 364-368.
Nathan, M. J., Eilam, B. & Kim, Suyeon (2007). To disagree, we must also agree: How intersubjectivity structures and perpetuates discourse in a mathematics classroom. *Journal of the Learning Sciences, 16*(4), 525-565.
Paulson, B., & Hammond, T. (2008). *Accurate primitive sketch recognition and beautification.* Paper presented at the Proceedings of the International Conference on Intelligent User Interfaces (IUI 2008), Spain.
Penner, D. E. (2001). Cognition, computers, and synthetic science: Building knowledge and meaning through modelling. *Review of Research in Education, 25*, 1-37.
Prangsma, M., Van Boxtel, C., & Kanselaar, G. (2008). Developing a 'big picture': Effects of collaborative construction of multimodal representations in history. *Instructional Science, 36(2),* 117-136.
Ohlsson, S., Moher, T., Johnson, A., Deep Learning in Virtual Reality: How to Teach Children that the Earth is Round, *Proceedings of the 22nd Annual Conference of the Cognitive Science Society*, Philadelphia, PA,
Radford, L., Demers, S., Guzmán, J. & Cerulli, M. (2003). Calculators, graphs, gestures and the production of meaning. In N. A. Pateman, B. J. Doherty, & J. Zilliox (Eds.), *Proc. 27th Conf. of the Int. Group for the Psychology of Mathematics Education* (Vol 4, pp. 55-62). Honolulu, USA.
Scaife, M., & Rogers, Y. (1996). External cognition: How do graphical representations work? *International Journal of Human-Computer Studies, 45*(2), 185-213.
Schwartz, D. L. (1995). The emergence of abstract representations in dyad problem solving. The Joumal of the Learning Sciences, 4(3), 321-354.
Sins, P. H. M., Savelsbergh, E. R., & Van Joolingen, W. R. (2005). The difficult process of scientific modelling: An analysis of novices' reasoning during computer-based modelling. *International Journal of Science Education, 27*, 1695-1721.
Spector, J. M. (2000). System dynamics and interactive learning environments: Lessons learned and implications for the future. *Simulation Gaming, 31*, 528-535.
Tversky, B. (2005). Visuospatial reasoning. In K. Holyoak & R. Morrison (Eds.), T*he Cambridge Handbook of Thinking and Reasoning* (pp. 209-249.). Cambridge: Cambridge University Press.
Van Meter, P. (2001). Drawing construction as a strategy for learning from text. *Journal of Educational Psychology, 93*(1), 129-140.
Van Meter, P., & Garner, J. (2005). The promise and practice of learner-generated drawing: Literature review and synthesis. *Educational Psychology Review, 17*(4), 285-325.
Vygotsky, L. S. 1986. *Thought and Language* (revised and edited by A. Kozulin). Cambridge, MA: MIT Press.
Williamson, V. M., & Abraham, M. R. (1995). The effects of computer animation on the particulate mental models of college chemistry students. *Journal of Research in Science Teaching, 32*, 521-534.
Zhang, Z. & Linn, M. (2008) Using drawings to support learning from dynamic visualizations, *Proceeding. of the 8th International Conference on the Learning Sciences,* vol. 3, 161-162.

The Design Framework: An Organizing Artifact for Enhancing the Fidelity of Educational Research, Implementation, and Assessment

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Abstract: *Design* provides a unifying metaphor for describing research across fields of education. We propose a *design framework* as a visual and cognitive representation to unify the discourse of educational researchers, instructional designers, teachers, and policy makers by providing a common vocabulary of practice. An artifact-based design perspective illustrates how education research can be conducted to investigate intended design outcomes, to critically study the mismatch between stated and unstated intentions and outcomes, and to evaluate studies that trace learning outcomes from designed learning interventions. We then explicate three applications of the design framework to different fields of educational inquiry.

Focus of the Symposium

We argue that design provides a unifying metaphor for describing research across fields of education. As education continues to grow as a field of inquiry, the different research traditions used by educational researchers continue to fragment the discourse. This presents a considerable problem for researchers who attempt to communicate across discourses as well as for researchers who seek to communicate research findings to a broader public. We propose a *design framework* as a visual and cognitive representation to unify the discourse of educational researchers, instructional designers, teachers, and policy makers by providing a common vocabulary of practice.

Significance

Contemporary education researchers explore a remarkable diversity of questions under the guise of educational research. However, while education departments have become an academic growth industry, educational researchers continue to struggle for the professional identity of their field. Some writers attempt to draw out the defining characteristics of the field in terms of research that is truly educational (Ball & Forzani, 2007) or scientific (Slavin, 2002; Feuer, Towne, & Shavelson, 2002). Others have situated the "problem" of educational research in the institutional and political culture of education schools (c.f. Levine, 2005; Clifford & Guthrie, 1988, Powell, 1980). Ellen Lagemann (2002), for example, locates the origins of the fractured identity of educational research in the early history of the field. Achieving respect for a new field of study in the world of academia led early educational researchers to "emulate their brethren in the 'hard' sciences (or at least the more developed social sciences)" (p. xii). Many educational researchers latched onto prevailing standards of academic quality in fields such as sociology, psychology, economics, linguistics, critical theory, or the humanities in order to legitimize their own work. The search for respect was compounded, according to Lagemann, by the lower status of people attracted to the field of educational research, which in turn reinforced the field's quest for legitimacy both in schools of higher learning and with the public. The quest for legitimacy often resulted in an uneasy double standard in which mainstream academic researchers continued to question the necessity of separate departments dedicated to (substandard) educational research, while advocates of disciplinary fidelity within education zealously enforced perceived standards of methodological rigor. This internal conflict within the field often resulted in the wholesale dismissal of educational research from legal disputes, policy making or local school governance issues in favor of experts in disciplines outside of education, and further marginalized educational researchers from participating in public discourse. The quest for legitimacy via disciplinary affiliation has diverted educational researchers from "pondering what distinctive characteristics might compromise rigor and relevance in this particular domain of scholarship" (Lagemann, 2002, p. xii).

The number of scholars thoughtfully revisiting the identity question indicates the felt need for educational researchers to understand their work as members of a field. This symposium offers a new approach intended to revive discussion about what constitutes the distinctive characteristics of education and how these characteristics might shape educational research. We consider the idea of re-organizing the educational research discourse around the concept of design. We begin by exploring the definition that education is design for learning, and tracing how this definition fits examples of education from different fields of study. Our discussion moves beyond the contemporary discussion of the legitimacy and value of design research as an educational research method. To that end, we develop a model to demonstrate how design can be seen as a powerful analytic model for understanding education.

We begin by presenting the idea of an artifact, that is, a policy, program, curriculum, assessment, or other device implemented to influence the learning of others. Education is facilitated as teachers and learners work through and with artifacts to shape learning. Artifact characteristics can be analyzed in two directions – either from the perspective of the features that designers build into artifacts to influence learners or from the affordances that learners perceive as the key characteristics of the artifacts. An artifact-based design perspective illustrates how education research can be conducted to investigate intended design outcomes, to critically study the mismatch between stated and unstated intentions and outcomes, or to evaluate studies that trace learning outcomes from designed learning interventions. We also trace how a design-based model can both capture the strength and spirit of current approaches to educational research and also integrate previously fragmented approaches into a unified model for educational research.

Our approach is intended neither to decry the low status of our field nor to elevate one perspective of the research landscape at the expense of others. Instead, we hope the design perspective will show how our research methods follow from distinctive characteristics of our interests, and we will illustrate how a unified design perspective allows educational researchers to ask new questions that bring educational inquiry into a more mature state of disciplinary self-sufficiency.

Symposium Presentations

1. A Modest Proposal: A Design Framework to Unify Educational Discourse

Rich Halverson and Erica Rosenfeld Halverson

We begin our discussion of a unifying framework by defining education as *design for learning.* By understanding education in terms of designs to influence learning, educational research then becomes about the development, implementation, and study of artifacts that influence learning. Seen from this perspective, educational research necessarily draws on methods and theories developed in psychology, sociology, economics, linguistics or neurology, but the focus on design sets its interests apart from these disciplines and establishes the need for an independent discourse.

We propose a framework that centers on a concept of the *artifact* (Halverson, 2002; 2004). Artifacts can be policies, programs, or pedagogical tools that individuals employ to promote, evaluate, or understand learning. Artifacts are the devices or tools implemented to influence action. The concept of artifact plays a central role in a design theory of education. Artifacts belong to the family of "meditational means," that is, the networks of tools, structures and languages that co-constitute human action (Wertsch, 1998). In common use, artifacts refer to material things such as pens, computers, cars, or groceries (c.f. Norman, 1991). These products are created for purposes that address, extend, or transform the practices of others.

The central analytic concepts involved with artifacts are *features* and *affordances*. Designers build features into artifacts, and these features reflect the ways that designers hope to influence the thinking and practices of artifact users. Designers create artifacts with certain intended uses in mind. They "inscribe" intended uses into the features of the artifact. A feature is an aspect of an artifact developed to support a possible use. Light switches, radio dials, cup handles, and paperclips all have features designed to support intended uses. More abstract artifacts, such as policies and textbooks, include features such as incentives for compliance and assessments with answer keys. Affordances, on the other hand, describe the ways that users perceive artifact features. Affordances reflect the perceptions, sense making, and pre-conceptions of users. We argue that the gap between artifacts and features, between intended and actual uses, and between design and implementation, constitutes the field in which most education research takes place. Artifacts completely enclose the space in which educators work, live, and even think. While the importance of artifacts are clearest in the context of research in classroom-based learning environments, artifacts are also central to non-classroom based research such policy research that measures the impact of teacher pay-for-performance models in school districts or essays criticizing the theoretical conceptualization of the achievement gap.

The visual representation of the design framework (see Figure 1) positions an educational "artifact" in the center of the research endeavor, as represented by a triangle. Within the triangle are the features and affordances of the artifact. The features of the artifact are generated based on the *intentions* of the artifact's designers, such as increasing student learning outcomes, decreasing drop-out rates, or improving teaching retention. Since the intentions are established by the designers, who are often external to the setting in which the artifact will be implemented, the artifact's features represent use as idealized by designers. When we examine the intentions, we find that they inform the artifact that is developed all the way through the design process.

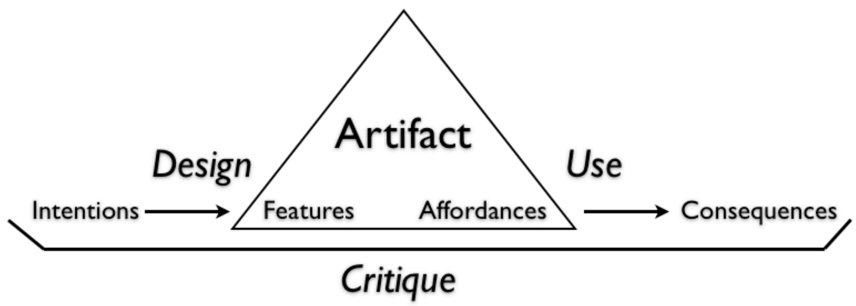

Figure 1: Visual representation of the design framework. Focus is on deconstructing the artifact by examining its intentions, consequences, and critical aspects.

On the right side of the artifact triangle are the *consequences*, or intended outcomes, of the design. Consequences are informed by the artifact's affordances, that is, the way the artifact is taken up by users. By examining consequences, we may find the answer to questions like: As a direct result of the implementation of this design, did students' test scores increase? Did drop-out rates decline? Or did the school retain a higher percentage of teachers, compared to previous years? The consequences of a design can be used to evaluate the artifact and determine whether a program, policy, or initiative was successful, as measured by the outcomes' congruence with the original intentions. In addition, consequences can and should be used to inform future designs, whether these are iterations of the present design or new design innovations.

And finally, the entire design framework is subject to the *critical* perspective, which sets the design within a sociocultural and historical framework. The critical perspective allows us to analyze how the implementations of designs are products of social and political contexts, how schools use designs to effectively (if unintentionally) reproduce dominant cultural ideologies, and how the positionality of designers can significantly affect the design process and, therefore, the potential success of implementation. When we consider education as design for learning, educational artifacts are ubiquitous and, consequently, the design framework serves as a visual representation for multiple aspects of the domain of education.

Artifacts provide occasions for tracing how practices occur and evolve. By studying how artifacts are developed and used in educational contexts, researchers can not only observe how teaching and learning changes, but they can also investigate practices prior to alteration. Much of educational research can be characterized as advocacy research in which a group promotes a particular method/artifact/program as a viable path to changed practice. A design-based perspective can reveal how artifacts might change practices and also shed light on the practices that artifacts intend to change. Artifact design and use can be analyzed as a form of asynchronous communication between designers at every level, from policy makers to local school curriculum creators, and the practitioners who work with artifacts.

The potential for understanding education as design for learning comes from the ways in which this imperfect method of communication fails, iterates, compounds, or is exapted by the circumstances of practice. A design perspective illustrates the four key occasions in which artifact design allows for investigating education: 1) translation of intention into artifact features; 2) the perception of features as affordances; 3) impact of affordances on practice; and 4) the relation of the artifact design/implementation cycle in a wider institutional, social, and political contexts.

Applications of the Design Framework

We will present three applications of the design framework to different fields of educational inquiry. The first focuses on how the design framework can be used to encourage collaboration between classroom teachers and researchers. The second contemplates the design framework as an organizational tool for understanding the practices of youth media arts organizations. The final examines the mismatch between features and affordances as a path toward understanding the implementation of a large-scale instructional policy.

2. Using the Design Framework as a Metarepresentation to Facilitate Teacher-Researcher Collaboration

Dana Gnesdilow and Jen Scott Curwood

Often, when one educational design fails, the response is to try another design rather than closely inspect the potential disconnects between the designers' intended features and users' perceived affordances. A design-based perspective on classroom curricular interventions may inform subsequent iterations of the design, which can benefit teachers, researchers, and students alike. Our theoretical work draws from the field of participatory design research to highlight the need for the utilization of the design framework as a metarepresentation to foster collaboration between teachers and researchers. Furthermore, it highlights six ways in which the design framework can be applied throughout the process of planning educational innovations to minimize disconnects that may occur between design, implementation, and iteration.

Metarepresentations allow individuals to more readily perceive and comprehend patterns that the unaided mind may overlook or dismiss. This alleviates an individual's need to keep track of complex information, providing "mental space" for higher order thinking (Norman, 1994). Several researchers in the participatory research field advocate for the use of a tool, such as a metarepresentation, to address perspectives of all members of a design team (Arias, Eden, Fischer, Gorman, & Scharff, 2000; Blomberg, Suchman, & Trigg, 1996; Kankainen, 2003; Maguire, 2001; Veryzer & Borja de Mozota, 2005). With this in mind, we suggest that the design framework will function as both a visual and a temporal metarepresentation to illuminate the design process. As Edelson (2002) notes, "Engaging in design as a research process means taking the elements of design that typically remain implicit in design and making them explicit" (p. 117). We seek to emphasize how the design framework can serve as a tool to facilitate productive interactions between teachers and researchers by explicating the entire process of educational research by serving as a metarepresentation.

We envision the design framework as having six specific applications within educational research: 1) as a visual tool to elucidate research design and development to all constituents involved in the design process, 2) a co-planning tool, 3) as a reference point for reflection during design implementation, 4) as a means to summatively assess the effectiveness of the research design and its implementation, 5) as a tool to re-envision the design for future iterations, and 6) as a means to record the intentions, implementations, and outcomes of the design process over multiple iterations. We conceptualize each of these six applications as a way to promote communication and collaboration between teachers and researchers during the design process manifesting greater fidelity in implementation and resulting in enhanced educational outcomes. Additionally, we believe that the design framework as a metarepresentation can be used to examine policies and craft interventions by deconstructing the design process after it occurs, in order to understand disconnects or implementation issues.

3. Artifact Families: An Affordance of the Design Framework

Michelle Bass

The design framework affords us the opportunity to see sameness and difference between similar artifacts. Many artifacts share similar, or sometimes identical, components which include features, intentions, and stated outcomes. Here, I present the idea of *artifact families* as a way to organize and describe artifacts that share design framework components.

The structure for the idea of organizing artifacts into families comes from the field of organization studies. Organization studies researchers are starting to explore positioning their work as a science for design, which "puts the interplay between organizational entities and phenomena as artifacts and as social facts at the center" (Jelinek, Romme, & Boland, 2008, p. 320). The authors contend that science for design can "bridge the worlds of theoretical and practical significance" (Jelinek et al., 2008, p. 317). They continue,

> According to Simon (1969) *science* views existing organizational systems as empirical objects from an outsider perspective, while *design* envisions systems that do not yet exist…Simon foresaw that a design science approach could help overcome the isolation of specialists by providing a common ground for

> bringing our diverse interests together in a search for more desirable states of (organizational) affairs. (p. 317-318)

The idea of isolation of specialists is true amongst researchers who study youth media arts organizations (YMAOs). YMAOs vary by participant demographics, geographic location, types of media produced, mentorship practices, and many other features. The complex variety of possible feature combinations results in difficulty comparing across organizations. Despite this fact, researchers continue discussing YMAOs as one type of artifact. I provide a worked example of organizing YMAOs into artifact families. This discussion begins with a critique regarding the field of multimedia literacy's overly simplified comparison of all varieties of YMAOs to draw overarching conclusions about these programs' impacts on youth. I then focus on a nested family in the larger artifact family of YMAOs, those that work specifically with youth to help them create identity-focused films (IFF).

Intentions of the organizations are determined through analysis of mission statements, followed by an examination across programs' major features, identified as staffing, entrance, core process, and retention, for the similarities and differences that make each a unique member of the identity film focused YMAO family. I also propose the idea of creating cross family memberships for IFF members by adding to their intentions and features, looking specifically at how these programs could focus on serving as a piece of their adolescent participant's transition process to college.

Identity film focused youth media arts organizations are one of many artifact families in the field of educational research. The idea of artifact families should not be conceived of as revolutionary or subversive. Rather, I hope that using the frame of science for design from the field of organization studies can help make discussions of artifacts in the field of education more understandable and less ambiguous.

4. Branching Up, Out or Off: How Features Become Affordances

Anne Karch

I look at the section of the design framework between intentions and consequences, where the designed features of the artifact become affordances, or not, in the use or operation of that artifact. I suggest that the process by which artifact users afford themselves of its features is an organic one in which emergent uses can sprout and grow from the original designed features. I offer the metaphor of a tree and its branches for this process and show how the design framework gives us a closer view of the mismatch between features and affordances than in fidelity of implementation analysis.

The artifact I examine is a policy for educational reform: the Wisconsin Student Achievement Guarantee in Education (SAGE) program, which is in place in over 500 elementary schools across the state. The design for this program is laid out in Wisconsin state law with the intention of increasing the levels of academic achievement of low-income students. SAGE law calls for schools to use four "improvement strategies," including: reducing student/teacher ratio to 15: 1 in grades K through 3rd; keeping schools open extra hours in order to provide recreational, educational, social and community services to students and their families; offering a "rigorous curriculum" in those smaller classes; and "staff development and accountability" (General School Operations, §118.43(3)). These strategies are the four main features of the law.

SAGE is an interesting artifact because its features are clearly spelled out in the law, yet researchers who have followed the progress of schoolchildren participating in SAGE have found that 'achievement' is not 'guaranteed' to all; SAGE schools have shown widely varying levels of academic success (Graue, Hatch, Rao, & Oen, 2007; Graue, Rauscher, & Sherfinski, 2008; Zahorik, Molnar, & Smith, 2003). Perhaps not surprisingly, researchers have found that SAGE does not look the same in each of the schools, even within the same district or sometimes across grades in the same school. A fidelity of implementation analysis would look at the enactment of SAGE, searching for ways it had not been "done right" at the low performing schools (Firestone, Fitz, & Broadfoot, 1999; Lee, Penfield, & Maerten-Rivera, 2009; O'Donnell, 2008; Spillane, Reiser, & Reimer, 2002). A design approach requires us to look first at the policy itself to see intentions, and then examine how its features are seen as affordances and whether those affordances still match the intentions (Norman, 1994; Spillane et al., 2002).

I consider each of the four features of SAGE, plus the fifth feature of funding, looking at its designed intent, the affordance(s) or perceived affordances it offers, and the way it is appropriated by the users, highlighting mismatches between intent and affordance where they occur. Then, using the tree metaphor, I trace the branching growth of the feature as schools afford themselves of it, sometimes causing more branches to grow up or out, sometimes breaking off. Where there is a match between a feature's intentions and affordances, there is growth. When there is a mismatch, the branch breaks off, although the user may adapt it for another purpose. I also show how the interaction between affordances, like interlocking tree branches, can lead to more vigorous growth. For education policy, the design framework allows for detailed analysis of what happens between intentions and outcomes and offers the possibility of fine tuning, through the recursive process of redesign, of features to create better matches between intentions and affordances.

Implications

We argue that the design framework can facilitate the examination of the design and implementation of educational initiatives by supporting cognition, communication, reflection, and generative questioning across space and time. By tracing the design process from its inception to its implementation and through its evaluation and subsequent iterations, we will suggest that policy makers, researchers, educational leaders, and teachers can clearly communicate their goals and needs to each other while working to increase the fidelity of reform initiatives. In addition, by integrating users (and their experiences) into the design process early on, real-world practices can inform an iterative design process, leading to greater faithfulness in enacting the intentions of the artifact.

We believe that the design framework can be used to communicate and explicate educational initiatives to all stakeholders, including superintendents, principals, community members, parents, and teachers. In this symposium, we look specifically at three examples: educational interventions that involve teacher-researcher collaboration, a youth media arts organization, and an intervention program for low-income elementary students. In each, we note that, on a very basic level, designs or reforms are often unsuccessful due to what Bernstein (1990) refers to as problems with *recontextualization*. In this model, researchers in any domain in academia work in a primary context, concerned mainly with the construction of new knowledge and the production of particular types of discourse. Those who make decisions about what takes place in schools, a secondary context, make judgments about what discourse and knowledge, produced within the primary context, is important to teach as well as how this information should be taught. In other words, those who make decisions about what is important for student to know, such as text book writers, policy makers, arts organization leaders, government officials, and superintendents, recontextualize what has been produced in the primary context for use in the secondary context.

When policy makers and designers designate schools and teachers who have not been privy to the design process as the agents of implementation, disconnects between the intentions of the innovation and actual school and classroom enactments often occur. To alleviate problems such as this, several researchers have advocated for the development of overarching representations to facilitate intersubjectivity (Arias, Eden, Fischer, Gorman, & Scharff, 2000; Blomberg, Suchman, & Trigg, 1996; Kankainen, 2003; Maguire, 2001; Veryzer & Borja de Mozota, 2005). Using the design framework as a metarepresentation for the field of education, the papers presented in this symposium focus on investigating the issues of fidelity of educational policy initiatives and the coordination and organization of ideas to minimize the disconnects that can occur. We suggest that, as a metarepresentation, the design framework can serve three key purposes. First, it can be used as a tool to understand the design process; in this way, it can be useful to those who work to plan, create, and implement reform initiatives. The design framework can be invaluable for individuals who seek to research teaching and learning, and it can offer an analytic, research-based perspective on the process as it occurs. Second, the design framework can also be used as a way to understand how to examine policies and craft interventions, and it can offer perspective on the process of making and implementing policy. Lastly, it offers a way to deconstruct the design process after it occurs, in order to understand the resulting disconnects or implementation issues.

References

Arias, E., Eden, H., Fischer, G., Gorman, A., & Scharff, E. (2000). Transcending the individual human mind: Creating shared understanding through collaborative design. *ACM Transactions on Computer-Human Interaction, 7*(1), 84-113.

Ball, D., & Forzani, F. (2007). 2007 Wallace Foundation Distinguished Lecture--What Makes Education "Research Educational"? *Educational Researcher, 36* (9), 529-540

Bernstein, B. (1990). *Class, codes, and control, Vol. 4: The structuring of the pedagogic discourse*. London: Routledge.

Blomberg, J., Suchman, L., & Trigg, R.H. (1996). Reflections on a work-oriented design. *Human-Computer Interaction, 11*, 237-265.

Clifford, J.J. & Guthrie, J. (1988). *Ed school: A brief for professional education*. Chicago: University of Chicago Press.

Edelson, D. C. (2002). Design research: What we learn when we engage in design. *Journal of the Learning Sciences, 11*(1), 105-122.

Firestone, W. A., Fitz, J., & Broadfoot, P. (1999). Power, learning, and legitimation: Assessment implementation across levels in the United States and the United Kingdom. *American Educational Research Journal, 36*(4), 759-793.

Graue, E., Hatch, K., Rao, K., & Oen, D. (2007). The wisdom of class-size reduction. *American Educational Research Journal, 44*(3), 670-700.

Graue, E., Rauscher, E., & Sherfinski, M. (July 2008). *SAGE implementation and classroom quality*. Madison: Value-Added Research Center Wisconsin Center for Education Research.

Halverson, R. (2002). *Representing phronesis: Supporting instructional leadership practice in schools*. Doctoral dissertation: Northwestern University: Evanston, IL

Halverson, R. (2004). Accessing, documenting and communicating practical wisdom: The phronesis of school leadership practice. *American Journal of Education, 111* (1), 90-121.

Halverson, E., Lowenhaupt, R., Gibbons, D., & Bass, M. (2009). Conceptualizing identity in youth media arts organizations: A comparative case study. *Journal of E-Learning, 6*(1), 23-42.

Jelinek, M., Romme, A.G., & Boland, R. (2008). Introduction to the special issue organization studies as a science for design: Creating collaborative artifacts and research. *Organization Studies, 29*(3) 317-329.

Kankainen, A. (2003). UCPCD: User-centered product concept design. *Proceedings of the 2003 Conference on Designing for User Experiences*, 1-13.

Maguire, M. (2001). Methods to support human-centered design. *International Journal of Human-Computer Studies, 55*, 587-634.

Labaree, D. F. (2004). *The trouble with ed schools.* New Haven, CT: Yale University Press.

Lagemann, E. C. (2000). *An elusive science: The troubling history of education research*. Chicago: University of Chicago Press.

Lee, O., Penfield, R., & Maerten-Rivera, J. (2009). Effects of fidelity of implementation on science achievement gains among English Language Learners. *Journal of Research in Science Teaching, 46*(7), 836-859.

Levine, A. (2005). Educating school leaders. *The Education Schools Report*, retrieved September 30, 2009 from www.edschools.org/report-leaders.htm

Norman, D.A. (1991). Cognitive artifacts. In J.M. Carroll, (Ed.). *Designing interaction: Psychology at the human-computer interface*. Cambridge: Cambridge University Press.

Norman, D. A. (1994). *Things that make us smart: Defending human attributes in the age of the machine*. Cambridge, Massachusetts: Perseus Books.

O'Donnell, C. L. (2008). Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in K-12 curriculum intervention research. *Review of Educational Research, 78*(1), 33-84.

Powell, A. G. (1980). *The uncertain profession: Harvard and the search for educational authority.* Cambridge, MA: Harvard University Press.

Shavelson, R. J., Phillips, D. C., Towne, L., & Feuer, M. J. (2003). On the science of education design studies. *Educational Researcher 31*(1) 25-28.

Simon, H.A. (1969). *The sciences of the artificial.* Cambridge, MA: MIT Press.

Slavin, R. E. (2002) Evidence-based education policies: Transforming educational practice and research. *Educational Researcher 31*(7). 15-21;

Spillane, J. P., Reiser, B. J., & Reimer, T. (2002). Policy implementation and cognition: Reframing and refocusing implementation research. *Review of Educational Research, 72*(3), 387-431.

Veryzer, R.W. & Borja de Mozota, B. (2005). The impact of user-oriented design on new product development: An examination of fundamental relationships. *The Journal of Product Innovation Management, 22*, 128-143.

Wertsch, J. V. (1998). *Mind as action.* New York, NY, Oxford University Press.

Zahorik, J., Molnar, A., & Smith, P. (2003). *SAGE advice: Research on teaching in reduced-size classes*. Tempe, Arizona: Arizona State University.

Using Digital Video to Investigate Teachers' In-the-Moment Noticing

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Abstract: Understanding teacher cognition – and in particular teacher noticing - poses significant challenges to researchers because of the ongoing nature of teaching. To overcome those challenges learning science researchers have used a variety of methods to help them understand how teachers reason and make decisions while teaching. In this symposium we describe a new digital technology that allows teachers to capture short video clips of classroom activity as they are teaching. The three papers explore different aspects of what we have learned about teacher noticing using this new technology. The first paper describes the potential of the camera to serve as a window into teachers' in-the-moment noticing. The second examines teacher noticing of their students' thinking. The third paper investigates our efforts to use clips captured using this methodology as the basis for video clubs in which teachers watch and discuss excerpts of one another's classrooms.

Introduction

Learning science researchers have, for many years, had a strong interest in teacher cognition. In particular, we would like to understand how teachers reason and make decisions in the act of teaching. Yet studying teacher thinking during instruction poses challenges for researchers. Because of the ongoing nature of teaching, it is not feasible to interrupt and ask teachers what they are thinking, what decisions they are considering, or what questions they have at the moment. Instead, researchers generally use other, less intrusive, approaches. For example, some researchers draw on observations of teaching to make inferences about a teacher's thinking (e.g., Schoenfeld, 1998). In this approach, researchers may try to construct a plausible chain of reasoning events that aligns with the teacher's actions and utterances during a lesson. Another approach involves asking teachers to reflect, after-the-fact, on their teaching. Using retrospective interviews, for instance, researchers may ask teachers to recall how they came to a particular decision or what alternatives they were considering at the time (Peterson & Clark, 1978). A third approach is to try to simulate teaching in some manner, for example, by showing teachers videos of instruction and asking them to comment (e.g., Copeland et al., 1994).

Each of these approaches, however, has limitations. Some of what a teacher thinks may not be visible in a teacher's actions or words, making it difficult to infer how a teacher is thinking simply by watching them. Also, in retrospective interviews, there is a risk that teachers will construct new interpretations of what took place during the interview, rather than recall their thinking during instruction. Similarly, even if simulations are carefully constructed to present teachers with situations that closely resemble instruction, teachers will lack the kind of detailed background information they use to make sense of real-world situations while teaching. It seems possible then that simulations will provoke a different kind of reasoning than takes place during instruction.

Whether or not these approaches suffice will depend in part on what aspect of teacher cognition the researcher is interested in. In our work, we are particularly interested in teacher noticing — in how teachers attend to and make sense of significant interactions during instruction. The classroom is a complex environment with many things happening at once. How does a teacher decide where to focus his or her attention? This issue is particularly important in light of efforts to reform mathematics and science education in the U.S. today. Teachers are called upon to continually assess the ongoing nature of lessons and to base their instruction, at least in part, on the ideas that students raise in class. In this context, how teachers direct their attention in the act of teaching is a critical area for researchers to investigate.

Given our interest in teacher noticing, the three approaches outlined above pose methodological challenges. First, it may be particularly difficult to observe a teacher "noticing;" noticing may not align with specific utterances or actions on the part of the teacher. In addition, because noticing is likely to take place in a fleeting manner it may be hard to capture retrospectively. Furthermore, during simulations noticing may operate in a manner that is quite different than how it operates during instruction. How then, can we effectively study teacher noticing?

The purpose of this symposium is to discuss a new technology that we are using to study teacher noticing during the act of instruction. Our claim is not that this new technology should replace the methods discussed above. Rather, we believe that this new technology has the potential to add an additional, complementary, window into teacher thinking in action.

Exploring New Technology

Recently, a new class of video cameras have been introduced, cameras that are small enough to be mounted on a hat or a pair of eyeglasses. Of particular interest are cameras that offer "selective archiving" capabilities. Selective archiving allows the user to select moments of video to capture immediately after they occur.

Two cameras were used in the studies we present here: the Deja View CamWear 100 (Reich, Goldberg, & Hudek, 2004) and the POV 1.5 (V.I.O., 2009). Both cameras include two components: a small wearable camera approximately one inch long, and a recording module about the size of a cell phone that can be attached to a belt. The cameras record in a loop mode, and record over themselves after a short time. Pressing the "save" button on the recording module interrupts this process and saves the previous "loop" of video in a digital file — 30 seconds in the case of the Camwear 100 and 3 minutes in the case of the POV 1.5. In both cameras, the digital files are stored on a video card that is housed in the recording module. The files can easily be downloaded and viewed on a computer.

We developed the following two-part methodology to support our use of the new cameras. First teachers were asked to wear the camera during instruction and to press the record button "when something interesting happens." Occasionally we used variations of this prompt, but in general we asked teachers to focus on events that they found "interesting." In order to capture a complete record of the lesson taught, we also videotaped the classroom from the back of the room using a single stand-alone video camera. Second, on the same day, a researcher met with the teacher to review the set of clips that had been captured. To do so, we developed a process intended to increase the possibility of teachers drawing on their thinking during instruction, rather than creating retrospective accounts of their noticing. Specifically, a still image of the start of the captured clip was shown to the teacher. If the teacher could recall, just from the still image, why he or she captured the clip, then the video clip was not reviewed further and the teacher explained at that point why the clip had been captured. If the teacher could not recall why the clip was captured, then the clip was played but only until the point at which the teacher was able to recall his or her reason for capturing the clip. Teachers were also asked to generally describe their experiences using the camera that day, and whether the clips represent the events that the teachers had intended to capture. All interviews were videotaped and later summarized and partially transcribed.

The three papers presented in this symposium explore different aspects of what we have learned about teacher noticing thus far using this new technology. The first paper describes what we have found about the potential of the camera to serve as a window into teacher noticing during the instruction. The second paper looks closely at those clips teachers describe as being about student thinking. The third paper investigates our efforts to use clips captured using this methodology as the basis for video clubs in which teachers watch and discuss excerpts of each others' classrooms. While all three papers share methodology for studying teacher noticing, the specific data examined are somewhat different across the papers.

The format of the symposium will be as follows. We will begin with a brief introduction of the goals of our project as well as a demonstration of the wearable video camera and illustration of the kinds of data that were collected. Following this, there will be three 12-minute presentations of the papers. Next our discussant, Rogers Hall, of Vanderbilt University will provide comments on the papers. Dr. Hall's research explores the relationship between one's perception of events and how one participates in such events in a number of contexts including teaching. Finally, we will have 30 minutes for questions and discussion with the audience.

Freezing Time: What Mathematics and Science Teachers "See" While Teaching

Bruce L. Sherin, Miriam Gamoran Sherin

Our methodology was designed to tap directly into teachers' in-the-moment noticing in a way that has not been possible before. Specifically, the idea is that the clips themselves have the potential to reveal the kinds of events that teachers pay attention to during instruction. In addition, the hope is that teachers' comments in the interviews will provide valuable information concerning the ways in which noticing acts during instruction, for example, the extent to which noticing is a conscious process and the reasons behind teachers' attention to various kinds of events. The goal of this presentation is to summarize and illustrate the data we have collected thus far, and then discuss the ways in which the methodology achieved its potential as well as problems we faced in the process.

Over the past two years, we have worked with 12 high school mathematics and science teachers who volunteered to use one of the cameras during instruction. The teachers taught in three different school districts in the Midwestern United States, all of which have diverse student populations. Most teachers used the cameras on three separate occasions; in all we conducted 39 interviews lasting approximately 45 minutes each. Each of these interviews was conducted after a teacher had worn a camera for one class session.

Overall, we found that teachers were able to use the camera to capture moments of instruction during teaching. About one-half of the teachers initially faced logistical problems using the camera — pressing the wrong button, or not pressing the button correctly, or other malfunctions of the camera. After one or two attempts at taping, however, these issues were generally resolved. The clips themselves illustrated a range of types of classroom events — whole group discussions, small group work, individual seatwork, and student presentations. Teachers reported to us that using the camera was not overly disruptive, either for themselves or for their students. This is also evident in the fact that teachers typically captured clips throughout a lesson; thus it was not the case that teachers captured clips only during the first 10 or 15 minutes of class at which point the demands of instruction took priority and camera use fell off.

On average, teachers captured 9 clips per 50 minute class period. We see this moderate number as suggesting that teachers were somewhat selective in capturing moments of instruction. Furthermore, the distribution of clips was not evenly spaced throughout a lesson. Teachers did not simply press the button every five minutes or so without regard to the specifics of the moment. Instead, teachers seemed to be sufficiently conscious of what they viewed as interesting to be able to push the button when an event stood out to them. Mason (1998) writes of the need for teachers to be "aware of their awareness." It is this kind of conscious awareness that we believe we have accessed with this methodology. Along the same lines, in many cases, teachers were able to recall what they had captured and why from looking only at the still image or a few seconds of video. Specifically, issues of student thinking, pedagogical techniques, and organizational issues were reported to have captured the teachers' attention.

Our methodology was not without problems, however. At times, teachers stated that they did not remember why a particular moment was captured. "I don't know why I pushed the button there, but I know I actively did because I can see myself [look down to press the button.]" In such cases, our methodology failed to tap into teachers' in-the-moment thinking about the noticed moment. Another concern is that there is some evidence that the act of wearing the camera and capturing moments may alter the very noticing that we intended to access. In particular, a few teachers suggested that using the camera heightened their sensitivity to noticing events that took place during instruction. "[Using the camera] made me more aware of what I thought was important." Thus while our efforts to access teachers' in-the-moment noticing appears to have been somewhat successful, there is reason to also be cautious as we move forward with the new technology.

Science and Mathematics Teachers' In-The-Moment Noticing: Attending to Student Thinking Within a Lesson and Beyond

Adam A. Colestock, Rosemary S. Russ

Recent reform efforts in science and mathematics education call for teachers to carefully attend and respond to their students' thinking in the classroom (Schifter, 2001; Hammer & Van Zee, 2006). To help teachers achieve this goal we must first understand their existing practices for attending to student thinking (Sherin, 2001; Levin, Hammer & Coffey, 2009). In this paper we investigate how the teachers in our sample attend to student thinking in the moments of instruction. In particular we draw on data collected with our new methodology to explore the question: "Why do particular moments of student thinking stand out as interesting to a teacher?"

For our analysis, we relied heavily on the teachers' reflections in the interviews. In particular, we used this data to explore teachers' ideas about the moments of student thinking they captured with the camera. First we reviewed the videotaped interviews and created descriptive summaries of what a teacher found interesting in each captured moment. Second, from those descriptions we identified and selected for analysis only those summaries in which the teacher discussed students' thinking as an important aspect of the reason they captured that moment. Of the 266 clip summaries we created, we identified 48% as relating to student thinking. We then looked across these summaries for evidence of why particular moments of student thinking stood out to the teacher. The four themes that emerged from the data suggest that a teacher's predictions and expectations for a particular lesson and their knowledge of their students' prior and future learning strongly influence the student thinking moments to which they attend. Below we describe these four themes, highlight how they relate to the work of teaching, and provide illustrative examples from the data.

Theme 1: Attending to unanticipated moments of student thinking. In planning for a lesson, teachers use their prior teaching experience, their knowledge of typical student thinking, and their understanding of this particular group of students to anticipate students' reactions to different parts of the lesson, including what students might find routine or easy and what they might find challenging or puzzling (Schoenfeld,1998). Thus teachers may have a set of expectations about what student thinking will emerge in the lesson. In our data we found that teachers often described the moments they captured as being surprising or unexpected. For example teachers sometimes focused their discussion of a moment on a particular student question or insight that they had not anticipated, but were nonetheless pleased with encountering. For example, one teacher captured a moment because a student was able to solve algebraic equations involving absolute value signs, something they had not yet learned as a class. At other times teachers described moments when students had trouble with aspects of the lesson that they had assumed would be straightforward. For example, a science teacher captured a moment in which a student has difficulty answering what she considered to be a straightforward question. In describing the moment, she explained, "I asked what the function of the cell membrane, which we've spent the last 15-20 minutes talking about… It is literally written on the slide. We've said it like ten times. And I call on Jess and she has no clue."

Theme 2: Attending to the progress of the lesson. Another aspect of lesson planning involves considering the pace of a lesson, the sequence of ideas, and the location of important conceptual checkpoints within the lesson (Leinhardt, 1993). When discussing why they captured particular moments of student thinking our teachers sometimes discussed the ways in which a student's idea related to the progress of the lesson. Some teachers reported specifically waiting for students to express certain ideas and capturing them because they were important benchmarks for monitoring lesson progress. For example, one science teacher captured several different moments in which her students were accomplishing her instructional goal of making the connection between the pattern recognition activity that they were engaged in and the organization of the periodic table of elements. In describing one interaction with a student she explains, "He said, 'Oh, this is just like the periodic table!' and I was like 'Ding, Ding, Ding! Yes, that is exactly what you were supposed to [figure out].'" In contrast, other teachers captured moments when the lesson was not progressing as they had hoped, such as when students struggled with a crucial part of the lesson. For example, a mathematics teacher captured a moment in which a number of students were having difficulty understanding why it wasn't necessary to write the variable t as part of the answer when finding the rate of change of a parametric linear equation. She took this as evidence that she should think about doing more work to help students understand slopes and rates of change.

Theme 3: Attending to students' prior knowledge. In planning a lesson, teachers make assumptions about the relevant prior knowledge students possess, either from the everyday world or from previous formal teaching. In our data teachers frequently described moments as being interesting for what they revealed about a student's prior knowledge. For example, during a lecture about membrane structure one science teacher captured a moment in which a student asked what a solute was and another student provided a poor explanation. This moment of student thinking stood out to her because she was surprised that despite their previous coursework the students were unable to accurately describe a solute, "It was mind-boggling to me that they do not know what a solute is because these are kids who have come through two years of honors chemistry and physics…so I have to think about assumptions that I make about what they have learned in the past." In addition to capturing moments in which student prior knowledge was lacking or problematic, our teachers also captured moments in which students productively drew on prior knowledge by making connections with previously learned material. For example, the same science teacher captured another moment because a student applied his understanding of protein structures that he had learned in class a month and a half ago to a new context in a class research presentation about a particular disease.

Theme 4: Attending to opportunities for future learning. Often teachers plan to leverage the understandings that students develop in one day's lesson as starting points for future lessons in the curriculum. As a result, teachers may draw on their awareness of how ideas will be used in the future to be alert for opportunities to foreshadow or motivate future learning. Several teachers in our sample discussed the student thinking they captured in terms of its importance for future lessons. For example, one Calculus teacher captured a student question and subsequent discussion about how a particular integration technique might be similar to other methods they would encounter later in the week. He was pleased because the discussion allowed him to foreshadow upcoming lessons; he said, "it was an interesting question because we've just started talking about these solids of revolution today…but eventually we will get to what Eric was talking about." The teacher also indicated that he decided to bring the conversation to a certain point and then stop it because they would be returning to these ideas later, "If we were working on cross sections we could have spent more time with Derrick's response but as it was I thought Dylan answered the question sufficiently for today."

In this work we have examined why teachers may attend to particular aspects of student thinking in the moments of instruction and not others. In particular we discussed how their attention to events is influenced by (1) the student responses they anticipate (2) the conceptual checkpoints that help them determine when to proceed (3) the relationship of the current lesson to students' prior knowledge and (4) the opportunity of the thinking to foreshadow future learning. Furthermore, the methodology we employed to access that teacher thinking allowed us to see teachers in their own teaching situations — situations in which they have rich knowledge of the curriculum, the students' learning history, and the possible paths along which the lesson will progress. Our analysis suggested that this detailed knowledge creates expectations and predictions that substantially influence which moments stand out to teachers. Thus we suspect that other methodologies that do not allow teachers to draw on this rich set of knowledge – either because teachers are reflecting on classrooms that are not their own or because they are too far removed from the in-the-moment use of that knowledge in their own classroom – may be unable to access the kind of thinking about student thinking we describe here. In our future work we plan to continue to use this methodology to explore how teachers attend to their students' thinking during instruction and the role that this noticing plays in shaping their teaching practice.

Supporting Video Club Conversations Using Teacher-Selected Video Clips

Melissa J. Luna, Martha Mulligan, Miriam Gamoran Sherin, Janet Walkoe

The other papers in this symposium report on the kinds of classroom moments teachers captured using wearable cameras and the reasons teachers give for capturing such moments. In this paper, we take a different approach. Specifically, we investigate using these captured moments to support conversations among teachers around their students' ideas in science and mathematics.

This work takes place in a particular context we call video clubs. A video club is a type of professional development experience in which a group of teachers watch and discuss classroom video excerpts of their instruction with a particular focus or framework in mind (Frederiksen, Sipusic, Sherin, & Wolfe, 1998). For example, discussions in a video club context can be intentionally focused on a range of issues such as discourse, student thinking, or management (Tochon, 1999). The use of video is central to the work of a video club. Video is able to capture the complexity of a classroom and meaningfully reduce that complexity by providing a record of interactions (Borko, Jacobs, Eiteljorg, & Pittman, 2008). With video, teachers do not have to respond immediately as they do when they are teaching. Therefore, watching and discussing video opens up rich opportunities for teachers to reflect upon and analyze events that occur during teaching.

Prior research on the use of video clubs demonstrated that this is an effective context for helping teachers notice and respond to students' ideas in mathematics (e.g. van Es & Sherin, 2008). This paper extends such work to include science teachers. Furthermore, the use of a new video technology—the wearable camera—inspired a slightly different video club design. Other video clubs typically ask teachers to reflect on and discuss video that researchers have selected of teachers' classrooms from footage from the back or side of the classroom (i.e., video from a researcher's point of view) (Sherin & Han, 2004). Here we instead asked teachers to reflect on and discuss classroom moments that the teachers themselves captured while wearing the Deja View or POV 1.5 camera. In doing so we had two main goals. First, we wanted to explore the ways in which clips from the wearable camera would support conversation around students' ideas. Would the fact that the video clips are exclusively from the teachers' point of view—and thus teachers are not visible—prompt consistent discussion of students' thinking? Second, we wanted to take a first step towards testing the feasibility and viability of making video clubs self-sufficient rather than relying heavily on a research team. In our experience, teachers do not usually have time to select excerpts from video of an entire class session. The wearable camera allows teachers to select the moments while they are teaching, thus removing this barrier. While we were still heavily involved in the logistics of the video clubs discussed here, we view this study as a valuable first step toward understanding what it would take for teachers to sustain a video club on their own.

The data in this study draw from our work with three separate video clubs. All video club meetings were videotaped.

(1) *High School Mathematics Video Club.* This video club consists of two experienced high school math teachers and a researcher-facilitator. Both teachers had previously participated in other video clubs to examine their students' mathematical thinking using classroom video. However, both were new users of the Deja View, which required them to capture classroom moments from their point of view for the video club discussion. Video club conversations focused on students' mathematical thinking.

(2) *Middle and High School Mathematics Video Club.* This video club consists of seven teachers with varying levels of teaching experience and a researcher-facilitator. Both the video club context and the POV 1.5 were novel for this group. At the start of the year the researcher videotaped the classrooms and selected video clips for the video club discussions. Then later in the year, teacher-captured clips were used as the focus of

discussion in the video club. Video club conversations focused on classroom discourse around mathematics.

(3) *Elementary School Science Video Club.* This video club consists of four 3-5th grade teachers with varying levels of teaching experience and a researcher-facilitator. The video club context and the POV 1.5 were new for this group as well. However, this video club was different from the others in that it only used teacher-captured video clips for discussion. Video club conversations focused on students' ideas in science.

While the three video clubs reported here differed in important ways, they were similar in that they all included the use of a small wearable camera by teachers. We argue that because of its capability to capture classroom moments as they happen, this tool helped support interesting conversations in the video club as teachers reflected on and analyzed those moments. In our analysis of the video club discussions, three issues stand out as noteworthy.

First, the short time length of the videos appeared to influence the teachers' initial conversations around the video clips. Video club discussions in general focus on 5 to 10 minutes of video footage from a participating teacher's classroom. The Deja View and POV 1.5, however, capture short episodes of classroom events ranging from 30 seconds to 3 minutes. In using these shorter clips as a basis for discussion, we found that this placed greater burden on the teacher whose clip was being discussed. Essentially, these shorter clips strip away contextual details and thus require the presenting teacher to provide sufficient context in order to reconstruct the event for others. In addition, the other teachers had to articulate a range of questions as they made sense of the event. For example, after watching a 30-second clip of students from Richard's class, Richard and Nancy conversed back and forth until they arrived at a shared understanding of the moment. In the video students were discussing how they expanded the binomial $(x+5)^3$.

Nancy:	[So] her question was, how do you multiply all three binomials at once?
Richard:	Yeah that['s]… right.
Nancy:	She was like… "How do you multiply three times three times three?" …
Richard:	Right. Times three…
Nancy:	So I think she wanted an easier way…to expand that binomial, but you haven't gotten to that. …But I don't really understand what the presenter said…
Richard:	Well, …the first girl, her question was, … "How do you know? If you do the first and the second…or the second or the third first, which do you do?" And so what the girl in front said is that it doesn't matter because it is multiplication.

Together these two teachers carefully scrutinized the short captured clip in order to understand both what the student was asking and what the student was thinking about expanding binomials. This level of scrutiny required close attention to a classroom event on the part of both teachers.

Second, when teacher-captured clips were shown in the video club, presenting teachers had already "noticed" these moments during instruction. Thus, they typically came into the video club with an established interpretation of what had taken place in the captured moment. Perhaps using the camera during instruction heightened their noticing somewhat as well as deepened their interpretations in the moment. Interestingly, however, we found that teachers remained open to considering alternative interpretations of the events when viewed with colleagues in the video club. In fact, these new interpretations often built on the ideas the presenting teachers brought to the group. For example, upon capturing a classroom moment Nancy initially thought her students had understood the classroom talk around the equation 2x + 3:

> I think I captured it because they [the students] *did* correct it [the problem]. …the girl did say "No wouldn't that be plus 3x?" But then I think something else happened after that. I think the presenter was convinced that she didn't need to say per week, … and she did change her mind.

However, while discussing her clip in the video club she realized something different:

> Well, ...now I noticed, as I think about this a little bit more, I'm thinking how she [the student] described her situation. I think it might have been just sort of tangled in semantics. [So] is *x* the total amount of money she saved, or is *x* the amount of money she saved that week? So, right now I don't know what it was…But I think that distinction matters and so this whole conversation, I don't know that anybody was clear on that.

This differs from other video clubs because teachers in those clubs did not capture the video clips themselves, and therefore, the first explicit interpretation of the event occurred in the context of the video club. We found that having teachers bring their in-the-moment interpretations into the video club discussion, as well as their willingness to consider other interpretations, added a level of depth to unpacking the classroom event captured.

Third, at times we noted a topic of discussion that was new for video clubs. Specifically, teachers occasionally mentioned and asked each other about the reasons why they had captured particular moments with the wearable cameras. For example, in the above example, the conversation later turned to why Richard captured the clip to begin with and he responded by explaining his thinking.

> Well, it's just really about multiplying, because I was thinking…a lot of times they don't quite understand a parenthetic expression is like, you can treat it like a number. And so, in terms of applying properties, she was saying it is just multiplication, it just doesn't really matter. So I think that is probably why.

We suspect this kind of talk occurred because we asked teachers to capture specific kinds of classroom events (e.g. “Capture students’ algebraic thinking.” or “Capture student ideas about magnets.”) while wearing the Deja View or POV 1.5. Since all teachers from one video club had the same prompt, it is not surprising they were curious of each others’ reasons for capturing a particular classroom moment, and thus turned the video club discussion towards unpacking the teachers’ thinking and reasoning behind the moment of capture. While we want video club discussion to focus on what students are saying and doing, we recognize that unpacking teacher thinking can be a productive focus for a video club conversation helping teachers understand their own thinking in this process.

In conclusion, video clubs that utilize clips captured by teachers in the moments of instruction do support sustainable conversations in the video club context. We have found that such conversations involve teachers in collaborative sense making often elaborating on contextual detail not apparent in the clips, being open to alternative interpretations when viewing practice, and focusing on their own thinking about why they identified a particular classroom moment as worthy of capture.

Implications of this Methodology

Our purpose in presenting these papers as a set is to give the reader a sense of the potential of a new digital video technology – selective archiving – for the study of teacher noticing. For us, the power of these cameras lies in that they allow teachers to record particular moments of classroom interaction as the interactions unfold and without interrupting the on-going instruction. Although the full breadth of our research program with these cameras is still emerging, our use of this technology so far has provided a window into the kinds of data we might collect when working with teachers, the kinds of questions that data will allow us to answer, and the kinds of theoretical issues that data will inform.

In terms of the data we can reasonably expect to obtain with this methodology, we have seen that teachers can implement this selective archiving technology to collect moments that are meaningful to them, and that those moments can ground both personal reflections and discussions with colleagues. This process then provides us with data about the range of things that teachers notice during instruction, their own thinking about what they notice, and their colleagues’ interpretations of that noticing. In terms of the questions this data can address, we see that this data may be useful for examining both population- and individual-level questions. For example, aggregating data across multiple teachers will allow us to answer questions about trends and patterns in teachers’ in-the-moment noticing. In contrast, identifying moment-to-moment relationships between a single teacher’s noticing as captured with the camera and that teacher’s instruction may allow us to better understand the how’s and why’s of a successful teacher’s noticing. The answers to both kinds of questions will be crucial for understanding and impacting teacher noticing. Finally, in terms of the theoretical issues our data might inform, we have found that just the possibility of capturing teachers’ in-the-moment noticing has forced us to examine our underlying conceptualization of teacher noticing. For example, the methodology raises questions about whether the noticing that is conscious - and thus captured with this data - and more tacit noticing are the result of similar or distinct cognitive processes. In addition, data from teacher reflections suggests that we as researchers may need to explore the possibility that noticing is not isolated to a single event in time but is rather distributed across multiple episodes. While we do not yet have definitive answers to all these questions, our preliminary analysis of the data suggests that this new technology will allow us to make substantial contributions to the study of teacher noticing – both methodologically and theoretically - in the near future.

References

Ball, D. L. (1997). What do students know? Facing challenges of distance, context and desire in trying to hear children. In B. J. Biddle, T. L. Good, & I. F. Goodson (Eds.), *International handbook of teachers and teaching* (Vol. II, pp. 769-818). Dordrecht: Kluwer.

Borko, H., Jacobs, J., Eiteljorg, E., Pittman, M.E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching & Teacher Education, 24*(2), 417-436.

Copeland, W. D., Birmingham, C., DeMeulle, L., D'Emidio-Caston, M., & Natal, D. (1994). Making meaning in classrooms: An investigation of cognitive processes in aspiring teachers, experienced teachers, and their peers. *American Educational Research Journal*, *31*(1), 166-196.

Frederiksen, J., Sipusic, M., Sherin, M., & Wolfe, E. (1998). Video portfolio assessment: Creating a framework for viewing the functions of teaching. *Educational Assessment, 5(4),* 225-297.

Hammer, D. & van Zee, E. (2006). *Seeing the Science in Children's Thinking.* Portsmouth, NH: Heinemann.

Leinhardt, G. (1993) On teaching. In R. Glaser (Ed.), *Advances in Instructional psychology* (Volume 4, pp. 1-54). Hillsdale, NJ: Erlbaum.

Levin, D. M., Hammer, D., & Coffey, J. E. (2009). Novice teachers' attention to student thinking. *Journal of Teacher Education, 60(2),* 142-154.

Mason, J. (1998). Enabling teachers to be real teachers: Necessary levels of awareness and structure of attention. *Journal of Mathematics Teacher Education. Vol 1(3) 1998, 243-267.*

Peterson, P. L. & Clark, C. M. (1978). Teachers' reports of their cognitive processes during teaching. *American Educational Research Journal, 15*(4), 555-565.

Reich, S., Goldberg, L., & Hudek, S. (October, 2004). *Deja View Camewear Model 100*. Paper presented at the First ACM workshop on Continuous Archival and Retrieval of Personal Experiences. New York.

Schifter, D. (2001). Learning to see the invisible: What skills and knowledge are needed to engage with students' mathematical ideas? In T. Wood, B. S. Nelson, & J. Warfield (Eds.), *Beyond classical pedagogy: Teaching elementary school mathematics* (pp. 109-134).Mahwah, NJ: Lawrence Erlbaum Associates.

Schoenfeld, A. H. (1998). Toward a theory of teaching-in-context. *Issues in Education, 4*(1), 1-94.

Sherin, M. G. (2001). Developing a professional vision of classroom events. In T. Wood, B. S. Nelson, & J. Warfield (Eds.), *Beyond classical pedagogy: Teaching elementary school mathematics* (pp. 75-93). Mahwah, NJ: Lawrence Erlbaum Associates.

Sherin, M. G., & Han, S. (2004). Teacher learning in the context of a video club. *Teaching and Teacher Education, 20,*163-183.

Tochon, F. V. (1999). *Video study groups for education, professional development and change*. Madison, WI: Atwood Publishing.

van Es, E.A. & Sherin, M.G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. *Teaching and Teacher Education, 24*, 244-276.

V.I.O., Inc. (2009). POV. 1.5. Retrieved September 21, 2009 from http://www.vio-pov.com.

Learning about Complexity and Beyond: Theoretical and Methodological Implications for the Learning Sciences

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Abstract: This paper provides an overview of a symposium that explored the implications of complexity for the field of the learning sciences. Two papers explored aspects of learning about complex systems in the domains of physics and electricity and of the mathematics of change and variation. The third paper viewed learning from a complexity perspective as an emergent phenomenon, and proposes to compliment traditional quantitative and qualitative methodologies used in learning sciences research with computational agent-based modeling methods. The fourth paper is a "theoretical case study" in which an "ontological network theory" based on scale free networks is proposed, and then used to reframe the debate in the learning sciences concerning "coherent knowledge" versus "knowledge-in-pieces" theories of conceptual change. Overall, it is hoped this session stimulated interest in new theoretical and methodological "lenses" for understanding the challenges of learning *about* complex systems and for doing research into learning *as* complex systems.

Overview

We live in an age where many 21st century scientists theoretically conceptualize and methodologically investigate complex physical and social systems in new ways that enable consideration of critical aspects of how these systems behave that have been simplified or ignored in earlier research. For example, whereas neo-Darwinian views of evolution highlighted the importance of natural selection, recent bio-complexity perspectives also stress notions of self-organization, interdependence, co-evolution, and emergent patterns (Bar-Yam, 1997; Gell-Mann, 1994; Holland, 1995; Kauffman, 1993, 1995; Simon, 1999). Other complexity concepts that scientists are using to study complex natural and even synthetic or artificial systems include multi-scale hierarchical organization, dynamical attractors, deterministic chaos, network theories, developmental trajectories, and fitness landscapes.

However, in the learning sciences, interest in complexity has to date focused primarily on issues associated with learning about complex systems, such as papers in the *learning about complex systems* strand in the *Journal of the Learning Sciences* by Sabelli (2006), Jacobson and Wilensky (2006), Goldstone (2006), Lesh (2006), Hmelo-Silver and Azevedo (2006), Hmelo-Silver, Marathe, and Liu (2007), and Goldstone and Wilensky (2008). An assertion explored in this symposium is that "concepts and methodologies from the study of complex systems raise important issues of theoretical and methodological centrality in the field of the learning sciences itself (p. 11) (Jacobson & Wilensky, 2006). Clancey (2008) has made a similar claim about the central role of complexity and systems thinking as scientific antecedents of views of situation cognition in the cognitive sciences.

The purpose of this symposium is to accept the premise that knowledge about the dynamics of complex physical and social systems *is* important for students in the 21st century to understand and to then look at empirical research into the learnability of these ideas. Two papers explored aspects of learning about complex systems in the domains of physics and electricity and of the mathematics of change and variation. Both of these papers employ agent-based models and visualizations as important interactive representational artifacts central to the respective learning interventions employed. In addition, other papers in this symposium considered ways in which theoretical and methodological perspectives from complexity may inform research in our field. The third paper in the symposium examined the methodological limitations of quantitative and qualitative methods used in the majority of learning sciences research if one views learning as an emergent phenomenon, and proposed complementing these methodologies with computational agent-based methods. The fourth paper was a “theoretical case study” that proposed an “ontological network theory” based on scale free networks, which then was used to reframe the debate in the learning sciences concerning “coherent knowledge” versus “knowledge-in-pieces” theories of conceptual change.

The papers in this symposium fit together in a complementary manner. All papers in this symposium employ various complexity conceptual perspectives such as agent interactions, self-organization, hierarchical levels, emergent properties, scale free networks, and three of the four papers explicitly use agent-based models either to facilitate learning or to enhance research. The format of the symposium followed this sequence: (a) comments on the symposium themes by the Chair (5 minutes), (b) 15 minute talks by each of the presenters (60 minutes), (c) discussant comments (10 minutes), and (e) moderated audience discussion (15 minutes). Overall, it is hoped this session stimulated interest in new theoretical and methodological "lenses” for understanding the challenges of learning *about* complex systems and for doing research into learning *as* complex systems.

References

Bar-Yam, Y. (1997). *Dynamics of complex systems*. Reading, MA: Addison-Wesley.

Clancey, W. J. (2008). Scientific antecedents of situated cognition In P. Robbins & M. Aydede (Eds.), *Cambridge Handbook of Situated* (pp. 11-34). Cambridge, MA: Cambridge University Press.

Gell-Mann, M. (1994). *The quark and the jaguar: Adventures in the simple and the complex*. New York: Freeman and Company.

Goldstone, R. L. (2006). The complex systems see-change in education. *The Journal of the Learning Sciences, 15*(1), 35-43.

Goldstone, R. L., & Wilensky, U. (2008). Promoting transfer through complex systems principles. *Journal of the Learning Sciences*, Manuscript in press.

Hmelo-Silver, C. E., & Azevedo, R. (2006). Understanding complex systems: Some core challenges. *Journal of the Learning Sciences, 15*(1), 53–61.

Hmelo-Silver, C. E., Marathe, S., & Liu, L. (2007). Fish swim, rocks sit, and lungs breathe: Expert-novice understanding of complex systems. *The Journal of the Learning Sciences, 16*(3), 307-331.

Holland, J. H. (1995). *Hidden order: How adaptation builds complexity*. New York: Addison-Wesley.

Jacobson, M. J., & Wilensky, U. (2006). Complex systems in education: Scientific and educational importance and implications for the learning sciences. *The Journal of the Learning Sciences, 15*(1), 11-34.

Kauffman, S. (1993). *The origins of order: Self-organization and selection in evolution*. New York: Oxford University Press.

Kauffman, S. (1995). *At home in the universe: The search for laws of self-organization and complexity*. New York: Oxford University Press.

Lesh, R. (2006). Modeling students modeling abilities: The teaching and learning of complex systems in education. *The Journal of the Learning Sciences, 15*(1), 45-52.

Sabelli, N. (2006). Understanding complex systems strand: Complexity, technology, science, and education. *The Journal of the Learning Sciences, 15*(1), 5-9.

Simon, H. A. (1999). Can there be a science of complex systems? In Y. Bar-Yam (Ed.), *Unifying themes in complex systems* (pp. 3-14). Cambridge, MA: Perseus Books.

Learning About Complex Systems

The Role of Perceptual Signatures and Agent-Level Mechanisms in Understanding Emergence: An Example in Learning Electricity

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Research Goals

Our primary research goal is to investigate the effectiveness and cognitive (epistemological) implications of representing electrical conduction in a multi-agent based computational learning environment based on agent-level, intuitive mechanisms.

Theoretical Framework

It has been widely noted that knowledge in the various sub-domains of physics, including electricity, is organized around a few central principles that in turn typically require knowledge of vector algebra and calculus (Belcher & Olbert, 2003; Bagno & Eylon, 1990; Larkin et al, 1981)[1]. A design goal that often drives instructional design in electromagnetism is to organize learners' knowledge around these principles (Bagno and Eylon, 1997; Belcher and Olbert, 2003; Reiner et al, 2000). In contrast to this, the central design principle of the NIELS learning environment (NetLogo Investigations in Electromagnetism, Sengupta & Wilensky, 2005, 2008) is to represent and organize phenomena in the domain of introductory electricity in terms of a few intuitive "mechanisms" that in turn are based individual agent-level behaviors and attributes. For example, resistance is represented in terms of simple electron-atom interactions ("collisions" or "bouncing"), and electric current is represented as the emergent "flow" flow of electrons, that depends on agent-level attributes (e.g., *number* and *speed* of electrons).

Context and Methods

In this paper, we will present the analysis of 5th grade (n = 20) students' interactions with a sequence of two NIELS models (Current in a Wire model (Sengupta and Wilensky, 2008a), and Series Circuit model (Sengupta and Wilensky, 2008b)). Activity Sheets accompanying each model scaffolded learners' interactions with these models, during which they were prompted to observe the agent-level attributes and interactions, and were asked provide written explanations of the following macro-level phenomena in pre- and post-tests: a) how a light bulb works; and b) the behavior of electric current in a light bulb circuit (i.e., whether and why electric current is equal throughout the circuit with a light bulb). The data presented here includes participants' written explanations and semi-clinical interviews with a few selected students.

Data & Analysis

Post-test responses show that all students indicated that electric current would be equal on either side of the light bulb, compared to less than 20% in the pre-test. Written explanations and interview responses show that participants were able to identify both the "mechanism" that produces light, as well as the reason(s) for constancy of electric current, based on the agent-level *natural* behavior of the electrons in the circuit – "bouncing up and down", and/or "friction" with the atoms – which in turn produced heat, and then, light.

Our argument here is that the intuitive nature of these mechanisms is due to the distinct perceptual signatures of some of the key agent-level behaviors. For example, although the Current in a Wire model depict electron-atom collisions, it does not contain any cues pertaining to the temperature of the system (wire). Yet, almost all the participants in their written explanations indicated it is the collisions (and the resultant friction) that would "heat up" the wire (filament) of the bulb and that in turn generates "light." The perceptual signatures here are "heat" and "light," both of which are ubiquitous and intricate components of our repertoire of everyday interactions with the physical world. Goldstone and Wilensky (2009) argued that such perceptual signatures are characteristics of multi-agent based computational representations of the underlying mechanisms that generate emergent complex phenomena across several domains.

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[1] For example, Maxwell's equations can explain a large number of different electromagnetic phenomena, and the behavior of most electric circuits can be predicted using Kirchhoff's laws.

Significance

These results suggest that representing electrical conduction in terms of intuitive, agent-level behaviors can enable learners as young as 5th graders to understand and explain (in a scientifically correct manner) the behavior of electric current in linear circuits, which misconceptions researchers have shown to be difficult for even college students to understand (Chi et al., 1994; Reiner et al., 2000; Bagno & Eylon, 1997).

References

Bagno, E., & Eylon, B-S. (1997). From problem solving to a knowledge structure: An example from the domain of electromagnetism. *American Journal of Physics, 65*, 726.

Belcher, J. W., & Olbert, S. (2003). Field line motion in classical electromagnetism. *American Journal of Physics, 71*, 220.

Chi, M. T. H., Slotta, J. D. and de Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction. 4,* 27-43.

Chi, M.T.H. (2005). Common sense conceptions of emergent processes: Why some misconceptions are robust. *Journal of the Learning Sciences*. *14*. 161-199.

Sengupta, P., & Wilensky, U. (2005). N.I.E.L.S: An Emergent Multi-Agent Based Modeling Environment for Learning Physics. *Proceedings of the Agent-Based Systems for Human Learning Workshop, 4th International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS 2005),* Utrecht, Netherlands.

Sengupta, P., & Wilensky, U. (2008). *Designing Across Ages: On The Low-Threshold-High-Ceiling Nature of NetLogo Based Learning Environments* . Paper presented at the annual meeting of the American Educational Research Association (AERA 2008), New York, NY.

Slotta, J. D. & Chi, M.T.H. (2006). The impact of ontology training on conceptual change: Helping students understand the challenging topics in science. *Cognition and Instruction*. *24(2),* 261 – 289.

Seeing Change in the World from Different Levels: Understanding the Mathematics of Complex Systems

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In an increasingly dynamic and data-driven world, it is important for all students to be able to understand and interpret mathematical patterns over time in the context of the real-world phenomena that generate them. While there is a growing body of evidence that students as early as middle school can understand some fundamental and powerful ideas related to the mathematics of change over time in terms of real-world contexts such as motion or banking (Confrey, Maloney, & Castro-Filho, 1997; Nemirovsky, Tierney, & Wright, 1998; Roschelle, Kaput, & Stroup, 2000), as well as the sophisticated dynamics of many complex systems (Wilensky & Reisman, 2006; Wilensky & Resnick, 1999), little is known about how they might think about mathematical change as it relates to complex systems: where a number of *different behaviors and entities all contribute to a single quantity* of interest, rather than a single behavior or phenomenon. But such systems are increasingly important in all aspects of academic and everyday life. From global temperatures that are increasing exponentially due to increased individual consumption to employment patterns that affect individual workers and are influenced by consumer spending, students must be able to understand not only how to interpret rates of change in the world, but also how individual entities and their actions and interactions contribute to and are affected by those rates of change.

Knowing how students think and learn about change over time in such systems is important not only because it can help prepare students as active and informed citizens (Sabelli, 2006), but also because it can serve as a new access point to more formal mathematical topics such as calculus (Nemirovsky, Tierney, & Ogonowski, 1993; Stroup, 2002), and provide a better foundation for students entering the natural and social sciences where such systems are especially common (AAAS, 1991). That traditional calculus-based mathematics and notions of rate of change are so widely applicable and powerful, yet can so easily obfuscate the very mechanisms and elements that are at the core of those systems, presents a fundamental challenge for mathematics and science educators. In this presentation, we will explore the potential for *Agent-Based Modeling (ABM)* to provide students with an alternative, intellectually honest means to construct and analyze the mathematical trends produced by complex systems.

Agent-based modeling shifts the encoding of *quantitative change* from an aggregate-level quantitative trend (for example, the rate of change of a population count) to a collection of agent-level behaviors that produce those trends (the reproduction behaviors of individuals). As a result of this shift, agent-based modeling can represent and reflect quantitative change in a way that includes notions of randomness, sensitivity to local conditions, the role of nonuniform distributions in aggregation, and other powerful aspects characteristic of change in *systems* that are not dealt with in traditional calculus. While considerable research has investigated how computation has expanded *who* can learn the mathematics of change, less is known about how it can expand *what* can be learned about the mathematics of change.

We propose that such a practice can:

- Broaden student access to the mathematics of change and variation, by providing an alternative language with which to "speak" and "build" mathematical models of multi-agent systems that change over time.
- Make more accessible to students the connections between the mathematical model(s) of a system, and the behavior and mechanisms that comprise that system.
- Provide students with an infrastructure within which the ideas of calculus can be applied to a large class of interesting, and personally relevant, phenomena.

We will support these claims with evidence from think-aloud (Ericsson & Simon, 1984), semi-clinical (Clement, 2000) interviews conducted with 12 high school students enrolled in a precalculus course, who engaged in agent-based model building activities related to population growth and analyzed the graphs of mathematical trends produced by those models. These interviews are part of a larger design research agenda that intends to explore the potential for a constructionist, computational agent-based modeling environment to provide students a flexible, meaningful context within which students can explore the mathematics of complex systems. Findings suggest that while students were initially able to connect the behavior of a population plot to the behavior of the agent-based model, they were not able to articulate how the modeled reproductive behavior of that population, or how certain real-world factors such as a catastrophic event or individual preferences on childbearing might be manifested in the notion of "rate of change" or in the featured plots. They were also likely to attribute fluctuations in the plot to real-world events that were not included in the model, or develop incorrect mathematical explanations for real-world factors. In other words, students had great difficulty connecting the behavior of the model to mathematical ideas such as rate of change; when they tried to do so, they struggled and were often unsuccessful. After interacting with, and building their own, agent based models of population growth, students were much more likely to consider explicitly how behaviors that they knew were included in the model might play a role in the mathematical trends generated by that model, and were better able to predict mathematical trends given behaviors that were not included in the model. They were more likely to consider issues of randomness, individual heterogeneity, and the "stripped down" nature of modeling (that is, that not every real-world factor can be included in a given model) when analyzing mathematical trends and discussing mathematical models.

References

Clement, J. (2000). Analysis of clinical interviews: Foundations & model viability. In R. Lesh (Ed.), *Handbook of research methodologies for science and mathematics education* (pp. 341-385): Lawrence Erlbaum.

Confrey, J., Maloney, A., & Castro-Filho, J. (1997). *Interacting diagrams: A new learning tool.* Paper presented at the PME-NA 19, Columbus, OH.

Ericsson, K. A., & Simon, H. A. (1984). *Protocol analysis: Verbal reports as data*: MIT Press.

Nemirovsky, R., Tierney, C., & Ogonowski, M. (1993). Children, additive change, and calculus. TERC.

Nemirovsky, R., Tierney, C. C., & Wright, T. (1998). Body motion and graphing. *Cognition and Instruction, 16*(2), 119-172.

Roschelle, J., Kaput, J., & Stroup, W. (2000). Simcalc: Accelerating students' engagement with the mathematics of change. In M. Jacobson & R. B. Kozma (Eds.), *Research, design, and implementing advanced technology learning environments*. Hillsdale, NJ: Erlbaum.

Rutherford, F. J., & Ahlgren, A. (1991). *Science for all Americans*. New York: Oxford University Press New York.

Sabelli, N. (2006). Complexity, technology, science, and education. *Journal of the Learning Sciences, 15*(1), 5-9.
Stroup, W. M. (2002). Understanding qualitative calculus: A structural synthesis of learning research. *International Journal of Computers for Mathematical Learning, 7*, 167-215.
Wilensky, U., & Reisman, K. (2006). Thinking like a wolf, a sheep or a firefly: Learning biology through constructing and testing computational theories - An embodied modeling approach. *Cognition and Instruction, 24*(2), 171-209.
Wilensky, U., & Resnick, M. (1999). Thinking in Levels: A Dynamic Systems Perspective to Making Sense of the World. *Journal of Science Education and Technology, 8*(1).

Theoretical and Methodological Implications of Complexity

Learning as an Emergent Phenomenon: Methodological Implications

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In this paper, we put forth a theoretical cum methodological proposal for a line of inquiry that seeks to understand learning as an emergent phenomenon. Our theoretical and methodological arguments detail how an emergent conception of learning places limits on experimental and descriptive approaches, whether used alone or in combination. These limits are not so much a function of causality or reduction, but the need to deal with the dialectical co-existence of linearity and non-linearity that often characterizes complex phenomenon. To overcome these limits, albeit only partially, we leverage complexity theory to advance computational agent-based models as part of an integrated, iteratively validated phenomenological-ABM inquiry cycle to understand learning as an emergent phenomenon from the "bottom up."

Although there is much excitement about the possibilities that computational methods bring to the table, there remains little theoretical and methodological exposition of why and how computational methods can be integrated with existing quantitative and qualitative methods to potentially expand the research toolkit of educational researchers. How do existing quantitative and qualitative methods fall short and how might computational methods be integrated to provide better understanding of the phenomenon of learning, and vice versa? Our argument is based on the premise that learning is a complex phenomenon, which under certain conditions exhibits emergent properties. Indeed, many contexts of learning—formal or informal, groups or individuals—are in fact complex systems (Jacobson & Wilensky, 2006; Kapur et al., 2007). It is this very complexity that sets up the stage for the emergence of knowledge structures, interactional patterns, values, norms, identity, culture, and so on. Invoking emergence, however, requires that we deal with a fundamental tenet of complexity: an emergent phenomenon is ontologically and methodologically irreducible, i.e., *an emergent phenomenon is its own shortest description* (Kauffman, 1995). This simple yet powerful tenet poses serious methodological challenges. Through a careful analysis of the assumptions underpinning quantitative and qualitative methods, we will build a case that existing methods fail to adequately address the issues of *non-linearity*, *temporality*, *spatiality*, and *phase-space* that are of central to understanding emergent phenomenon. We will discuss how and the extent to which these issues can be addressed by *integrating* computational agent-based methods with existing quantitative and qualitative methods (Abrahamson & Wilensky, 2005; Blikstein, Abrahamson, & Wilensky, 2006; Goldstone & Janssen, 2005). In the final analysis, we propose an iterative process of building from and validating with phenomenological theory and data to seek a better understanding of the complex phenomenon of learning noting very well that, any method, be it quantitative, qualitative, or computational, used alone or in combination, will necessarily remain reductive.

References

Abrahamson, D., & Wilensky, U. (2005). Piaget? Vygotsky? I'm game!: Agent-based modeling for psychology research. Paper presented at the annual meeting of the Jean Piaget Society, Vancouver, Canada.
Blikstein, P., Abrahamson, D., & Wilensky, U. (2006). Minsky, mind, and models: Juxtaposing agent based computer simulations and clinical-interview data as a methodology for investigating cognitive

developmental theory. Paper presented at the annual meeting of the Jean Piaget Society, Baltimore, MD.
Goldstone, R. L. (2006). The complex systems see-change in education. *The Journal of the Learning Sciences*, *15*(1), 35-43.
Goldstone, R. L., & Janssen, M. A. (2005). Computational models of collective behavior. *Trends in Cognitive Sciences*, *9*(9), 424-429.
Jacobson, M. J., & Wilensky, U. (2006). Complex systems in education: Scientific and educational importance and implications for the learning sciences. *The Journal of the Learning Sciences*, *15*(1), 11-34.
Kapur, M., Voiklis, J., & Kinzer, C. (2007). Sensitivities to early exchange in synchronous computer-supported collaborative learning (CSCL) groups. *Computers and Education*, *51*, 54-66.
Kauffman, S. (1995). *At home in the universe: The search for the laws of self-organization and complexity*. New York: Oxford University Press.

Ontologies as Scale Free Networks: Implications for Theories of Conceptual Change

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This paper provides a "theoretical case study" of how perspectives from complexity research might provide insights into debates of theory in the learning sciences. The debate we examine concerns the "fault line" in the field related to the "knowledge-in-pieces" versus "coherent knowledge" about conceptual change (diSessa, 2006), which extends back to the seminal monograph in *Cognition and Instruction* in which diSessa (1993) articulated his theory of phenomenological primitives (p-prims) and of "knowledge-in-pieces."

An Ontological Networks Theory (ONT) is proposed in this paper that combines complexity views about scale-free network topologies with learning sciences perspectives about knowledge representation, conceptual change, and learning. Briefly, scale-free networks (Barabasi, Albert, & Jeong, 1999; Barabasi & Bonabeau, 2003; Steyversa & Tenenbaum, 2005; Watts & Strogatz, 1998) resemble the airline system that consists of *hubs*, which are nodes with a very high number of links, in contrast to *random networks*—such as a national highway system—that consist of *nodes* with randomly placed connections. Barabasi et al. (1999) demonstrated that the basic mechanism that produces a scale free network involves: (a) *growth* (addition of new nodes), and (b) *preferential attachment* (the probability of a new node linking with an existing node is proportional to the number of links the existing node has).

The ONT is explicitly based on these core properties of scale-free networks. We propose that the representation of knowledge about a variety of scientific phenomena consists of network configurations of nodes and hubs involving preferential attachment and selection processes. *Ontological nodes* or O-Nodes are relatively "small" domain specific ideas about natural phenomena. O-Nodes are conceptualized as being similar to the construct of phenomenological primitives or p-prims (diSessa, 1993). In contrast, *ontological hubs* or O-Hubs are highly connected nodes (i.e., hubs in scale free network theory) that we regard as similar to the psychological construct of "ontological categories" (Chi, 1992, 2005; Lakoff, 1987). (The full paper discusses the ONT in more detail, including selection processes and deactivating of nodes.)

Recently it has been argued by diSessa (2006) that several theories about how people solve problems and learn often conceptualize knowledge as being relatively stable, consistent, and "coherent." He maintains that these "coherent knowledge" theories have been more common than "knowledge-in-pieces" theories (such as diSessa's) in which ideas are viewed as fragmented and highly influenced by contextual cues and factors. Chi and her associates have articulated one representative theoretical view of "coherent" knowledge and conceptual change. Chi (1992) proposed a theory (which has been iteratively revised for several years, see Chi (2005)) that difficulties learners have with changing their concepts about certain types of knowledge, particularly in the sciences, may be explained as a result of ascribing the concepts being learned to inappropriate ontological categories. Chi's basic argument is that students will need to make an ontological shift if they are to achieve conceptual change about such scientific concepts.

In this paper, we propose that the ONT may be used to reframe this debate in a principled manner. First, p-prims appear to be "node-like" in that they are described as "*Elements*: P-prims are rather small knowledge structures, typically involving configurations of only a few parts…" (diSessa, 1993, p. 111). In contrast, other major theories of conceptual change, such as by Chi, seem to describe cognitive structures such as "ontological categories" that are more "hub-like" than the "node-like" p-prims of diSessa. We believe the ONT has theoretical properties that are consistent with the major assertions and empirical findings associated with these two major conceptual change theoretical camps in the learning sciences (i.e., "coherent knowledge" versus "knowledge-in-pieces"). Further, the ONT as advantages over the learning sciences theory, such as the incorporation of a mechanism or process for how and why certain ideas link or do not link together, that is, the principle of preferential attachment, whereby more highly connected nodes (and hubs) have a higher probability of being linked to than less connected nodes. Thus new scientific ideas we might wish for students to learn would have a higher probability of linking to already formed ontological hubs (i.e., ontological categories), and thus there is a degree of "coherence" or consistency in how a conceptual network is activated, which research on conceptual change by researchers such as Chi has shown. Another potential advantage of the ONT is that as other researchers make progress on the properties and characteristics of scale-free networks mathematically and in terms of applications in other domains (e.g., neuroscience), these advances may in turn inform and enhance our understanding of processes of learning in our field. Finally, it is hoped this "theoretical case study" might be suggestive of how complexity perspectives more generally may be explored for their potential to inform other issues of theory and methodology in the learning sciences.

References

Barabasi, A.-L., Albert, R., & Jeong, H. (1999). Mean-field theory for scale-free random networks. *Physica A, 272*, 173-187.

Barabasi, A. L., & Bonabeau, E. (2003). Scale-Free Networks. *Scientific American, 288*(5), 60-69.

Chi, M. T. H. (1992). Conceptual change within and across ontological categories: Implications for learning and discovery in science. In R. Giere (Ed.), *Minnesota studies in the philosophy of science: Cognitive models of science* (Vol. XV, pp. 129-186). Minneapolis: University of Minnesota Press.

Chi, M. T. H. (2005). Commonsense conceptions of emergent processes: Why some misconceptions are robust. *The Journal of the Learning Sciences, 14*(2), 161-199.

diSessa, A. (1993). Towards an epistemology of physics. *Cognition and Instruction, 10*(2), 105-225.

diSessa, A. A. (2000). *Changing Minds: Computers, Learning, and Literacy*. Cambridge, MA: Bradford Book, The MIT Press.

diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 265-281). Cambridge, UK: Cambridge University Press.

Lakoff, G. (1987). *Women, fire, and dangerous things: What categories reveal about the mind*. Chicago: University of Chicago Press.

Steyversa, M., & Tenenbaum, J. B. (2005). The Large-Scale Structure of Semantic Networks: Statistical Analyses and a Model of Semantic Growth *Cognitive Science, 29*, 41–78

Thelen, E., & Smith, L. B. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.

Watts, D. J., & Strogatz, S. (1998). Collective dynamics of "small world" networks. *Nature.*(393), 440-442.

Understanding the Role of *Place* in Environmental Education across Settings

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Abstract: This session explores the role *place* plays in environmental science learning of youth in formal and informal settings. Environmental education has failed to address the lived experiences and narratives of youth living in areas most in need of social, political, and environmental change; and little is known how or why youth might position themselves or be positioned as members of the complex ecology of our changing environments. These papers report on the role of place by looking at the way it is manifested in situated activity systems. We argue that place is socially (re)constructed by youth where we come to understand the relations youth develop to a place, and the ways in which youth position themselves and are positioned socioculturally, politically, and geographically. To illustrate how this plays out, we draw on a 'envisioning your future neighborhood' mapping activity, a community based program, 'GET City', that is focused on green energy issues, and an instructional unit, 'My Place in Puget Sound' to understand how youth make connections to *place* and are empowered to make decisions and changes in their local communities.

Introduction

With rising worldwide concerns about detrimental human impacts on the environment, it is becoming increasingly essential that we educate youth to both understand environmental issues and have the agency and expertise to solve these issues (NAAEE, 2004; Grass & Agyemon, 2002). However, environmental education is failing to address issues of environmental justice—especially around issues of race, social class, and power relations—that reflect multiple cultural perspectives, thus serving to reinforce dominant societal values and marginalize those groups of youth who are most impacted by the most pressing modern environmental issues (Agyemon, 2003; Grass & Agyemon, 2002; Lewis & James, 1995). Specifically, environmental science education needs to address the lived experiences and narratives of youth living in areas most in need of social, political, and environmental change. Literature in science education has acknowledged the importance of connecting formal science instruction with students' out of school lives (cf. McIntyre, Rosebery & Gonzalez, 2001). In so doing, environmental education may play a role in helping youth see the places in which they live, learn, play, and work as places in which they can enact positive social change. What is needed, therefore, is a way to connect environmental education with the places where youth live their lives and how places are constructed for and by youth has implications for the learning pathways that are available to them.

In this session we take a social justice perspective to challenge the implicit purposes and goals of environmental education and understand the power relationships that intersect the cultures of school, environmental education, and home. We also argue for a systematic understanding of the role that *place* plays in environmental learning of youth in formal and informal settings. In order to think about *place* as a construct, we draw from a spatialized critical social theory. *Place* is political and ideological because it is shaped from historical and natural elements (Lefebvre & Enders, 1976). It is also a medium through which culture is reproduced because of the way it is organized and experienced (Gruenewald, 2003b). According to Rodman (1992), *place* is also socially constructed which is determined by individual agency and forces beyond individual control. For the individual, places have multiple meanings in terms of physical, emotional, and experiential realities at particular times. Consequently, Wacquant (1995: 427) posits that places are understood as social entities where they are "*produced institutionally*, within ecological and technical constraints, by social and political struggles over competing uses of spaces, resources, and people."

This paper set explores the role *place* plays in environmental science learning of youth in formal and informal settings. Specifically, the papers explore how place, within situated activity systems, is socially (re)constructed by youth where we come to understand the relations youth develop to a place, and the ways in which youth position themselves and are positioned socioculturally, politically, and geographically. Moreover, we look at how the design of an instructional unit, called *'My Place in Puget Sound'*, connects Puget Sound science and action with youths' everyday lives and cultural practices. The *first symposium paper* looks at the social construction of place where youth from a community center, called Riverside Park Community Center, were asked to design a future map of their neighborhood. In this paper we argue that the positioning of the youth in their neighborhood is relative to their cityscapes (Nespor, 1997). Their relations with their neighborhood are patterned in space and time, and are realized by the ways they come to negotiate their positions in spaces through resistance, agency, and/or affiliation; and the ways they make inaccessible spaces accessible. The *second symposium paper* examines how youth and their families in an after school, "voluntary" science/technology/social club, called *'GET City'* in a mid-sized Midwestern city, come to talk about energy issues, IT, and STEM energy related careers; and how the language they use positions them with particular roles and expertise. The analysis focuses on the intersecting discourse communities that play a role in how science and place are constructed. The *third symposium paper* examines the role of place and its implications in the design of an instructional unit where we provide youth with a context to connect Puget Sound science and action with youths' everyday lives and cultural practices. We examine the ways in which youth learn about issues in their local marine environment; and how they are empowered to take action by participating in civic activities, for example the Puget Sound 2020 Action Agenda, where students come to develop new or more nuanced understandings of issues in Puget Sound; and develop an awareness of applying multiple perspectives including scientific understandings, personal and cultural values as well as social and ethical concerns to understanding and decision making related to marine science and to marine-science-related societal issues.

Understanding the Role of Place in Situated Activity Systems

We use the construct of *narrative* to articulate an account of the construction of place. Specifically, we look at how narratives highlight or obscure certain social realities influence the construction of activity systems, and position youth in certain ways in environmental education. Building from Bruner's account of narrative cognition (1987), we define narratives for our purposes as socially shared accounts of human intention and action. In this account of social narrative there is an inseparability of character, setting, and action from a situational perspective.

Narrative can exist and influence learning at multiple levels. Therefore, we look at narratives from three planes of analysis: individual, social, and cultural, as well as the accompanying learning phenomena for each.

Cognitive ecology refers to the diverse terrain of influences on the way an individual cognitively makes sense of, or assigns meaning to, the world. For example, an individual may have certain narratives about herself as a learner (epistemological knowledge) based on cultural, gender, age, and class identities, and these narratives influence the way she acts upon the world (cf., diSessa [2002] for his notion of conceptual ecology). These "lifeworlds embody the multiple histories that give rise to experience and the interpretation of that experience" (Lim & Calabrese Barton, 2006). Situated activity systems refer to activity that takes place within the boundaries of a (socially constructed) place (Goffman, 1961). Individuals can "boundary cross" (Phelan, Davidson & Cao, 1991) as they move between activity systems, in each of which are embedded culturally-based narratives. We consider the social plane to be the space where individuals enact their personal epistemologies and where cultural toolkit elements set up lines of action in social interactions and in situated activity systems. As individuals come to places, they interact not only with each other but also with the cultural narratives and resources available in those places. As individuals move within places and perceive those places in certain ways based on their own cognitive ecologies, they *construct* places and fill those places with meaning (Casey, 1996). Cultural toolkits (Swidler, 1986) refer to the ideologies, technologies, and narratives that are uniquely present at a given historical moment. We consider cultural activities and toolkits broadly, to include resources from environmental education, environmentalism, school, ethnic group memberships, and religious participation. These toolkits then shape activities in certain ways and interact with an individual's own cognitive ecology. Narratives can exist at all three planes of analysis in the form of prevailing cultural narratives of environment, local narratives about places that shape activity systems, and individual narratives based on personal epistemologies and repertoires of practice (Gutierrez & Rogoff, 2003). Individuals who come to those places and activity systems bring with them certain personal narratives that shape how they perceive the activity systems in which they engage. This perception has influences on learning and engagement and is important for us to look at in terms of how to construct learning pathways for students that leverage their personal narratives and expertise. We also argue that individuals coming to environmental education can contest the prevailing ideologies within cultural narratives, and that we need to empower youth to do so. Looking at narratives across the three planes of analysis gives us a specific lens with which to ask, from a social justice perspective, by whose narratives, for what purposes, and with what consequences for learning does environmental education get shaped.

Paper 1: Ideological dimensions of place: (re)creating an urban area by *Giovanna Scalone & Philip Bell, University of Washington*

Introduction

From a spatialized critical social theory, place is political and ideological because it is shaped from historical and natural elements (Lefebvre & Enders, 1976). It is also a medium through which culture is reproduced because of the way it is organized and experienced (Gruenewald, 2003). According to Rodman (1992), place is also socially constructed which is determined by individual agency and forces beyond individual control. For the individual, places have multiple meanings in terms of physical, emotional, and experiential realities at particular times. Consequently, Wacquant (1995: 427) posits that places are understood as social entities where they are "*produced institutionally*, within ecological and technical constraints, by social and political struggles over competing uses of spaces, resources, and people."

This paper describes the social construction of place where students from Riverside Park Community Center were asked to design a future map of their neighborhood. We argue that the positioning of the students in their neighborhood is relative to their cityscapes (Nespor, 1997). The students' relations with their neighborhood are patterned in space and time. For one student, her neighbor is a commercial company where her experiential reality rests on trucks running all day polluting her space with fumes, making it difficult to breathe; for another student getting to the downtown area means taking multiple buses that run at limited times, spatially isolating her neighborhood from the downtown area. These relations are realized by the ways that students come to negotiate their positions in spaces through resistance, agency, and/or affiliation; and make inaccessible spaces accessible.

In this study we asked two questions: (1) How is place socially constructed in the future map of the students' neighborhood? (2) In what way(s) do the students position themselves in relation to their (re)constructed neighborhood and how is their positioning relative to their cityscapes?

Research Design and Context

This study took place in a research setting in an urban center in the Pacific Northwest at a community center that we call Riverside Park Community Center. It was an environmental justice program for high school students. The Riverside Park community lines the banks of an industrialized river that was designated by the Environmental Protection Agency as a Superfund site in 2001, which means that it is one of the most toxic waste sites in the country. The river's pollution is but one of the many environmental issues facing Riverside Park. In addition, it is one of the few communities left in the city that is zoned for both commercial and residential use, which means that commercial companies can be physically located next to private residences.

The environmental justice youth program was sponsored by a local community-based non-profit organization. The goal of the program was to educate youth about issues in environmental justice, using the Superfund site as a context for learning. Classes were held at the community center after school once a week. In addition, the group performed community service every Saturday for 4-6 hours. The program ran for 12 weeks. There were 12 youth who consistently attended the program, ranging from freshmen to juniors. Two were African American, 2 were European American and Native American, and the rest were Latino. Isa and Gabriela were co-facilitators of the program.

The overall data for this study is from a cross-setting ethnography of environmental education. As participant-observers, we followed the youth from January to June of 2008 as they experienced environmental education in various settings. We collected digital photography and fieldnoted accounts of the instruction, interactions, and stories of the participants as they navigated through these varied settings. For this study, the data is from a mapping activity that the students engaged in class. The students were given a current map of their neighborhood and tracing paper was placed on top of it so that they may design a future map of their neighborhood. They were asked to think about what they want their future to look like. Eventually, this exercise will be used to help other children in the community center to map their neighborhood.

We analyzed the fieldnotes for episodes where we could see—through the instructional materials used, the discourse of the participants, or their actions—aspects of place being socially (re)constructed. These episodes were coded for in the data using first open coding (Strauss & Corbin, 1998), and then axial coding (Strauss & Corbin, 1998) to further articulate the categories within the episodes once they were identified. Working from the assertions that emerged through the coding, we then systematically looked for disconfirming evidence across the data set (Erickson, 1986). Finally, for each episode we identified and categorized as being relevant to (re)constructing place. This analysis forced us to look more holistically at the data set in order to understand the context around each episode, the processes involved in defining that episode, and how each episode fit in with the larger data set.

Findings

In this study we present findings from an analysis of the students' future neighborhood mapping activity and an analysis of our fieldnotes. We identified episodes of place being socially constructed by the students. A recurrent theme in our findings is the ideological dimension of place (cf. Gruenewald, 2003). We draw on Gruenewald's (2003) 'ideological dimension of place' as a construct to understand, firstly, how place is socially constructed in the future map of the students' neighborhood; and secondly, how students position themselves in relation to their (re)constructed neighborhood and how their positioning is relative to their cityscapes. Drawing from spatialized critical social theory, Gruenewald (2003) examines how spatial relationships shape culture, identity, and social relationships. These relationships are, in turn, expressive of ideologies and relationships of power. We found that these relationships were realized in the maps that the students had drawn. The students' construction of commercial and consumption spaces in their future neighborhood could be indicative of the way in which space, which is society, is imbued with power relationships. In the reconstructed map, the students had made accessible for themselves spaces that reflect not only their cultural heritage (for example, the 'Mexican Plaza') bust spaces that express the interests of the upper class (for example, 'mansions') as well as sites for recreational activities which are inaccessible for the students, such as soccer fields.

Places reflect and reproduce social relationships of power and domination. The control of place by government and other social institutions, such as "Microsoft" and "Boeing" legitimizes and reproduces the authority of those institutions (Gruenewald, 2003). However, bell hooks metaphorical/material concept of marginality shows how place can be constructed as a space of domination and a place of hope (hooks, 1990) where the students have filled spaces on the map with cultural products, such as Chinese Downtown and Mexican Plaza. For hooks (1990) these spaces can be seen as a site for resistance, agency, and affiliation. It is at these sites that students may come to understand and recast their social positions through their experiential and material cultural conditions (Smith & Katz, 1993). In turn, we become responsible for place making.

Another theme in our findings is the ways in which the students see themselves navigating their future neighborhood. While their construction of spaces evokes ideological dimensions of place, it also illustrates how they are positioned in their community, neighborhood, and beyond. For these students' the mapping activity shows how essential sites of consumption are, such as malls; and how valued sites that are currently inaccessible become accessible, such as "Wild Waves". Spaces that invoke popular culture become a resource for the students to mark their identities and forge ties across their current and envisioned neighborhood (Cf. Nespor, 1997: 195). Students' ideational systems are juxtaposed with dominant ideational systems. This is manifested in the ways they make place through their identity and culture. For example, "Museum of Cris"; "Canada"; "SFC" (S's Freshman Court).

What is striking in the reconstructed maps is the positioning of the play spaces, for example the soccer fields to the businesses. While our data does not attend to the students' histories, it may indicate the value that students attach to economics and the role it plays in providing resources for themselves and their families. This, in turn, has forced us to look at the role place plays in terms of employment – for the students and their families. On several occasions the students made repeated reference to fast food establishments. For the students, these were indicators of employment. This especially stands out in the illustrations where in terms of time, students currently aspire to work at "Chucky Cheez" or "McDonalds", and in the future "Microsoft" and "Boeing". Here, capital becomes important when it is made available and activated in spaces. These constructed places also bear significance on students' identities (cf. Lim and Calabrese Barton (2006) notion of "lifeworlds")

Understanding sense of place can be seen as a political activity where it is about the politics of identity and local understanding (Aikenhead, Calabrese Barton & Chinn, 2006). Gruenewald (2003) argues that the lack of attention to space in education has obscured the role of citizens in the process of place making. It is, thus, essential that educators and students develop an analysis of how an economy functions through space, geography and social institutions. If educators and students are to understand culture in places where they live, they must explore the interdependent economic, political, ideological, and ecological relationships between places (Gruenewald, 2003).

Implications

This study is an attempt to understand how places are socially constructed by the students; and how they position themselves in relation to their (re)constructed neighborhood and how their positioning is relative to their cityscapes. Understanding why students draw on particular sites of consumption, constraint, and sites that provide resources for the students and their families requires an examination of the students' histories in relation to the neighborhood (cf. Nespor, 1997). The episodes in our data illustrate the economic, political, ideological, and social relationship the students have to their spaces, yet by analyzing the interactions around the mapping activity with a critical lens on the power relationships of place, and the social construction of place, we can gain insight into the students' relationships with their neighborhood and their positioning relative to their cityscapes. Gruenewald (2003b:626) discusses the social dimension of place as being a product of culture by means of one's experience of places that are mediated by culture, education, and personal experience. It is within this construct that place-based education allows students to reflect and unpack particular cultural meanings attached to place. Nevertheless, Gruenewald (2003b) maintains that little research has been done in documenting and explaining what youths' sense of place is and how it might matter in educational contexts. Gruenewald (*Ibid*) contends that as educators we need to develop connections with places where we are able to invest meaning.

Basso (1996: 72) writes that ideational systems around features of the local landscape become symbolically constituted, socially transmitted, and individually applied in a way that places flexible constraints on how the physical environment can (and should) be known, how its occupants can (and should) be found to act and, how the doings of both can (and should) be discerned to affect each other. Ideational systems are made up of shared ideas, values, beliefs, rules, and meanings that are expressed through social institutions, and influence the ways on which places are organized. Youth adapt to their socially constructed places in culturally specific ways that can be interpreted as self-determinate. Ricoeur (1979 as cited in Basso 1996) maintains that ideational systems delineate a distinctive way of being-in-the-world. However, we cannot account for the ways in which youth construct their reality that reflects a personalized manifestation of a shared perspective on their human condition (cf. Basso, 1996). This issue needs to be addressed in future research.

For future research, it is also essential to account for and view sense of place drawing on the "visible particulars of local topographies, the personal particulars of biographical associations", and "the notional particulars of socially given systems of thought" (Basso, 1996:144).

Paper 2: "The Coal Plant Could Give People Jobs, But at the Same Time, It could Pollute the Air" Science learning as participation with and in a place by *Shari Rose & Angela Calabrese Barton, Michigan State University*

Introduction and Conceptual Framing

Framing learning as changing participation is a powerful step forward in documenting the goals of science education. Learning as changing participation has its history within sociocultural studies of learning (Lave & Wenger, 1991), but, at the same time it calls into question the complicated ways in which the outcomes and goals of learning are shaped by the relations of power and privilege that often constitute a community of practice as well as by other historical, political, social, cultural, and physical factors (Gutierrez, 2008).

A focus on changing participation calls attention to the role of place. How individuals value an activity depends, in part, upon the purposes and goals of that activity, its relationship to a place (including local knowledge and resources), and the relative positions of power of the agents within that place. Informed by cultural historical perspectives, we value *place* as a conceptual framework that helps us to understand the importance the relationship between the individual and the society and also the local and the global (Nasir & Hand, 2006). In other words, part of understanding how learning is mediated culturally and historically developing, is to recognize how structures and trajectories interact in place-based ways.

We work in out of school urban environmental education contexts. Despite recent calls to engage youth in socio-environmental decision-making (Covitt et al, 2009), science education more generally and environmental education more specifically, seems to have ignored its intimate and unique connection with the local community, marginalizing the role of place in education (Bowers, 1997; Gruenewald; 2003a, 2003b; Sanger, 1998; Sobel, 1993, 1996). Yet, place matters because it orients science learning in particular ways - it imbues the learning of science with certain expectations, practices, values, and materials. Furthermore, place matters in yet another way because it positions youth in unique ways toward science learning: How youth are positioned socioculturally, politically, and geographically shapes how and why students and their teachers might choose to engage in science or in how they assign meaning or value to it. This latter point is important because it underscores that by engaging in the knowledge and practices of science in embodied ways, youth (and their teachers) can also transform the worlds they traverse in ways that matter to them. This is especially important in the contexts in which we work because historically, environmental discourses have often existed in tension with the economic concerns of low-income families (Jones, 2008). Consequently, we know very little about how or why youth might position themselves as important members of the complex ecology of our changing world. We are particularly concerned about this issue from the perspective of low-income urban youth who are often positioned outside "power" discourses of their schools and their communities.

Research Questions

Our study merges two theoretical traditions – sociocultural perspectives on learning (i.e, Lave & Wenger, 1991) and critically oriented and place-based environmental science (i.e., Covitt et al, 2009) to better understand the Discourses, funds of knowledge, and hybrid practices (Gutierrez, 2008) that youth draw upon as they make sense of complex scientific content rooted in local placed-based controversy – that of a proposed new coal-biomass power plant. In particular our research questions include:

What salient Discourses and funds of knowledge frame how youth define an environmental problem, seek to acquire new information and take a stand in their community? How does explicitly incorporating the primary and secondary Discourses and a sense of place of urban youth into the environmental decision-making process affect how youth engage environmental justice?

Research Design and Context

Our study takes place in the context of a year-round community based program focused on green energy issues, "GET City," in a mid-sized Midwestern city. GET City is an after school, "voluntary" science/technology/social club for youth ages 10 – 14. GET City holds as it dual goals to foster deep and meaningful learning among urban youth in the areas of advanced information technologies (including data acquisition, management and

analysis tools and communication tools) and the science and engineering of green energy issues.
GET City adopts a place-based, youth participatory action research (PAR) approach which focuses on community science issues related to green energy in the urban center. The program provides opportunities for urban youth to investigate science issues in their own community and actively participate in change making processes in their own place as "community science experts" (Calabrese Barton & Tan, accepted). The PAR approach provides an opportunity to closely observe 1) how youth leverage their identities as they try to participate in community science projects as community science experts and 2) in what ways a place-based community science project could facilitate and support youth learning as participation.

The study took place while the youth engaged in a 4-month investigation into whether their city should build a hybrid power plant, a highly contentious issue. In addition to gathering more traditional ethnographic forms of data such as program documentation (i.e., attendance, lesson plans, etc.), fieldnotes recorded daily and separately by both authors, and interviews with youth and club staff, we also conducted interactive conversations and worked with youth to create products that reflected their curiosities and desires. We folded these products into our database as well, offering us an opportunity to engage in content analysis of a range of student works.

Data analysis involved multiple stages and levels of coding (Strauss & Corbin, 1998). We developed coding schemes on those aspects of GET City, which seemed to be particularly relevant to engaging youth in energy issues and in advanced IT. We have paid attention to the quantity and quality of youth and family engagement, including documentation of which youth and their families participate in what ways, we have honed in on how science meanings have been negotiated by youth and their families, and on how youth and families talk about energy issues, IT, and STEM energy related careers, noting how the language they use positions themselves with particular roles and expertise.

Findings & Significance

Our findings reveal that "place" facilitates and constrains participatory learning by the contextual scaffolds it gives rise to. By contextual scaffolding we reference the situated cognitive stance that the contextual dimensions of meaning making are deeply entrenched in the social, historical, geographic, and political relations of which it is a product (Brown, Collins, & Duguid, 1989). For example, although environmental stewardship discourses framed youth's decision-making process, concerns about the need for jobs, the rising cost of fossil fuels, and our reliance on electricity to provide refrigerated food, framed the questions youth asked and the information they sought to acquire as they struggled to decide what was best for their community. The value of scientific information took on significance as youth attempted to figure out how they might reconcile these sometimes competing and conflicting Discourses.

To unpack how we view the ways in which place frames participatory learning, in our paper we first describe how place brings out tensioned dialectics in doing community-based science, including science versus place, knowledge versus action, and scientific versus cultural, and how these tensioned dialectics shape the process by which youth worked to transform (and were supported to transform) their participation. For example, explorations of the power plant positioned the youth by virtue of their role as community members and students as legitimate stakeholders. Youth were empowered both to negotiate the ways in which they engaged with the science activities and to use the science knowledge and skills they gained to bring about strategic changes to the place they inhabit through hybrid practices.

Second, we also discuss how these tensioned dialectics served as contextual scaffolds in support of participatory science learning because of the dialectical hybrid discourses and practices they afforded. Through hybrid practices, the youth reconciled tensioned dialectics in science learning by authoring their learning: what they learn (place vs. science), why they learn (knowledge vs. action), and how they learn (scientific vs. personal/cultural). In particular, participating youth engaged at least three reconciling "hybrid" discourses (Green Jobs, Save our Mountain Tops, and Earth and Jobs in the Balance), which span a trajectory for how science, community and environmental justice were positioned with respect to each other and their role in that reconciliation. By explicitly positioning youth Discourses within the power plant debate, youth challenged the either/or questions that framed the debate and expanded the role of environmental justice in the process.

We conclude by looking more closely at how these tensioned dialectics shape the process by which youth expanded their epistemic, place and science identities through the dialectical, hybrid science practices they support.

<u>Paper 3: "My Place in Puget Sound": Leveraging youths' sense of place in ocean sciences education</u> by Carrie Tzou, University of Washington Bothell

Introduction

This work builds off of ethnographic research and findings that argue for *place* as a construct for connecting youths' lived experiences and science learning (Authors, in press). In previous design-based research that has attempted to leverage students' out of school expertise into the design of science instruction (Authors, 2007), we have struggled with how to seriously connect this expertise with deep learning of discipline-specific content. In this project, we take *place* as a construct that connects disciplinary learning around the ocean with students' sense of place. We have designed a 4-week curriculum called *My Place in Puget Sound* that begins with students situating themselves in their local neighborhoods, communities, and cities, and then seeing the connection between those places and the ocean (by which they all live in close proximity). They do this through a mapping exercise in which they first map out their neighborhoods, then overlay topographical maps and maps of waterways so that they can see how water might drain from their communities out to the ocean. This is entryway into learning about watersheds, wastewater treatment, and environmental impacts of pollutants in the Puget Sound. The unit empowers students to make positive change in their communities by engaging them in an action project, in which they propose and carry out a community-based project that affects one aspect around the health of Puget Sound.

Methods and Data

We situate this work under the umbrella of *design-based research* (Collins, 1992, Author 2004), in that we are attempting to understand how to design a personally consequential science curriculum that highlights children's everyday cognition at the same time that it engages children in systematic, authentic scientific practices. Under the umbrella of design-based research, there is wide variation in the theoretical perspectives, methods, settings, and purposes of the work. Author (2004) outlines some major distinctions between the types of design-based research families in the literature, ranging from developmental psychology (c.f. Brown, 1992), to cognitive science (White & Frederiksen, 1998), to cultural psychology (Cole, 1996). Bell also discusses design-based research that integrates ethnographic methods into design research (Stevens, 2000).

The data from this study come from observations of three classrooms enacting the *My Place in Puget Sound* curriculum. Field notes of classroom activity and talk were taken and transcribed, and artifacts from the students were collected.

Findings & Significance

Preliminary analysis of the data indicate two major findings: (1) that students need support noticing the places where they live-especially as these places pertain to relevant features that might have environmental impacts (businesses, green spaces, topographical features, etc), and (2) mapping is a powerful way to connect students' sense of place with the science learning. This work has significance addressing environmental education for social justice, as poor youth of color disproportionately live in the most polluted urban areas (Bullard, 2002) and access to environmental education that empowers youth to make positive change in their local environments is a civil rights issue that should be a focus of their science education.

References

Aikenhead, G. S., Calabrese Barton, A., & Chinn, P. W. U. (2006). Forum: Toward a politics of place- based science education. *Cultural Studies of Science Education*, 1, 403 – 416.

Basso, K.H. (1996). *Wisdom Sits in Places: Landscape and language among the Western Apache.* Albuquerque: University of New Mexico Press.

Bowers, C. A. (1997). *Culture of denial*: *Why the environmental movement needs a strategy for reforming universities and public schools.* Albany, New York: State University of New York Press.

Brown, A. L., & Campione, J.C.(1998). Designing a community of young learners: Theoretical and practical lessons. In N. M. Lambert & B. L. McCombs (Eds.), *Howstudents learn: Reforming schools through learner-centered education* (pp. 153-186). Washington, DC: American Psychological Association.

Brown, J.S., Collins, A. & Duguid, S. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18(*1), 32-42.

Bruner, J. (1987). *Actual minds, possible worlds*. Cambridge, MA: Harvard University Press.

Bullard, R. (1990). *Dumping in Dixie: Race, class, and environmental quality*. Boulder, CO: Westview Press.

Calabrese Barton, A. & Tan, E. (accepted). We be burnin: Agency, Identity and Learning. Journal of the Learning Sciences. (Accepted Sept. 2009).

Casey, E.S. (1996). How to get from space to place in a fairly short stretch of time: Phenomenological Prolegomena. In S. Feld & K.H. Basso (eds). *Sense of place* (13-52). Santa Fe, NM: School of American Research Press.

Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Belknap Press.

Cole, M., & Engstrom, Y. (1993). A Cultural-historical approach to distributed cognition. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 1-37). New York: Cambridge University Press.

Collins, A. (1999). The changing infrastructure of education research: Issues in educational research. In E.C. Lagemann & L. S. Shulman (Eds.), *Issues in education research: Problems and possibilities* (pp.289-

298). San Francisco: Jossey-Bass.
Covitt, B., Tan, E., Tsurusaki, B., & Anderson, A. (2009). Students' Use of Scientific Knowledge and Practices When Making Decisions in Citizens' Role. Paper presented at the annual NARST Conference, Anaheim, CA.
diSessa, A. (2002). Why "conceptual ecology" is a good idea. In M. Limón & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 29-60). Dortrecht: Kluwer.
Elmesky, R. (2003). Crossfire on the streets and into the classroom. *Cybernetics and Human Knowing*, *10*(2), 29-50.
Erickson, F. (1986). Qualitative methods in research on teaching, pp. 119-145 (up to "Data analysis and reporting.") Monograph reproduced from M. Wittrock (Ed.), *Handbook of Research on Teaching*. New York: MacMillan.
Goffman, E. (1961). *Encounters: Two studies in the sociology of interaction.* Indianapolis, IN: The Bobbs-Merrill Company, Inc.
Gruenewald, D. (2003a). The best of both worlds: A critical pedagogy of place. *Educational Researcher, 32*(4), 3-12.
Gruenewald, D. A. (2003b). Foundations of place: A multidisciplinary framework for place-conscious education. *American Educational Research Journal, 40*(3), 619 (636 pages).
Gruenewald, D. A. (2004). A foucauldian analysis of environmental education: Toward the socioecological challenge of the earth charter. *Curriculum Inquiry 34*(1), 71-107.
Gutiérrez, K. D. (2008). Developing a sociocritical literacy in the third space. *Reading Research Quarterly 43*(2): 148-164.
Gutiérrez, K., & Rogoff, B. (2003). Cultural ways of learning: Individual traits or repertoires of practice. *Educational Researcher, 22*(5), 19-25.
Holland, D. (1998). *Identity and agency in cultural worlds*. Cambridge: Harvard University Press.
hooks, b. (1990). *Yearning: Race, gender, and cultural politics.* Boston: South End Press.
Jones, V. (2008). *The Green Collar Economy*. NY, NY: Harper Collins. Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
Lefebvre, H. & Enders, M.J. (1976). Reflections on the Politics of Space. *Antipode,* 8(2), 30-37.
Lim, M. & Calabrese Barton, A. (2006). Science learning and a sense of place in an urban middle school. *Cultural Studies of Science Education, 1*, 107-142.
Nasir, N.S., & Hand, V.M. (2006). Exploring sociocultural perspectives on race, culture, and learning. *Review of Educational Research, 76*(4), 449-475.
Nespor, J. (1997). *Tangled up in School: Politics, Space, Bodies, and Signs in the Educational Process.* Mahwah, New Jersey: Lawrence Erlbaum Associates.
Phelan, P., Davidson, A., Cao, H. (1991) Students' Multiple Worlds: Negotiating the Boundaries of Family, Peer, and School Cultures. *Anthropology & Education Quarterly, 22*(3) 224-250.
Pinar, W. F. (1991). Curriculum as social psychoanalysis: On the significance of place. In J. L. Kincheloe & W. F. Pina (Eds.), *Curriculum as social psychoanalysis: On the significance of place* (pp.165-186). Albany: SUNY Press.
Rodman, M.C. (1992). Empowering Place: Multilocality and Multivocality. *American Anthropologist, New Series,* 94(3), 640-656.
Sanger, M. (1998). Sense of place and education. *Journal of Environmental Education, 29*(1), 4-8.
Smith, G. A. (2002). Place-based education: Learning to be where we are. *Phi Delta Kappa, 83*(8), 584-594.
Smith, N. & Katz, C. (1993). Grounding Metaphor: Toward a spatialized politics. In Keith, M. & Pile, S. (Eds.), *Place and the politics of identity* (pp. 67-83). New York: Routledge.
Sobel, D. (1993). *Children's special places: Exploring the role of forts, dens, and bush houses in middle childhood*. Tuscon, AZ: Zephyr Press.
Sobel, D. (1996). *Beyond ecophobia*. Great Barrington, MA: Orion Society.
Strauss, A. & Corbin, J. (1998). Basics of Qualitative Research. California: Sage Publications.
Swidler, A. (1986). Culture in action: Symbols and strategies. *American Sociological Review, 51*(2), 273-286.
Wacquant, L.J.D. (1995). The Ghetto, the State and the New Capitalist Economy. In Kasinitz, P. (ed.), *Metropolis: Center and Symbol of our Times* (pp. 418-449). New York: New York University press.
White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction, 16*, 3-118.

Supporting Young New Media Producers Across Learning Spaces: A Longitudinal Study of the Digital Youth Network

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Abstract: In this symposium, we will report on a mixed method, three-year longitudinal study that documented a learning environment intentionally designed to provide urban youth with tools and learning opportunities that would allow them to create, collaborate and communicate with new media production technologies. The design of this in-school and after-school program was motivated by concern over growing divides with respect to access to learning environments that can support empowered and generative uses of technology. Through a unique program that offered both a wide array of special interest after school clubs (e.g. robotics, graphic design, digital broadcast and movie making, music recording and remixing, video game development) and mandatory media arts classes during the school day, learners were able to develop broad and deep experiences across the middle school years. The program of research involved an ethnographic study focused on the learning environment, nine case studies of young producers and their learning ecologies across home, school, and community, and quantitative tracking of the entire cohort over time. In this session, four papers will be shared that describe 1) the environment; 2) the theoretical framework guiding the research, research questions, and associated methods; 3) the development of learners as creative producers; and 4) the role of artist-mentors as media arts instructors. The contributions of the symposium include sharing a unique interdisciplinary collaboration and the results of a unique experiment designed to bridge divides while innovating a new ecological model of learning.

Introduction

When the 6th graders of today enter adulthood in 2020, what will it mean to be a productive, informed and literate citizen? We contend that being literate in 2020 will require the need to fluidly use multiple modalities (e.g. text, aural, graphic, cinematic, and interactive) to communicate locally and globally for personal and professional uses. An informed and empowered citizen will need to be digitally literate, possessing the ability to both produce and critically analyze media in multiple forms in order to fully communicate. New media literacies, broadly defined by Jenkins (2006) as "a set of cultural competencies and social skills that young people need in the new media landscape" include abilities to not only interpret, but also *create* using various digital modalities. This shift in the communicative value of media objects beyond the field of entertainment raises the question of how to ensure that all citizens, especially youth, are prepared to communicate effectively. The national dialogue, in the form of calls for more technology in the classroom, more tech savvy teachers, technology standards (NRC, 1999; ISTE, 2007), and a better prepared workforce (Levy & Murnane, 2004), has apparently placed this task in the hands of schools, with communities and homes providing backup support.

On the surface this makes sense, as the development of students as literate beings has traditionally and "officially" been the purview of the school. However, research shows that the literate practices of the home and community have a predictive pattern in determining how literate a student will become (Neuman & Roskos, 1993). Thus, while schools do support youth in becoming literate, they have not routinely been able to close the gap that is already apparent when students first enter school. In addition to the historical inability of schools to close the literacy gap, we must also draw attention to the evidence that shows that schools traditionally have not played a major role in the development of young people's new media and other 21st century literacies. The accounts we have of "digital natives" reveals that their motivations, access, and mentoring is located most often outside of the school through their families, neighbors, peers, and/or summer programs even in the most advantaged of communities (Ito et al, 2008; Barron, 2004; Prensky 2001).

While acknowledging the many challenges of assigning responsibility for the development of new media literacies to schools, we must recognize that schools have assumed the role of developing youths' literacy (text or digital) because they are the one institutional commonality for almost all American youth, and hence, provide the best opportunity of ensuring all citizens access to literacy instruction. We contend that any solution for the development of digital literacy for all must include the school to ensure that all youth can access learning opportunities in addition to computing tools. Our challenge is to create learning environments that apply findings from research on digital natives and traditional literacy instruction and that build upon previous successes in digital media-based out-of-school programs in order to develop all youths' new media literacies, especially those in underserved communities.

In this symposium, we will report on a mixed method, three-year longitudinal study that documented one learning environment intentionally designed to provide urban youth with tools and learning opportunities that would allow them to create, collaborate and communicate with new media production technologies. The design of this in-school and after-school program was motivated by concern over growing divides in access to learning environments that can support empowered and generative uses of technology. Through a unique program that offered both a wide array of special interest after school clubs (e.g. robotics, graphic design, digital broadcast and movie making, music recording and remixing, video game development) and mandatory media arts classes during the school day, learners were able to develop broad and deep experiences across the middle school years. The program of research involved an ethnographic study focused on the learning environment, nine case studies of young producers and their learning ecologies across home, school, and community, and quantitative tracking of the entire cohort over time. In this session, four papers will be shared that describe 1) the environment; 2) the theoretical framework guiding the research and associated methods; 3) the development of learners as creative producers; and 4) the role of the artist-mentors as media arts instructors. The contributions of the symposium include sharing a unique interdisciplinary collaboration and the results of a unique experiment designed to bridge divides while innovating a new ecological model of learning. Our discussant for the symposium section will be Roy Pea.

The Digital Youth Network Model (Pinkard & Gomez)

Digital Youth Network

DYN offers youth a collection of overlapping affinity spaces that challenge them to develop and use new media literacies in their interactions with classmates, mentors, teachers, family, and friends in a variety of contexts. The voluntary social networks formed around new media have been termed affinity spaces by Gee (2004), participatory cultures by Jenkins (2006), and networked publics by Ito (2008). According to Jenkins (2006), the key characteristics of participatory cultures are low barriers to individual expression and engagement, strong support for creativity and sharing one's creations, and informal mentorship of less experienced participants. In successful cultures of participation, individuals believe their contributions matter and care about how their creations are viewed by others. Participatory cultures can support youth in the collaborative creation of new media artifacts that serve personally meaningful goals—such as engaging in media exchanges via social networks—while simultaneously developing new media literacies essential to 21st century citizenship. In recent work, Ito (2008) has provided a window into how youth are participating in these social networks and how participation affects their identities as individual consumers and producers of new media as well as citizens in the world.

Informed by these and other findings, the Digital Youth Network explicitly combines the affordances of the different contexts where youth spend their time into a dynamic learning environment that both teaches youth how to use new media literacies and creates meaningful opportunities for youth to use these new media literacies. It is a model for the construction of a new youth-serving institution that is unbounded by time or space. The core of the model spans the worlds of school, home, after-school, and online activities, and provides youth with: (a) access and training in the use of new media literacy tools; (b) meaningful activities where the development of new media literacies is essential for accomplishing goals and (c) a continuum of established new media artist-mentors (high school through professionals) who develop students' technical skills, serve as role models, and provide students access to the communities of practice surrounding digital media-based careers. In addition, the program has a social agenda that recognizes the uniquely urban minority experiences of the students and draws from, refers to, and uses these experiences as a means of challenging students to analyze and critique current forms of media and take reflexive stances. Students are encouraged to use critique to improve upon the existing content and form found in popular media and incorporate this knowledge into their original media products.

Opportunities for students to use their new media literacies include explicit connections to school-based curricula, interest-based clubs, called "pods", that require youth to use new media literacies in order to participate, and spaces and competitions (both virtual and place-based) where youth are supported in using new media literacies to explore their own questions and push their imagination. The DYN program is structured into two components: in-school media arts classes and after-school pods. The mandatory school-day media classes ensure that all students are exposed to a broad set of literacies while the optional after-school pods (e.g.

including digital design, digital music, digital radio, digital video, digital queendom [a girls only space], spoken word, video game design, and robotics) enable all students to build on the breadth of exposure received in school and to identify skills of their choice to explore in-depth. The combination of in-school and out-of-school programming allows teachers to embed digital literacy into instruction with a confidence that the students have a base of knowledge and understanding with new media concepts and tools. Below are brief descriptions of two key components of the DYN Model.

New Media Fluent Artist-Mentors

A key component of the DYN program is the use of practicing new media artists as teachers and pod leaders. These artist-mentors are able to combine their work portfolio, technical fluency and their cultural capital to develop learning spaces that often mimic professional studios and provide a contrast to traditional learning environments found in schools. While artist-mentors enter with many resources, the DYN model provides extensive professional development designed to guide them to take their knowledge of new media and present it in learnable chunks for youth. In addition, all artist-mentors are asked to enact the DYN model of instruction in order to provide youth some consistency across the DYN program.

RemixWorld: A Social Learning Network

Youth have access to virtual spaces for collaboration that address the need to provide diverse methods for reaching a large number of youth. RemixWorld is DYN's private social networking and learning online space. It is a community of active media producers and consumers made up of DYN youth participants and select adult mentors. With a familiar interface and similar functionality to popular online communities, students are able to easily share and critique videos, songs, podcasts, graphic designs, and more. Users share perspectives and dialogue through regular blog postings and discussion threads. While the basic skeleton resembles many existing social networking sites, customized adaptations (e.g. virtual currency, media rubrics, competency-based new media leveling up system, self-paced online learning modules), targeted modeling of productive use, and integration of the site in DYN activities, has positioned RemixWorld as a promising tool for scaffolding media critique. We've been able to leverage the affordances of traditional social networking sites to increase student engagement and extend youth and artist-mentor collaborative opportunities. Less outgoing students have found it easier to share their voices online, and all students are able to immediately share their projects with peers and experienced artists for immediate feedback.

Theoretical Framework and Research Methods (Barron & Martin)

Theoretical Framework

In order to capture the multiple, interwoven facets of the DYN program model, our theoretical framework draws on ecological and developmental perspectives that draw attention to the many life spaces where learners spend time that can all contribute to learning. These perspectives also highlight the important roles of social support in developing and supporting their emerging interests and point to the role of the child in creating their own learning opportunities (Barron, 2006; Bronfenbrenner, 1979). We also draw on theories of interest development that conceptualize the evolution of topical interests as moving from temporary periods of fleeting attention to more sustained interests that become stable and increasingly self-sustaining (Dewey, 1913; Hidi & Renninger, 2006). Finally, we draw on socio-cultural historical theories of learning that foreground the intertwining of cultural practice, identity and the development of skills, knowledge, and expressive capacities (Lave & Wenger, 1991; Wenger, 1998). In particular we draw on positioning theory, which has developed to account for the process by which people become socially identified with broader social categories (Harre & VanLagenhove, 1991; Nasir & Saxe, 2003). As described by Davies and Harre (1990), this process can include interactive positioning, when one individual positions another, and reflexive positioning, when one positions oneself. These theories broaden the scope of what has traditionally been considered as learning to go beyond knowledge or expertise to include the ways that learners' conceptualize themselves, and they draw attention to the role of social processes in positioning learners as particular types of contributors.

Methodological and Analytical Approach

Our research is designed to chart the varied ways adolescents choose to take up different media production activities and to begin to understand the conditions under which students adopt goals for developing their own creative work with digital media tools. Guiding questions for this study were exploratory and four-fold: 1) Under what conditions do new media design projects lead to a diversification and enrichment of students' learning ecologies across school, home, and community settings?; 2) What 21st century capacities are nurtured through new media design projects and how can we assess these?; 3) How do design projects support students' current and future identities as creators, authors, and critiquers of new media?; 4) Finally, what design principles can be derived that might be shared with other sites?

Renaissance Academy, one of several schools currently using the DYN model, is an inner-city charter school serving approximately 140 6-8 graders from middle to low-income households, most of whom are African American. Our research uses a longitudinal design to chart the growth of students' technology-based interests, participation, and project work. We follow a whole cohort of 50 learners at Renaissance Academy using quantitative metrics that gave us insight into their confidence, interest, expertise, access to tools and use of learning resources, and carry out focused case studies with a subset of the students. For these students we have constructed technobiographies (Barron, 2006) based on accounts provided in interviews, through observations, and through analysis of project artifacts in order to chart learning activities across time and setting. We use interviews to obtain an historical account from the learner's perspective of the emergence and evolution of projects. Interviews with mentors provide first person accounts of goals for learning, creation, and their perceptions of student growth.

Students were observed during DYN programs during and after school and on the Remix World virtual space. Researchers used field notes to document students' skills, creation of media artifacts, artifact critiques, and informal conversations about student experiences in the physical and virtual media consumer and producer spaces. Three researchers observed more than 195 hours of in school classes and after school pods and documented this observation using field notes. Researchers focused on: (1) instructional delivery, (2) opportunities for production and presentation, and (3) adult and youth interactions around instruction and creation. Student work and video documentation of student projects collected by researchers and artist-mentors offer additional data.

Positioning learners as creative and critical producers (Levinson, Mertl, Stringer, & Rogers)

As part of our analysis of students' learning ecologies, our study looks at instructor practices as they position learners in the DYN program. This section of the symposium explores in detail how students are positioned as creative and critical producers. We describe examples of student creation in context, and how the DYN artist-mentors position students not only to look critically at ideas presented to them, but also to create their own responses to what they see and hear. We use the term "creative producers" to designate individuals who express their own ideas by producing original artifacts. "Critical producers" is an adaptation of "critical consumers." The latter are individuals who can analyze messages they receive in a critical way, understanding intent behind them and recognizing the structures of manipulation or oppression they might contain. We use the term "critical producers" to recognize individuals who do not only analyze messages but produce media that communicates their own response.

Positioning theory has developed to account for the process by which people become socially identified with broader social categories, often to the detriment of those who hold less power (Harre & VanLagenhove, 1991; Nasir & Saxe, 2003). As described by Davies and Harre (1990), positioning can include interactive positioning, when one positions another, and reflexive positioning, when one positions oneself. Our analysis is based on a framework informed by Holland & Leander, who consider positioning a productive process that allows for agency on the part of an individual who may not agree with an assigned position (2004). The production or use of cultural artifacts such as songs, stories, or images can mediate positioning because they persist over time and can be used as resources for either interactive or reflexive positioning (Holland & Leander, 2004). The mediated nature of positioning is particularly relevant for our analysis, as we show that the production of an artifact provides a basis for the repeated repositioning of girls as legitimate contributors to a particular creative form. The artifact verbally articulates a rejection of a perceived position and evidences the position's fallacy. Holland & Leander's work shapes how we consider positioning, providing us with a series of underlying questions we use to understand how mentors support the development of students' creative agency.

Our analysis uses two examples from the DYN program as a window into the positioning process - a rap song written and recorded by a group of female students and a set of projects produced by an individual student. In describing how student production was inspired, carried out and disseminated, we identify three phases of positioning in the instructor practices: (1) inviting students to discourse, (2) guiding them through the process of creating original artifacts as statements or responses in that discourse, and (3) using artifacts produced to inspire and provoke further creations by the students. In addition, we observe that the instructors use dominant stereotypes and structures of oppression as instigators of discourse. Beyond the students' interactions with the program artist-mentors, aspects of the program design such as specialized online sharing forums augment the potential impact of these positions. The symposium presentation of this paper will include examples of these processes and examples of work that we exclude here due to space limitations.

A collaborative group project case: Jappin'

In the collaborative project case, a group of female students produced a rap song entitled "Jappin,'" inspired by a conversation in the school-day New Media Arts class. In the first phase of the positioning process, students were invited to discourse around "Merchants of Cool," a documentary screened in class. The film presented "personas" – in this case, stereotypes of male and female teens that are often projected in mainstream media. The artist-mentor then led a discussion about the documentary, where students invited to position themselves in relationship to these figures, accepting, rejecting or renegotiating the personas in the film. The classroom conversation became heated, as the boys in the class expressed approval of the female stereotypes and the girls took the opposite viewpoint. A group of girls, inspired by the discussion itself and the journal entries they were asked to write afterwards, responded to the boys' attitudes in the form of a rap song. At this point, the second phase of positioning, guided production, began. All students were familiar with recording and poetry/song techniques introduced during the Media Arts class and some students had additional knowledge from the after school pods. Although the song was their own idea, the girls took advantage of the resources available to them in the DYN program, seeking guidance from the artist-mentor teaching the class, and recording their piece in the DYN studio. Lastly, in the third stage, once the song had been written, performed and recorded, the artist-mentors helped position the girls' work in such a way that it circulated within the school community. *Jappin'* invited responses from other students online, in pods, and in classes, starting a new cycle of critical production.

An individual student case: Maurice

Maurice, came into the sixth grade with only basic knowledge of computers and simple productivity software but quickly emerged as one of the most active participants and creators in the DYN program. Just as the group of students in the previous case were invited to discourse via the documentary screening, in school day and after-school classes Maurice was invited to research or reflect on a range of topics including minstrel shows, black pride and global warming, which formed the basis for some of the videos. In addition to the DYN artist-mentors, Maurice's parents served as important "inviters" in this stage of positioning.

Maurice adopted the DYN classes and pods as a forum for communicating his beliefs and ideas, positioning himself as a creator and as a "student activist." On his own time, as well as for classes and pods, Maurice created at least 13 digital videos and 4 Web sites, including a social networking site where he aimed to "get people to be more open to new ideas, to redefine the 21st century." An artist-mentor reflected on the role of the DYN program in Maurice's development as a creator:

> "Just watching him kind of as a creator… the influences I think DYN kind of had on him in the idea of the eye of the individual has the ability to change society through media if one takes agency. I think him being a part of this group, he really gets a platform to use his mind in a way where kids aren't like, ugh, why do you think like that or… Because giving him the agency to not only speak his mind, but all right, how do we get this information to the community? Through video, through posters and radio shows."

Maurice's portfolio of work, similar to the Jappin' song and video, took on a life of its own within DYN. The DYN community came to see Maurice as a video artist, talented musician, and a leader. When other DYN students were asked who they admired or sought to emulate, Maurice was named by several of his peers. Adults in the DYN community often invited Maurice to represent the school. He spoke at a large school community event, attended conferences and events, appeared on radio broadcasts, and led a workshop for teachers interested in using online social networks in the classroom. These experiences positioned him as a model student in the DYN program.

The three phases of positioning that emerged during student production with the DYN program highlight the important roles of mentorship and the school community in student and project growth and development. Throughout these three stages, social issues and popular culture emerge as important tools mentors use to invite students to occupy, reject or renegotiate personas presented to them. Furthermore, the act of positioning as creative agents proves to be an iterative process based upon the cultivation, exchange, and re-articulation of ideas.

The cases discussed in this section of the symposium also illustrate the tendency that emerges wherein students learn several creative media and production skills through in- and after-school activities, and then take these learnings outside the realm of assignments. Students build off of each others' ideas and initiate creative projects on their own. Exchanging such boundary-crossing projects with mentors, teachers, and peers within the DYN community creates a culture of sharing that important to students' creative growth. The structures of the DYN program are designed to encourage students' creativity to spill over into their out-of-school experience, where students can develop sustainable creative practices.

Artists as Mentors and Teachers (Richards & Austin)

In year two (2007-2008), the Digital Youth Network (DYN) expanded to include professional development components as an intervention designed to create a DYN instructional model and framework. In addition to the after school and in-school programming, this professional development component resulted in the DYN artist-mentors needing to shift between in and out of school learning environments and structures. These structural variations between the after school, in school and professional development contexts affected the positioning of the artist-mentor to also include that of a teacher. In order to negotiate these various positionings within the DYN model, the DYN artist-mentor had to be willing and able to adapt and *shape-shift* identity and knowledge within these different networked spaces (Gee, 2004), related to artist, mentor and teacher stances. As a way to help to facilitate and support the mentors through this programmatic shift into the school day, a professional development component was added to the program to encourage artist-mentors to develop teacher or pedagogical stances within the school day space. Legitimate participation for the DYN artist-mentor in year three required that besides fulfilling the role of artist, the artist-mentor also had to become a teacher (Lave & Wenger, 1991). The *teacher stance* became a new identity and knowledge from which the artist-mentors had to negotiate along with the *artist stance* as they shifted between the in school and after school spaces. Out of this need to adapt shape-shifting stances to space and to become legitimate members within a community of practice, emerged tensions and struggles for specific artist-mentors. For some, the teacher stance would be an accepted transformation, while for others, the teacher stance was resisted. These moments of transformation and resistance were made visible in the professional development spaces where mentors became legitimate or marginalized members within the DYN community of practice (Wenger, 1998). Examination of the DYN learning environments and shape-shifting mentor stances can offer insights into 1) the relationship between the learning environments within in school and out of school spaces and how this influences interactions and positioning between mentor and student within the DYN program; and 2) how mentors negotiated and resisted these stances within a community of practice where pedagogical stance became mandatory for artist-mentors.

Evidence of the shape-shifting stance as well as resistance to these stances emerged from three years of ethnographic field notes and interviews of the artist-mentors using qualitative coding methods and discourse analysis of mentor interactions within the in school, after school and professional development spaces (Richards, 2005; Wells, 2006). Out of this study emerged preliminary findings that suggest that a major challenge for the DYN professional team was negotiating between shifting roles, identities and knowledge as artist-mentors had to interact with youth in different in school and after school contexts. The ability to shape-shift within different learning environments was linked to artist-mentor affinities to particular stances. Out of seven DYN artist-mentors, four are included in this paper. The following cases have emerged: 1) Artist-Mentor-Teacher: one mentor was able to negotiate and accept all three stances, 2) Mentor-Teacher: one mentor developed an affinity to the mentor-teacher stance, and 3) Artist-Mentor: two mentors developed an affinity to the artist-mentor stance.

To fulfill their duties the artist-mentors had to adapt and shift between the artist-mentor-teacher stances according to different learning environments. For example, the structural spaces between the DYN in-school and after-school components afforded different learning opportunities that impacted the stance taken by the artist-mentor. Classroom time was 50 minutes, whereas after school pod time was 90 minutes. Classrooms consisted of 30 students, whereas pods consisted of five to ten students. In-school classes required mandatory attendance, while pods were attended on a voluntary basis, and classroom pedagogy required grades and evidence of learning in contrast to pods, where evaluations were based on artifact production and role of critique from other members.

The in-school component gave more students access to DYN and new media literacy learning. However, in the classroom, artist-mentors had to encourage learning and participation from students that did not necessarily have an affinity to digital media. Additionally, there were up to 3-6 times more students within the classroom space, and the artist-mentors had about half the time that they were afforded within the after school context. Mentor-teacher stances were based on curricular goals rather than the artist-mentor stance that encouraged creative, youth-driven goals. The artist-mentors had to grapple with these shifting identities and knowledge as they designed and implemented the DYN curriculum and as they made decisions about the nature of their interactions with students.

Conclusion

The DYN program provides an initial model for supporting youth – specifically minority youth in an underserved inner-city area – to acquire 21st century skills and our research shows how this learning occurs in a broader ecological system. The four sections of this symposium will be a window into the initial findings of our three-year study that address multiple viewpoints on student learning. From a program design perspective, we will discuss the inspiration for and construction of this framework – the research and beliefs that informed it as well as the structure chosen to implement it. The section on our theoretical framework and related empirical methodology presents ways in which research can capture the varied contexts in students' lives, informing in greater depth our knowledge of how students develop new media literacies. From the angle of student creative production, we show how students are positioned as creative and critical producers in activities that flow across formal and informal learning spaces. Finally, we present a view from the perspective of the DYN artist-mentors, and an iteration in program design that facilitated their movement between learning spaces in order to accompany youth more effectively across contexts.

References

Austin, Kimberly. (2008). "The Organization and Management of Informal and Formal Learning: Structure and language use in the Digital Youth Network model." Paper presented at the International Conferences on Learning Sciences: Amsterdam, Netherlands.

Barron, B. (2004). Learning ecologies for technological fluency: Gender and experience differences. Journal of Educational Computing Research, 31(1), 1-36.

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecologies perspective. *Human Development*, *49*, 193-224.

Bronfenbrenner, U. (1979). *The ecology of human development: Experiments by nature and design*. Cambridge, MA: Harvard University Press.

Davies, B., & Harre , R. (1990). Positioning: The Discursive Production of Selves. *Journal for the Theory of Social Behavior* 20(1):43–63.

Dewey, J. (1913). *Interest and effort in education*. Cambridge, MA: The Riverside Press.

Gee,J.P. (2008). Situated Language and Learning:A Critique of Traditional Schooling.New York: Routledge.

Hargittai, E. & Walejko, G. (2008). The participation divide: Content creation and sharing in the digital age. Information, Communication and Society, 11(2), 239-256.

Harre,, R. & Van Langenhove, L. (1991). Varieties of Positioning. *Journal for the Theory of Social Behavior*, 21(4): 391–407.

Hidi, S. & Renninger, K. (2006). The four-phase model of interest development. *Educational psychologist*, *41*(2).

Holland, D. and Leander, K. (2004.) "Ethnographic Studies of Positioning and Subjectivity." In *ETHOS*, Vol. 32, Issue 2, 2004, pp. 127–139.

ISTE National Educational Technology Standards 2007. DOI= http://www.iste.org/inhouse/nets/cnets/index.html

Ito, M., Okabe, D., and Matsuda, M. (2005). Personal, Portable, Pedestrian: Mobile Phones in Japanese Life. MIT Press

Ito,M. (2005)."Technologies of the Childhood Imagination:Yugioh,Media Mixes and Everyday Cultural Production,"in Network/Netplay:Structures of Participation in Digital Culture,ed.J.Karaganis and N.Jeremijenko.Durham,NC:Duke University Press.

Ito,M. (2005). Personal,Portable,Pedestrian:Mobile Phones in Japanese Life.Cambridge,MA: MIT Press.

Ito, M., Horst, H., Bittanti, M., Boyd, D., Herr-Stephenson, B., Lange, P. G., Pascoe, C. J., & Robinson, L. (2008). *Living and learning with new media: Summary of findings from the Digital Youth Project*. Chicago, IL: The John D. and Catherine T. MacArthur Foundation Reports on Digital Media and Learning.

Jenkins, H. (2006). Confronting the Challenges of Participatory Culture: Media Education for the 21st Century. Occasional papers. Building the Field of Digital Media and Learning. John D. and Catherine T. MacArthur Foundation.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Levy, F. & Murnane, R.J. (2004), *The new division of labor: How computers are creating the next job market*. New York: Princeton University Press and Russell Sage Foundation.

Nasir, N. S., & Saxe, G. B. (2003). Ethnic and academic identities: A cultural practice perspective on emerging tensions and their management in the lives of minority students. *Educational Researcher, 32*(5), 14-18.

National Research Council (1999). *Being fluent with information technology*. Washington, DC: National Academy Press.

Neuman, S. & Roskos, K. (1993). Access to print for children of poverty: Differential effects of parent mediation and literacy-enriched play settings on environmental and functional print tasks. *American Educational Research Journal*, 30, 95-122.

Peppler K., & Kafai Y. (2007). From SuperGoo to Scratch: Exploring creative digital media production in informal learning. *Media, Learning, and* Technology, *32*(2), 149-66.

Pinkard, N., Barron, B., Martin, C., Rogers, M., & Gomez, K, Zywica, J. (2008). Digital youth network: Fusing school and after-school contexts to develop youth's new media literacies. Paper presented at AERA '08: American Educational Research Association Annual Meeting, New York, NY.

Prensky, M. (2001). Digital Natives, Digital Immigrants. *On the Horizon*. NCB University Press, 9(5), October.
Richards, L. (2005). *Handling Qualitative Data.* London: Sage.
Wells, G. (2006). Dialogue in the Classroom. *The Journal of the Learning Sciences*. 15(3), pp. 379-428.
Wenger, E. (1998). *Communities of practice*. Cambridge, UK: Cambridge University Press.

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Motivation and affect in peer argumentation and socio-cognitive conflict

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Abstract: Whereas the cognitive processes and effects of collaborative learning have been intensively studied within the Learning Sciences, little attention has been paid to the way motivational and emotional factors may affect them. In this symposium, we present recent findings from three independent lines of research that focus on the way motivation and affect shape the interaction between peer learners and how this, in turn, affects cognitive gains from this interaction. All three presentations focus on learning within a socio-cognitive conflict task design, while drawing on different data sources, each highlighting different aspects of the interaction process: (1) Students self-reported perceptions of the self, the other and the interaction; (2) Epistemic and motivational features of verbal dialogue content; and (3) Interactants' emotional reactions using facial signals and content-free vocal parameters of speech. The findings shed new light on how motivational and affective factors may promote or inhibit productive interactions in the face of socio-cognitive conflict.

Symposium overview

The study of peer collaborative learning has been a central theme in the Learning sciences. Considerable progress has been made in the identification of the cognitive mechanisms that enable learning in collaborative settings: For example, individual gains have been attributed to the fact that group work promotes the construction of abstract representations (Shirouzu, Miyake, & Masukawa, 2002), provides the opportunity to obtain feedback on one's own ideas (Okita & Schwartz, 2006) and primes learners to make productive use of subsequent experiences (Howe, McWilliam & Cross, 2005). In addition, studies on the quality of peer-to-peer dialogue have found that the extent to which students gain from group work depends on the depth and the quality of the dialogue they engage in (e.g., Asterhan & Schwarz, 2009a; Coleman, 1998; Webb, Troper & Fall, 1995). In spite of these advances, a considerable amount of the variance in both group productivity as well as individual learning gains remains unaccounted for. Furthermore, whereas much attention has been given to the underlying cognitive mechanisms, the study of collaborative learning has often neglected the socio-emotional aspects of these inherently social settings.

Motivation theory, on the other hand, has traditionally looked at the individual, focusing on personality characteristics, individual dispositions, and the influence of external factors on the behavior of the individual learner. For example, achievement goal theorists have extensively studied the relation between individual learning behaviors and personal goal orientations on the one hand (e.g., Butler & Neuman, 1995), or classroom goal structures on the other (e.g., Meece, Anderman & Anderman, 2006; Turner, Midgley, Meyer, Gheen, Anderman, Kang & Patrick, 2002). Until recently, the role of achievement goals in small group interaction had not been studied.

In this symposium, we aim to contribute to a rapprochement between these two lines of research, by focusing on the role of motivational and emotional aspects of collaborative learning in situations characterized by socio-cognitive conflict (Doise & Mugny, 1984). In the design of group tasks, socio-cognitive conflict is often stimulated by pairing collaborators who have different initial ideas and conceptions, by providing them with different information sources or by presenting them with data that contradicts their initial ideas. This incongruence between solutions or ideas introduces doubt concerning the correctness of one's own knowledge (Doise & Mugny, 1984), which is then hoped to cause learners to reconsider, renegotiate and/or reconstruct this knowledge through reasoned argumentation (Asterhan & Schwarz, 2007). However, when this incongruence occurs in a social realm, it may also raise uncertainty about self-competence, especially in a competitive context (Butera & Mugny, 1995). A perceived threat to self-competence may cause learners to focus more on the relational, rather than the epistemic aspect of the conflict (Darnon, Muller, Schrager, Panuzzo & Butera, 2006). In order to avoid public exposure of lesser competence, learners may choose to comply with their co-actors and seek a quick consensus without much cognitive engagement. Conversely, they may focus on 'winning the argument' at any cost, without genuinely trying to understand any of the ideas proposed by others.

The main goal of this symposium then is to come to a better understanding of the way learners interact in and learn from collaborative learning tasks that are designed according to principles of socio-cognitive conflict. We include three independent, yet complementary lines of research that focus on the role of motivational and affective factors in these tasks. In each study, the effect of different goals is investigated, both on the way learners regulate the interaction, as well as on individual cognitive gains from these interactions. In addition, each paper investigates the interplay between the individual and the group and between the cognitive and the social, while drawing from different types of data that highlight different aspects of this interplay:

In the first paper, Fabrizio Butera and Céline Darnon review a series of studies they have conducted on the role of individual achievement goals in socio-cognitive conflict regulation. They distinguish between two types of regulation, epistemic and relational, and show that the goals that students pursue direct their attention towards different aspects of the interaction, leading to different outcomes.

In the second paper, Christa Asterhan, Baruch Schwarz and Ruth Butler focus on peer-to-peer argumentation as a vehicle for learning and understanding complex scientific concepts. They distinguish between argumentation as an activity of competitive debating and argumentation as a space in which learners can critically, yet constructively examine different ideas. They examine how these different types of dialectical argumentation can be elicited and measured, and what their relationship is to conceptual learning.

In the third paper, Timothy Nokes, John Levine, Dan Belenky and Soniya Gadgil report on a study that examines the relationship between different debate scenarios and individual learning outcomes. To get insight into the underlying cognitive and social processes that mediate these effects, they focus both on epistemic content of the interaction, as well as measures of student engagement and affect including, among others, behavioral indices and content-free vocal parameters of speech.

Socio-cognitive conflict and learning: past and present.

Fabrizio Butera & Céline Darnon

In the present talk, we contend that dissent with others' points of view should be a customary and promoted activity whenever learning is concerned. Indeed, dissent occurring during group or peer learning favours cognitive development and knowledge acquisition. We present a theory of socio-cognitive conflict, which argues that dissent with one or several partners over a task in which learning is concerned may stimulate task-related cognitive activity and result in progress (Doise & Mugny, 1984). Should, therefore, socio-cognitive conflict be prescribed in educational settings? We address this question by drawing on research in which we found that socio-cognitive conflict is beneficial for learning to the extent that conflict is regulated in an epistemic manner, that is, by focusing on the task or on the knowledge at hand. On the contrary, socio-cognitive conflict can result in detrimental effects whenever conflict is regulated in a relational manner, that is by focusing on status and on interpersonal dominance (Darnon, Buchs, & Butera, 2002). A recent experiment illustrates these dynamics (Darnon, Doll, & Butera, 2007). University students participated in a fictitious computer-mediated interaction about a text with a bogus partner who introduced through her/his rhetoric either an epistemic conflict (a conflict that referred to the content of the text), or a relational conflict (a conflict that questioned participants' competence). Results indicated that compared to the epistemic conflict, the relational conflict enhanced threat and reduced the perceived contribution of the partner. Moreover, when the conflict was epistemic, the stronger the perceived conflict, the more participants said they worked through the problem to understand it better and tried to integrate the two points of views, that is, the more they regulated the conflict in an epistemic way. On the contrary, after a relational conflict, the stronger the perceived conflict, the more participants said they tried to assert they were right and the other person was wrong, that is, the more they engaged in a relational regulation of the conflict. Finally, epistemic conflict elicited better learning than relational conflict.

This distinction is of importance with respect to the question of the usability of socio-cognitive conflict, as recent research has shown that the two forms of conflict regulation are predicted by different achievement goals, goals that can be implemented in the classroom (Meece, Anderman, & Anderman, 2006). Indeed, we have found that epistemic regulation is predicted by mastery goals (the will to acquire knowledge and develop competences), and relational regulation is predicted by performance goals (the will to demonstrate competence relative to others; Darnon et al, 2006). In this study, French introductory psychology students – for whom mastery and performance self-set goals had been recorded – were asked to imagine a discussion with another person who disagreed with them about an experiment they had studied in class during the previous semester. They were then asked to report to what extent during this "debate" they would try to regulate the conflict in an epistemic way or a relational way. Items related to epistemic regulation asked students to what extent when disagreements occurred they would try (a) to think about the text again in order to understand better, (b) to examine the conditions under which each point of view could help them understand, and (c) to think of a solution that could integrate both points of view. Items related to relational regulation asked students to what extent when disagreements occurred they would try (a) to show they were right, (b) to resist by maintaining their initial position, and (c) to show their partner was wrong. Results indicated that mastery goals positively predicted the reported amount of epistemic conflict regulation whereas performance goals positively predicted the reported amount of relational conflict regulation.

Importantly, we have also found that achievement goals interact with socio-cognitive conflict to predict actual learning (Darnon, Butera, & Harackiewicz, 2007). In this study, participants were led to think they interacted with a partner via a computer sharing opinions about a text that they were studying. Mastery and performance goals were manipulated. During the "interaction", they received either disagreeing or agreeing answers from this bogus partner. Results showed that the condition in which mastery goals were induced led to better learning than the performance goal condition only when the partner disagreed. No differences between goal conditions were observed when the partner agreed. In other words, when conflict is elicited during interaction, mastery goals have the potential to make conflict constructive, and lead to better learning than performance goals.

Notwithstanding the positive effects of mastery goals, in a further line of research we have discussed the problem that education takes place in organisations that are concerned with formation *and* selection. Because of this very functioning, a profound ambivalence is embedded in achievement goal promotion in universities (Darnon, Dompnier, Delmas, Pulfrey, & Butera, 2009). Mastery goals promotion is recommended by most researchers, and promoted in the discourse of most teachers. Thus, the student who strongly endorses mastery goals fulfils the teachers' motivations and aims and is consequently perceived as someone who is appreciated by teachers. This is not the case for performance goals, which are not valued by teachers in their discourse. However, the selection processes through which the students have to go in their university career implicitly indicate that, in order to succeed, they not only have to improve knowledge but also get better grades than other students. Thus, not only mastery goals but also performance goals are seen by students as effective tools to succeed at university (see also Dompnier, Darnon, Delmas, & Butera, 2008). In sum, it appears that students are aware of the two functions of university, namely education (apparent in teachers' official discourse) and selection (hidden in the university structure). This means that self-presentation concerns may interfere with mastery goals in shaping the students' social interactions and academic achievement.

The finding that students are aware of this double function of educational organisations, at least as far as university is concerned, may shed light on puzzling but consistent result that mastery goals positively impact achievement-related outcomes, but paradoxically hold an inconsistent relation with academic achievement. Dompnier, Darnon and Butera (2009) hypothesized that this relationship depends on why students endorse mastery goals—namely, to garner teachers' appreciation (social desirability) or to succeed at university (social utility). First-year psychology students completed a mastery goal scale in a standard format, with social desirability instructions and social utility instructions. Participants' grades on academic exams were recorded later in the semester. Results indicated that students' perceptions of both social desirability and social utility related to mastery goals moderated the relationship between mastery goal endorsement and final grades. The less participants perceived these goals as socially desirable, the more the goals predicted grades. Conversely, the greater their perceived social utility, the higher their predictive value. In other words, mastery goals appear to be related to learning to the extent that students do not endorse it for self-presentation reasons (Dompnier, Darnon, & Butera, 2009). We conclude this talk by reflecting upon the goals promoted by educational organisations that may favour or hinder the constructive effects for learning of socio-cognitive conflict.

On competitive and co-constructive dialectical argumentation

Christa S. C. Asterhan, Baruch B. Schwarz and Ruth Butler

Recent research seems to indicate that simply designing tasks according to principles of socio-cognitive conflict may often not be sufficient for students to capitalize on the affordances that are created in such task designs, and that this may be particularly true for learning that involves conceptual change: In two separate experimental studies, students who were instructed to engage in dialectical argumentation on the topic of natural selection gained from interaction with an equal-status peer, whereas students that were not instructed to do so did not (Asterhan & Schwarz, 2007). Moreover, a follow-up study showed that conceptual gains were dependent on the extent to which students engaged in argumentation moves that are characterized by a dialectical and critical stance towards proposed explanations (Asterhan & Schwarz, 2009a).

However, further in-depth analyses of selected dialogue protocols seemed to indicate that not all forms of dialectical argumentation may have the same beneficial outcomes (Asterhan, 2007): Learners did not seem to gain when the dialogue was characterized by an adversarial, debate-like atmosphere. The dialectical argumentation of gaining dyads, on the other hand, was characterized by a particularly pleasant and constructive, yet critical atmosphere. These dyads used several sophisticated techniques (such as, for example, spontaneous role-playing and posing "What if.." scenarios) to preserve the delicate balance between critically examining each others' ideas while maintaining a pleasant and supportive atmosphere. Moreover, the episodes of critical examination were interspersed with episodes of collaborative construction of explanations. We therefore called this type of dialogue *co-constructive, dialectical argumentation* (Asterhan & Schwarz, 2009b). In the present presentation, we aim to explore the following questions: (1) How can this particular type of peer dialogue be elicited; (2) Can co-constructive, dialectical argumentation be reliably and quantitatively distinguished from adversarial argumentation; and (3) Do these different types of peer dialogue lead to differences in learning and understanding conceptual content?

In a recent series of studies Darnon, Butera and colleagues investigated the role of motivational differences of individual learners' achievement goal orientations in academic situations characterized by socio-cognitive conflict (e.g., Darnon et al, 2002, 2006, 2007). These studies showed that both existing as well as manipulated differences in achievement goals can predict learning from short computer-mediated communication with a fictitious, disagreeing partner: Whereas mastery goals (a focus on learning and personal improvement) positively related with learning, performance goals (a focus on individual ability comparisons) did not. We sought to extend this research to the domain of peer argumentation and learning that involves conceptual change. Unlike in the settings investigated by Darnon, Butera and colleagues, in learning tasks that target particularly difficult scientific concepts students are often uncertain of the correctness of their prior knowledge and their ability to perform well.

In a first study, we focused on the relation between students' individual achievement goal orientations and four different types of self-reported collaborative behavior (Asterhan, Schwarz & Butler, 2009). Undergraduates were situated within an educational setting in which they were asked to solve and reveal their knowledge concerning an ill-structured, complex astronomy-related topic. They were then asked questions concerning their behavior in a peer collaboration setting in which they were to discuss their solution with a disagreeing peer. Four different categories of self-reported peer collaboration behavior were assessed: Quick consensus seeking, adversarial argumentation, co-constructive dialectical argumentation and private dialectical deliberation. The results showed, among others, that mastery orientations predicted co-constructive dialectical argumentation, whereas performance-approach goals predicted adversarial argumentation. These findings encouraged us to further explore the relation between goals, argumentation and conceptual learning in an experimental set-up. In addition, since certain patterns of peer collaboration behavior are believed to mediate the relation between achievement goals and learning from socio-cognitive conflict, the verbal interactions were analyzed with the help of a coding scheme that aimed to distinguish between adversarial and co-constructive dialectical argumentation.

A description of the study

Forty-two undergraduates (22 female, 20 male) without any prior formal education on the topic of natural selection participated in this study. The general procedure and materials were based on and adapted from Asterhan and Schwarz (2007). All students participated in the following sequence of activities: 1) Individual pretest to assess prior evolutionary understanding; (2) Instructional intervention: screening of a 20 *min* instructional movie excerpt on natural selection; (3) Experimental intervention: Students were randomly paired in same-sex dyads and instructed to engage in un-scripted, computer-mediated peer argumentation on two novel transfer items, according to two different sets of goal instructions; (4) Delayed post-test administered a week later. The pre- and delayed post-test contained equivalent items on different evolutionary phenomena. Following the movie, each participant communicated with one peer alias, which was predefined in the instant messaging environment (Yahoo! chat). All students received instructions to try and solve a particular transfer item themselves and then engage in 'a critical discussion' on their explanations of the phenomena. Half of the dyads were told that the goal of a critical discussion is to persuade the other to adopt one's own explanation (emphasizing it as an interpersonal competition and a win-loose situation), and half of the dyads were told that the goal is to gain a better understanding through discussion (emphasizing the importance of co-constructive, yet dialectical argumentation). They were given several examples of different dialogue moves, appropriate to each condition. Individual evolutionary understanding was assessed in terms of (a) the mean quality of the explanatory schemas students used, and (b) the mean number of correct Darwinian principles that students explicitly mentioned in their written explanations of different evolutionary phenomena.

Two complementary, independent coding schemes were developed to analyze the computer-mediated dialogue protocols. Both used turns as the unit of analysis and both were non-exhaustive: The first distinguished between different *epistemic activities* (de Vries et al, 2002; Ohlsson, 1995) students engaged in when trying to understand the concept of natural selection. Only on-task dialogue content was coded. Based on distinctions proposed by Asterhan and Schwarz (2009) it mainly distinguished two categories of epistemic dialogue moves: those that reflect consensual construction and validation of explanations (including, among other, elaborations, justifications and agreements; hereafter referred to as CCVE) and those that reflect critical-dialectical argumentation (including, among others, counterarguments, rebuttals, challenges, critical questions and oppositions; hereafter referred to as CDA).

The aim of the second coding scheme was to assess the extent to which the verbal dialogue contained overt markers that indicated the endorsement of a competitive interpersonal goal or the endorsement of a collaborative interpersonal goal. It was applied to all dialogue turns. The scheme was inspired by distinctions proposed by Chiu and Khoo (2003) and included the following: Competitive markers included verbal content that overtly emphasized the interpersonal conflict between persons instead of solutions (e.g., "*You* say that X whereas *I* claim that Y"), increase face threat (e.g., explicitly stating that the other is wrong) and/or relate to the inferiority of the partner's abilities or explanations (e.g., using sarcasm when evaluating an explanation proposed by partner). Collaboration markers included overt verbal content that aimed at decreasing face threat when a conflict arises (e.g., using smileys and other positive emoticons, or framing disagreements in a neutral, non-personal way), emphasizing a common goal and shared responsibility (e.g., "We should find the right explanation") and/or decreasing interpersonal competitiveness and potential differences in competence (e.g., hedging explanations and complimenting partner).

Main findings and discussion

No significant differences in conceptual gains were found between the two condition (framing dialectical argumentation as a mechanism for learning or as a competitive activity). However, for both measures of conceptual understanding an interaction effect was found for condition and gender, such that female students significantly outperformed male students in the competitive framing condition, but not in the 'argumentation for learning' condition. The overall pattern showed that female students fared better when dialectical argumentation was framed as a competitive rather than as a co-constructive activity, whereas for male students the competitive framing was detrimental for learning (no gains) and the co-constructive framing resulted in moderate learning gains. The dialogue analyses shed some light on these surprising findings. In spite of the *competitive* framing, the female dialogues in this condition were actually characterized by co-constructive dialectical argumentation: They included a high number of both CDA as well as CCVE dialogue moves. Moreover, whereas the dialogues included a relatively high number of competitive dialogue markers, this was compensated for by an even larger number of collaborative markers. The male dialogues in this condition, on the other hand, were characterized by adversarial dialectical argumentation (a high number of CDA and competitive markers and virtually no collaborative markers).

Even though it is difficult to generalize from this first study, the data seem to support the claim that co-constructive dialectical argumentation fosters the learning of complex concepts, whereas adversarial argumentation does not. However, it is also clear that either form of peer-to-peer dialogue is not easily elicited and that goal instructions may have different effects for different types of learners (e.g., male and female). Moreover, manipulated goals seem to have a lesser effect in prolonged activities that more closely resemble actual collaborative learning settings. The implications of these findings for theory and future research will be discussed in the presentation.

Investigating the Impact of Dialectical Interaction on Engagement, Affect, and Robust Learning

Timothy J. Nokes, John M. Levine, Dan Belenky, and Soniya Gadgil

Our work lies at the intersection of motivation, affect, social interaction, and learning. We are interested in how dialectical interaction impacts conceptual learning vis-à-vis motivation and affect. In this research, we focus on situations in which two or more people with roughly equal status but alternative viewpoints either compete with one another or work together to accomplish some goal or task, such as winning a debate or achieving consensus on a controversial issue. In this symposium, we will report some of our initial work examining the impact of various types of debate scenarios on students' conceptual learning, engagement, and affect.

This work builds on prior research investigating the relationship between cognitive conflict and learning (e.g., Doise & Mugny, 1984), the links between motivation, affect, and cognition (e.g., Forgas, 2001; Schwarz & Clore, 2007), and the mechanisms underlying conceptual learning (e.g., Chi & Ohlsson, 2005; Nokes & Ross, 2007). Although much prior work has investigated each of these areas separately, few studies have tried to build connections across all three. We hypothesize that conflict scenarios that increase engagement, arousal, and positive affect will facilitate participants' deep processing of discourse through a variety of cognitive mechanisms including inference generation, elaboration, analogy, and the framing and re-framing of the information discussed. Participants in such scenarios are expected to develop more complex and coherent knowledge of the issue and to learn both their own and their opponent's side of the issue. In contrast, conflict scenarios that decrease engagement, arousal, and induce negative affect should lead to less robust learning. Participants in these scenarios are expected to focus on their own side of the debate, ignoring their opponent's view, and to engage in shallow cognitive processing strategies such as rehearsal of their own argument.

These hypotheses are consistent with prior research on collaboration showing that when participants are more engaged in performing a task (as measured, for example, by their elaborations of a peer's contributions) they show larger learning gains than do those who are less engaged (Meade, Nokes, & Morrow, 2009). Similar findings have been shown in human tutoring (e.g., Chi, 2009) and learning from intelligent tutoring systems (e.g., Baker, Corbett, Koedinger, & Wagner, 2004). In addition, research has shown that participants in a positive mood are more likely to rely on prior knowledge and assimilate new knowledge into that understanding, whereas participants in a negative mood show more bottom-up processing and less integration (e.g., Forgas, 2008). We aim to extend these lines of research by examining the relationships that emerge between learning, engagement, and affect under different debate scenarios.

Study Description

To investigate these general hypotheses, we are conducting a study in which we manipulate two aspects of a debate: the *format* (open-ended versus alternating) and the *performance criterion* on which participants are evaluated (substance versus style of their arguments). We expect participants in the open-ended condition to learn more and to show higher task engagement and arousal than those in the alternating condition. Further, we predict that, compared to participants evaluated on the style of their arguments, those evaluated on substance will learn more, will be more engaged, will show more positive affect, will engage in deeper cognitive processing (inference generation, explanation, framing, etc.), and will pay more attention to the logic, coherence, and consistency of their argument as well as their opponent's argument. In addition, we predict an interaction between our two independent variables, such that the participants in the style condition will benefit more from the open-ended debate format than will participants in the substance condition. This prediction is based on the assumption that participants evaluated on substance will focus on the content of their opponent's arguments regardless of the format of their debate, whereas participants evaluated on style will process more of their opponent's argument in the open-ended than in the alternating condition.

Fifty-two undergraduates at the University of Pittsburgh have so far participated in the experiment for course credit (total sample will be 160). The study uses a 2 (debate format: open-ended vs. alternating) X 2 (performance criterion: substance versus style) between-subjects design with participants randomly assigned to one of the four conditions. Participants are run in dyads, and the experiment is composed of three parts: a study phase, a debate phase, and a test phase. There are two study booklets, one for each participant in the dyad. Both booklets have the same 1-page introduction to the topic (the "Fall of the Ottoman Empire") and description of the historical significance of the issue, along with a map of the Middle East. This is followed by two pages of text containing arguments for either external or internal causes for the fall of the empire. The test booklet consists of a 26-question multiple-choice test assessing information contained in the study booklets and an open-ended essay question in which participants describe the reasons for the fall of the Ottoman empire. Next, participants complete the 'Need for Cognitive Closure' scale (Kruglanski, Webster, & Klem, 1993).

Within each dyad, one participant is randomly assigned to the external causes condition and the other to the internal causes condition. After studying the materials for their side of the issue for 15 minutes, participants are given instructions for the debate. In the "substance" condition, participants are told they will be evaluated on the substance and the logic of their argument. In the "style" condition, they are told they will be evaluated on the style of their arguments. All participants are told that their goal is to win the debate. In the "open-ended" condition, participants engage in an 8-minute free-form debate. In the "alternating" condition, participants speak for eight alternating one-minute turns (four/participant), which are timed by the experimenter. Immediately afterwards, participants are given a brief questionnaire, assessing their subjective experiences and feelings in the debate. The winner (as assessed by the experimenter) is then awarded a small prize, and participants are debriefed and thanked for their participation.

During the debate, participants are audio and video taped for later behavioral coding of their arguments, task engagement, and affect. For example, we will analyze participants' verbal protocols to determine instances of inference generation, explanation, elaboration, analogy making, and framing. Moreover, we will assess participants' task engagement and affect by coding selected vocal qualities of their speech (Fussell, 2002; Justin & Scherer, 2005).

Preliminary Results and Future Analyses

Preliminary results (based on one-third of our planned sample) suggest that, on the multiple-choice test, participants in the substance condition are learning more than those in the style condition. In addition, participants are performing better on questions that assess their side of the argument than their opponent's side. Finally, participants in the substance conditions are performing better than those in the style condition in learning *both* their own and their opponent's argument. So far, we are not seeing a clear trend in the findings regarding debate format.

In the symposium, we will discuss results from the full sample and will report findings from the full range of dependent measures that we are obtaining. We will provide an in-depth analysis of student engagement and affect based on both questionnaire measures and behavioral indices. We will also analyze the content of the debates to gain insight into the underlying cognitive and social processes that mediate the learning outcomes. We will conclude our presentation by discussing implications of our work for instruction and pedagogy.

References

Asterhan, C. S. C. & Schwarz, B. B. (2009a). The role of argumentation and explanation in conceptual change: Indications from protocol analyses of peer-to-peer dialogue. *Cognitive science*, *33*, 373-399.

Asterhan, C. S. C., & Schwarz, B. B. (2009b). Transformation of robust misconceptions through peer argumentation. In: B. B. Schwarz, T. Dreyfus, & R. Hershkowitz (Eds.) *Transformation of Knowledge through Classroom Interaction* (pp. 159-172). New York, NY: Routledge, Advances in Learning & Instruction series.

Asterhan, C. S. C., & Schwarz, B. B. (2007). The effects of monological and dialogical argumentation on concept learning in evolutionary theory. *Journal of Educational Psychology, 99,* 626-639.

Asterhan, C. S. C., Schwarz, B. B., & Butler, R. (2009). Inhibitors and facilitators of peer interaction that supports conceptual learning: The role of achievement goal orientations. In: N. A. Taatgen & H. van Rijn (Eds), *Proceedings of the 31st Annual Conference of the Cognitive Science Society* (pp. 1633-1638). Mahaw, N.J.: Erlbaum.

Baker, R. S., Corbett, A. T., Koedinger, K. R., Wagner, A. Z. (2004). Off-Task Behavior in the Cognitive Tutor Classroom: When Students "Game The System". *Proceedings of ACM CHI 2004: Computer-Human Interaction*, 383-390

Butera, F. & Mugny, G. (1995). Conflict between incompetences and influence of a low-expertise source in hypothesis testing. *European Journal of Social Psychology, 25*, 457-462.

Butler, R. & Neuman, O. (1995). Effects of task and ego achievement goals on help-seeking behaviors and attitudes. *Journal of educational Psychology, 87*, 261-271.

Chi, M. T. H. & Ohlsson, S. (2005). Complex declarative learning. In K. J. Holyoak & R. G. Morrison (Eds.), *The Cambridge Handbook of Thinking and Reasoning* (pp. 371-399). Cambridge University Press.

Chi, M. T. H. (2009). Active-constructive-interactive: a conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*, 73-105.

Chiu, M. M. & Khoo, L. (2003). Rudeness and status effect during group problem solving: Do they bias evaluation and reduce the likelihood of correct solutions? *Journal of Educational Psychology, 95*, 506-523.

Coleman, E. B. (1998). Using explanatory knowledge during problem solving in science. *Journal of the Learning Sciences, 7,* 387–427.

Darnon, C. & Butera, F., & Harackiewicz, J. (2007). Achievement goals in social interactions: Learning with mastery *vs.* performance goals. *Motivation and Emotion, 31,* 61-70.

Darnon, C., Buchs, C., & Butera, F. (2002). Epistemic and relational conflict in sharing information during cooperative learning. *Swiss Journal of Psychology, 61*, 139-151.

Darnon, C., Doll, S., & Butera, F. (2007). Dealing with a disagreeing partner: relational and epistemic conflict elaboration. *European Journal of Psychology of Education, 22,* 227-242.

Darnon, C., Dompnier, B., Delmas, F., Pulfrey, C., & Butera, F. (2009). Achievement goal promotion at university: Social desirability and social utility of mastery and performance goals. *Journal of Personality and Social Psychology, 96,* 119-134.

Darnon, C., Muller, D., Schrager, S. M., Pannuzzo, N. & Butera, F. (2006). Mastery and performance goals predict epistemic and relational conflict regulation. *Journal of Educational Psychology, 98*, 766-776.

De Vries, E.,, Lund, K., & Baker, M. (2002). Computer-mediated epistemic dialogue : Explanation and argumentation as vehicles for understanding scientific notions. *Journal of the Learning Sciences, 11*, 63-103.

Doise, W., & Mugny, G. (1984). *The social development of the intellect*. Oxford: Pergamon Press.

Dompnier, B., Darnon, C., & Butera F. (2009). Faking the desire to learn: A clarification of the link between mastery goals and academic achievement. *Psychological Science, 20,* 939-943.

Dompnier, B., Darnon, C., Delmas, F., & Butera F. (2008). Achievement goals and social judgment: the performance-approach paradox. *International Review of Social Psychology, 21,* 247-271.

Forgas, J. P. (2001). (Ed.) *Affect and social cognition*. Mahwah, NJ: Erlbaum.

Forgas, J. P. (2008). Affect and Cognition. *Perspectives on Psychological Science, 3*, 94-101.

Fussell, S. R. (Ed.) (2002). *The verbal communication of emotions: Interdisciplinary perspectives.* Mahwah, NJ: Erlbaum.

Howe, C., McWilliam, D. & Cross, G. (2005). Chance favours only the prepared mind: incubation and the delayed effects of peer collaboration. *British Journal of Psychology, 96*, 67-93

Juslin, P. N., & Scherer, K. R. (2005). Vocal expression of affect. In J. A. Harrigan, R. Rosenthal, & K. R. Scherer (Eds.), *The new handbook of methods in nonverbal behavior research* (pp. 65-135). New York: Oxford University Press.

Kruglanski, A. W., Webster, D. M., & Klem, A. (1993). Motivated resistance and openness to persuasion in the presence or absence of prior information. *Journal of Personality and Social Psychology, 65*, 861-876.

Meade, M. L., Nokes, T. J., & Morrow, D. G. (2009). Expertise promotes facilitation on a collaborative memory task. *Memory, 17*, 38-48.

Meece, J. L., Anderman, E. M., & Anderman, L. H. (2006). Classroom goal structure, student motivation and academic achievement. *Annual Review of Psychology, 57*, 487-503.

Nokes. T. J., & Ross, B. H. (2007). Facilitating conceptual learning through analogy and explanation. In L. Hsu, C. Henderson, and L. McCullough (Eds.), *2007 Physics Education Conference* (pp. 7-10). American Institute of Physics Conference Proceedings.

Ohlsson, S. (1995). Learning to do and learning to understand: A lesson and a challenge for cognitive modeling. In P. Reimann and H. Spada, (Eds.), *Learning in humans and machines: Towards an interdisciplinary learning science* (pp. 37-62). Oxford, UK: Elsevier.

Okita, S. Y., Schwartz, D. L., (2006) When observation beats doing: Learning by Teaching. Proceedings of the *7th International Conference of the Learning Sciences* (ICLS) Bloomington, IN.

Perret-Clermont, A. N. (1980). *Social interaction and cognitive development in children*. New York: Academic Press.

Schwarz, N., & Clore, G. L. (2007). Feelings and phenomenal experiences. In A. W. Kruglanski & E. T. Higgins (Eds.), *Social psychology: Handbook of basic principles* (pp. 385-407). New York: Guilford.

Shirouzu, H., Miyake, N., & Masukawa, H. (2002). Cognitively active externalization for situated reflection. *Cognitive Science, 26*, 469-501.

Turner, J. C., Midgley, C., Meyer, D., Gheen, M., Anderman, E. M., Kang, Y., & Patrick, H. (2002). The classroom environment and students' reports of avoidance strategies in mathematic: A multimethod study. *Journal of Educational Psychology, 94,* 88-106.

Webb, N. M., Troper, J.D., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. *Journal of Educational Psychology, 87*, 406-423.

Learning to Understand the Tree of Life

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Abstract: Tree-thinking is increasingly recognized as a crucial skill in the biological sciences. However, for students, the task is wrought with challenges. Even as representations are meant to facilitate reasoning about difficult concepts such as macroevolution and the phylogenetic relationships among taxa, existing tree diagrams that are so crucial to the biologist's profession present many challenges that hinder students' understanding. The presenters in this symposium take multiple theoretical and methodological lenses to examine the many-faceted challenges of tree-thinking with representations – from the issues of representation and symbolization, to the cognitive and developmental issues of reasoning, to the implementation of a classroom intervention. Brought together in this symposium, the researchers initiate an ongoing agenda to understand and to design interventions that will support students' reasoning with this important representational tool.

Introduction

Natural historians have long created diagrams to represent their beliefs about the relations among species. With Darwin's famous 1837 sketch, the metaphor of a "tree of life" that illustrates the origin and divergence of species captured scientific thought. Thereafter, it became an icon of evolution, and firmly associated with biological understanding (Figure 1). In modern biology, tree diagrams such as cladograms have become invaluable tools for scientific reasoning. They have played roles in such diverse areas as the discovery of new biological compounds, the restoration of damaged ecosystems, and the understanding of the functional role of genes. Such representations are gateways to what biologists call tree thinking, which, contrary to much of evolutionary reasoning before the 20[th] century, recognizes the divergence of species, and the interconnected relationships between them (O'Hara, 1997).

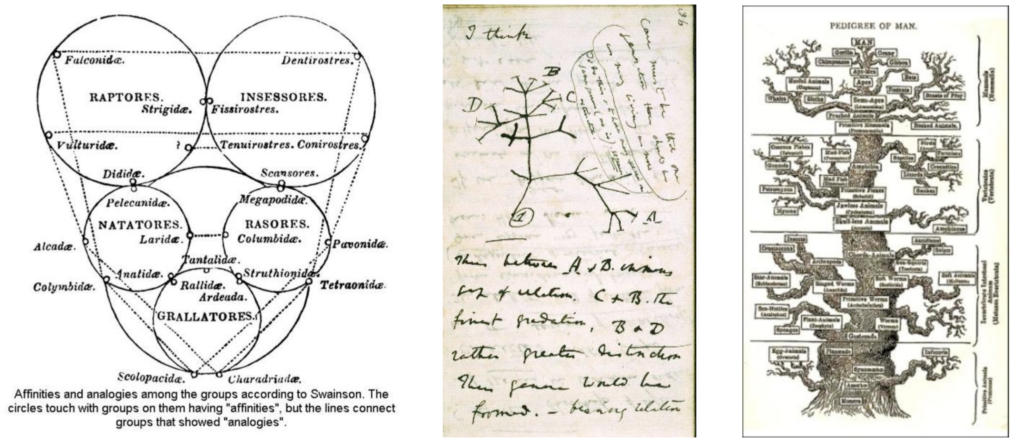

Figure 1. Early illustrations of species relationships by Swainson, 1836-1837 (left); Darwin, 1837 (center); and Ernst Haeckel, 1891 (right)

Cladograms come in many forms, but generally consist of interconnected lines, or branches, which represent the lineages of groups of organisms referred to as taxa. Taxa are named at their branch tips, and nodes, where two such branches intersect, represent the most recent ancestral traits shared by those taxa (see examples in Figures 2, 3, and 5). By identifying the relative recency of these ancestries, one can reason about the relatedness among the taxa depicted. Experienced biologists use cladograms to test evolutionary hypotheses, to learn about the characteristics of extinct and newly discovered species, and so to better understand the relationships among organisms on earth. The ability to read cladograms is thus crucial for understanding fundamental concepts of evolutionary biology (Baum, Smith, & Donovan, 2005; Catley , 2006) and is as well an important component of scientific literacy. Educators are moreover urged to teach these tools of professional practice (American Association for the Advancement of Science, 2001; National Research Council, 1996).

Yet, despite their simple forms, there is growing evidence that students find tree diagrams difficult and are prone to misinterpret them. Consequently, one strand of research has begun to document the types of mistakes that students make when make when reading cladograms. Common errors include reading increasing qualities in species from the bottom toward the top of the diagram, reading progress across the branch tips, and viewing the cladogram as a story of linear transformation rather than as one of divergence toward species diversity (e.g., Gregory, 2008; Halverson, Pires, & Abell, 2008; Meir, Perry, Herron, & Kingsolver, 2007; Novick & Catley, 2007). Other research has explored the factors that influence cladogram interpretation. For example, Novick & Catley (2007) point to the Gestalt principle of Good Continuation as a perceptual hindrance to interpreting a particular form of cladogram. Catley and Novick (2008) moreover find that this form of cladogram most prone to misinterpretation is also the one most prevalent in biology textbooks..

It is clear from existing research that meaning from a cladogram is constructed by the viewer, as it is in the case of other scientific representations. It is also clear that we cannot design more effective interventions to support that construction until we better understand the interaction of the multiple factors involved in interpretation. This symposium brings together researchers active in the budding area of tree-thinking. Together, the papers tackle the many dimensions of interpretation – be they representational, cognitive, educational, or developmental – and address the mechanism of diagrammatic reasoning through different methodological and theoretical lenses.

In the first paper, Phillips, Novick, and Catley examine the role of prior content knowledge in tree diagram interpretation. They compare high school and college students' performances on core tree reading skills, and show how reasoning strategies vary with students' biology background. Namely, they find that specific knowledge of taxa depicted in a tree diagram can interfere with students correctly reasoning based on the structure of the diagram. This carefully designed study contributes to untangling the influences of conceptual knowledge and perception in diagrammatic interpretation. In this manner, the authors provide us with valuable foundational components to consider in the design of an effective tree-thinking learning progression based in representations.

Meanwhile, Matuk and Uttal filter out specific content from the cladogram in order to more closely examine the perceptual and representational issues underlying the challenges with tree-thinking. In their study, they ask students to invent representations of *relatedness* and then observe how invention influences students' later interpretations of a standard cladogram. Most interestingly, they find differences in the kinds of representations students' invented to represent evolutionary relationships, vs. the kinds they invented to represent social relationships. However, they also observe that the common errors made reading cladograms persisted no matter whether the student was in the evolution or the non-evolution condition. Their work at once demonstrates the powerful influence of visual structure independent of content, as well as the influence of content beliefs on representational acts. It furthermore suggests more intuitive representational forms that may help support novice understanding of standard cladograms.

Next, Ainsworth and Saffer present a surprising finding. Given appropriate but only limited training (10 to 15 minutes), they find that children as young as seven years old can be successfully taught to read these complicated representations. On the one hand, their work reinforces the messages of the first two papers, that adults' reasoning errors are largely due to perceptual and conceptual biases acquired from prior knowledge in other domains; and on the other, it suggests promise for developmentally appropriate educational interventions. The authors encourage us to imagine possibilities beyond conventional educational standards, and challenge us to rethink when, and what we consider to be developmentally appropriate material for students to learn.

Finally, Halverson presents findings on the impact of novel instructional interventions among undergraduate students enrolled in a tree-thinking course. By documenting students' developing reasoning skills over three semesters, she demonstrates how certain specific challenges of representational competency can be addressed through scaffolded activities that involve students manipulating a three-dimensional cladogram fabricated with pipe cleaners. Halverson's study teaches us that sometimes, simple and elegant solutions exist, although these often only become clear through better understanding the problem.

An important component of scientific literacy is to understand the tools of scientific practice. Each of the papers in this symposium addresses issues of scientific literacy within the discipline of biology. Through the specific case of evolutionary trees, the authors consider important questions of representational competency: What are the conceptual and perceptual influences on diagrammatic interpretation? What is the role of content knowledge vs. perception? How does tree thinking develop from childhood through high school, through college? What interventions and scaffolds can educators provide to support tree-thinking? Together, the authors apply multiple methodological and theoretical perspectives to paint a more complete picture of the reasoning process and of diagrammatic interpretation and understanding. Each seeks to better understand when and how students imbue diagrammatic marks with evolutionary meaning; and each takes their findings a step further to suggest useful learning progressions, designs for more effective interventions, and scaffolds to help students develop reasoning skills in the domain of evolution. Led by our discussant, Karl Rosengren, this symposium promises lively interaction among presenters and members of the audience. It is an opportunity to discuss issues of interest to researchers concerned with how representations mediate our understanding of complex topics, as well as to those specifically interested in biological learning.

How high school students reason about the tree of life: A developmental perspective

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In 1996, the National Research Council put forth a set of guidelines for K-12 science education that state that students be introduced to the theory of evolution in primary and secondary schools. Tree thinking is an essential tool for understanding evolutionary hierarchies, based on the distribution of derived characters among a set of taxa; yet, there is little research devoted to the acquisition of tree thinking skills during development. The present study examines the cognitive processes that underlie high school students' abilities to engage in tree thinking. We compare students' responses to those recently obtained from a college sample of students with weaker and stronger backgrounds in biology (Novick & Catley, 2009). These results will provide critical information regarding the developmental trajectory of tree thinking skills during adolescence and early adulthood.

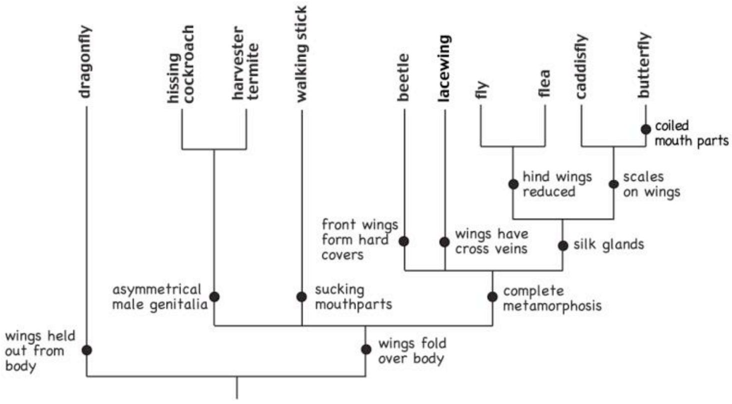

Figure 2. An insect cladogram

Methods

60 students (31 males, 29 females) who were enrolled in a 10th grade high school biology class at a public high school in a rural area of western North Carolina (*M*=15.65, range of 15-17 years) completed a 4-page booklet, which included a cladogram and three questions on each page. Students were instructed to utilize each cladogram to answer questions regarding the evolutionary relations among several taxa, including insects (Figure 2), dinosaurs (Figure 3), placental mammals, and marsupial mammals. Students' tree-thinking skills were assessed in five domains including identifying a character shared by a most recent common ancestor (MRCA) and a set of taxa based on a given derived character. Students were also asked to identify clades (i.e., monophyletic groups) and evaluate the relative evolutionary distance (degree of relatedness) between taxa. A fifth skill required students to make inferences about what taxa are likely to share a derived character (the focus of the analysis presented in this symposium). Students were told that birds are warm-blooded (dinosaurs cladogram) or that termites digest cellulose (insects cladogram) and were asked which taxon is most likely to share this character. The answers (*T-Rex* and hissing cockroach) can be seen in Figure 3 and 2, respectively.

Results

College students with a stronger background in biology had the highest number of correct responses overall. However, all students were more likely to make correct inferences when asked about insects as opposed to dinosaurs (Table 1).

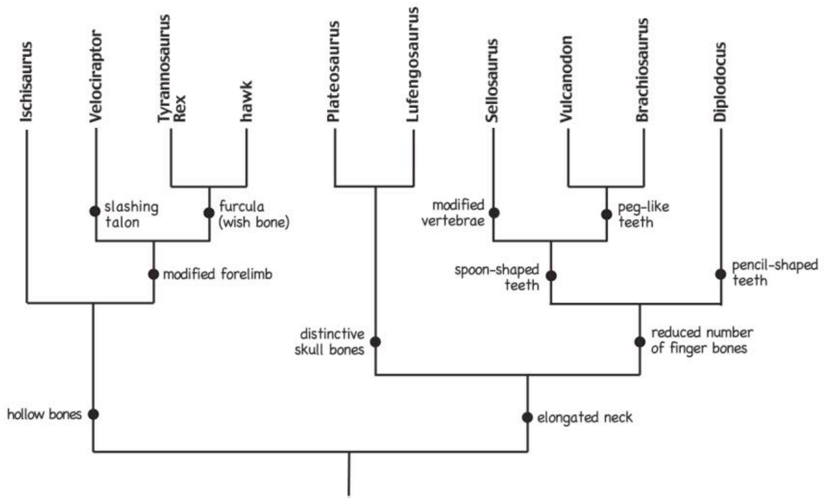

Figure 3. A dinosaur cladogram

Table 1. Mean accuracy scores for inference questions

Sample	Insect Cladogram	Dinosaur Cladogram
College Students (stronger biology background)	.77	.47
College Students (weaker biology background)	.58	.25
High School Students	.67	.27

Students' justifications provide further information regarding their tree-thinking abilities. Across samples, students appealed to the best evidence – most recent common ancestry or evolutionary relatedness – only to support correct inferences. In comparison, students who made incorrect inferences frequently provided categorical justifications (e.g., hawks share warm-bloodedness with birds because they are birds; see Table 2). High school students and college students with weaker backgrounds in biology were significantly more likely to provide this justification when asked about dinosaurs than insects.

Table 2. Mean proportion of categorical responses

Sample	Insect Cladogram	Dinosaur Cladogram
College Students (stronger biology background)	.29	.21
College Students (weaker biology background)	.22	.43
High School Students	.32	.52

These results indicate that prior knowledge of the specific taxa can interfere with successful tree thinking. Students' justifications underscore the conflict they had with reasoning with the information that birds are dinosaurs. Our results suggest that for younger students, as well as those with less biological knowledge, the combination of shaky biological knowledge and evidence presented in an unfamiliar diagram leads to poor understanding of macroevolution. The present baseline results will be used to help guide the development of empirically-based curricula and instructional practices at the high school and undergraduate levels that will lead eventually to a more widespread appreciation for and understanding of tree thinking.

Inventing a representation of relatedness

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Prior research has shown that reasoning with cladograms is a skill that must be taught. Novice students, who do not understand the peculiarities of the representational system, can rely only upon prior content knowledge and perceptual resources (e.g., embodied and culturally-learned spatial metaphors (Tversky, Kugelmass, & Winter, 1991) and Gestalt perception (Novick & Catley, 2007) to make sense of them. The problem is that students' prior knowledge is sometimes incorrect or incomplete. They rely upon misconceived folk theories of evolution as a linear transformation through successive stages; and their intuitive perceptions often counter the obscure symbolic rules by which the cladogram operates. It is such that even with instruction, many students tend to make errors when interpreting cladograms (Meir et al., 2007), which keeps them from mastering an important component evolutionary reasoning.

In spite of the difficulties this diagram presents, it is nonetheless a standard representational tool within the field of biology. As such, designers are faced with a different task: How to design an effective learning sequence that addresses the issues students are known to encounter. Where previous work has both identified the common errors that students make when reasoning with cladograms (Gregory, 2008; Meir et al., 2007), and as well has examined the reasoning processes underlying those errors (Halverson et al., 2008) this research addresses more fundamental questions of the nature of representation and of intuitive symbolization in the domain of evolution. Specifically, we ask (1) What kinds of representations will students intuitively invent to represent the central concept of cladograms, “relatedness?” (2) How does the act of inventing a representation influence the interpretations students later make of the standard cladogram? and (3) How do students’ inventions and interpretations differ when the content of the representation does or does not concern evolution?

Methods

To investigate our questions, we conducted individual interviews with 33 undergraduate students. Of these, 22 students were first asked to invent a diagram (on a tablet pc) to depict the relationships among either a group of species with shared traits (the *Evo* condition), or among a group of children with shared toys (the *Toy* condition), and to discuss why they invented what they did. Except for the content of the problem, the data sets given to students in the *Evo* and *Toy* conditions were equivalent. In the *control* condition, 11 students were asked to sketch and discuss any image they recalled of evolution. Afterwards, they were shown a solution to the problem in the form of a standard cladogram. In a series of open-ended and fixed choice questions, all 33 students were then asked to use this diagram to reason about the relative relatedness among the items depicted, and to interpret its various symbolic attributes. Interviews were video recorded and transcribed for later analysis and demographic data was collected on students’ science coursework and belief systems.

Results

Students drew upon a rich array of representational resources to depict "relatedness," including familiar representational forms (e.g., Venn diagrams, networks, graphs, tables) and devices for organizing information (e.g., colour cues, systematic variation of graphic qualities). With one exception, only the *Evo* condition elicited temporal-based inventions, which depicted linear progressions from an ancestral to a more contemporary species (n = 7 vs. n = 1). Meanwhile, only the *Toy* condition appeared to elicit propositional-like statements (n = 2 vs. n = 0). These observations suggest particular manners in which students’ beliefs about the content will influence the form of the representation they invent. Specifically, the concept *evolution* appeared to elicit the very kind of linear thinking that may be at the root of students’ difficulties with interpreting tree diagrams.

However, our qualitative analysis of students’ reasoning processes with the standard cladogram, showed that students that first invented a representation appeared to focus more attention on the relationships depicted. They tended to describe the symbolic functions of lines and nodes as indicating conceptual relations, rather than as timelines or as paths of change as did the students in the control condition. The latter rather tended to interpret the cladogram in terms of a misconceived folk theory of evolution. That is, despite the cladogram’s branching structure, students in the control condition described the progressive transformation of a species through a series of states from left to right of the graphic space. Our findings extend prior work on inventing representations (e.g., Schwartz, 2006) by contributing a particularly challenging example from the domain of biology. They suggest that an opportunity to consider the problem of representing relatedness helps students better understand the standard diagram as a solution, no matter the kind of representation these students first invented (e.g., Cox & Brna, 1995). The fact that common errors made reasoning with the cladogram were still evident among all students, suggests the powerful influence of visual structure and of perceptual processes on interpretation. Our findings suggest intermediate representations and activities that might serve to bridge novice and expert understanding (Roschelle, 1996).

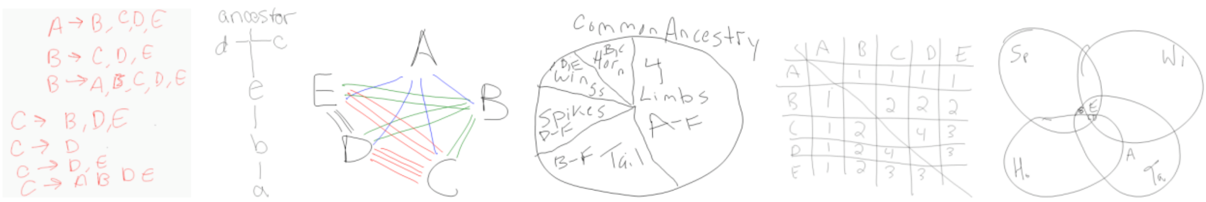

Figure 4. A sample of students’ inventions

Can children read trees?

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The research reported in other papers in this symposium reveal difficulties in adult and teenage interpretation of cladograms. This paper explores if children in middle childhood could interpret cladograms given minimal training and if so what factors might influence their success. In particular, we explored if their reasoning was influenced by the species represented or the way that cladogram was presented (its rotation).

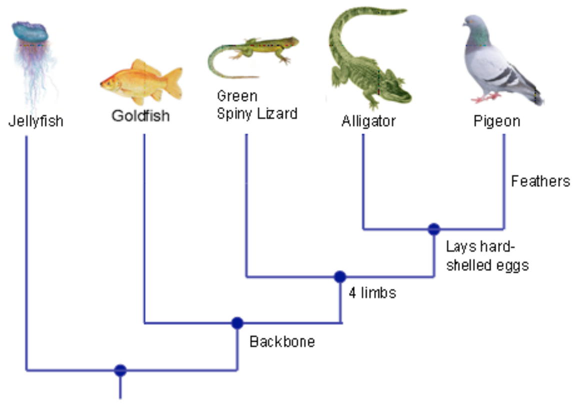

Figure 5. Pigeon cladogram in RRRR rotation

Methods

13 boys and 15 girls aged 7:1 to 11:11 years were trained for 15 minutes on 'fake' cladograms before answering 8 questions on each of 4 new cladograms. Children were introduced to key terms before proceeding to finding common ancestors, determining relatedness, how synapomorphies (features) are inherited and the arbitrary nature of branching. Training was designed to support four types of reasoning: finding the most common recent ancestor of two species; identifying a species' features based upon its ancestry; describing which animals have particular features; and determining which species are most closely related to a particular example. They then answered eight questions on each of four new trees (one each of the different contents and rotation counterbalanced by Graeco Latin square). After every second answer they were prompted to explain their reasoning. A [4 by 4 by 4 by 4] repeated measures study examined: species depicted in the cladogram; branch rotation, the depth of tree searched and type of question. Just those answers including only correct responses were considered correct (e.g. "Which animals are most closely related to the green spiny lizard?"; 'alligator and pigeon'). Analysis was by four (4 by 1) ANOVAS with post-hoc comparisons using the Bonferroni correction. Children's performance was surprisingly good with an average of 56% of answers completely correct. This is significantly above chance (Ancestor: 25%, Feature/Relation: 6.67%, Animal: 3.22%).

Results

Species represented influenced performance ($F(3,81)=9.63$, $p<0.001$). Children reasoned with flea (45%) more poorly than pigeon (63%) and human (64%) cladograms. Other researchers (e.g. Evans, 2006) have found poorer evolutionary reasoning by children about invertebrates that, in our case, cannot be explained simply by unfamiliarity (as piloting ensured these were known insects). However, Philips, Novick & Catley (this symposium) found insect cladograms were associated with better performance than dinosaur cladograms. There was no evidence of the human cladogram leading to different reasoning. Rotation had no impact ($F(3,81)=1.87$). It may be that children have yet to develop these biases or potentially they did not affect overall accuracy but did affect children's erroneous strategies. Children's performance worsened as the depth of tree that needed to be searched increased $F(3,81)=28.58$, $p<0.001$, $\eta 2 = .51$): Level one questions (82%) were answered more accurately than any other level (level 2 (53%) level 3 (51%) and level 4 (45%). It seems wise to recommend that cladograms for children should be relatively shallow.

Children found some types of question easier than others ($F(3,81)=10.48$, $p<0.001$, $\eta 2 = .28$). Questions about relations (39%) were answered worse than those concerning ancestors (69%) and animals (63%). Performance on the ancestor questions is particularly encouraging as it is a key skill that other tree-thinking practices build on. Children's explanations were examined to explore whether they were able to justify their responses using correct semantic explanations (e.g. *because that's* [pointing to the appropriate node] *the ancestor of the stick insect and the flea*"); correct syntactic explanations ("*because the lines link to it"; "that's the first dot they have in common')* incorrect syntactic reasoning (for example reasoning by tip proximity;

'*because they are next to each other*') or were not based on the tree at all ("*because I've seen a lizard before and I can see all the legs of the alligator*"). Unsurprisingly, age and number of correct answers correlated significantly (r=.64, p<0.001). The youngest quartile of children answered 39% of questions correctly and the oldest 68%.

This study suggests that after a short amount of training children can begin to reason with cladograms. This has important implications for biological education as tree-thinking could be used with younger children than has previously been considered appropriate (our results suggest from around nine year upwards). Naturally, much of the complexity of tree-thinking will remain hard for this age group (as it is for adults) but given demonstration of this basic competency researchers can now determine how best to teach children to tree-think and to further explore which cladogram designs help novice tree-thinkers.

Improving undergraduates' approaches to understanding tree thinking

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Evolutionary biologists see biology through the perspective of phylogeny, or evolutionary history. However, it is clear that most students do not interpret trees in the same manner as evolutionary biologists (Baum et al., 2005; Gregory, 2008; Halverson, Abell, Friedrichsen, & Pires, 2009; Halverson et al., 2008). The alternative types of reasoning students use can cause them to generate a variety of responses when interpreting and using phylogenetic trees (Halverson, 2008). Yet, few studies have focused on why students misinterpret trees or how students can overcome these misconceptions to develop internalized tree thinking skill. The purpose of this study was to examine how undergraduates developed and used phylogenetic trees during a plant systematics course as well as identify/design scaffolds to facilitate improvements in core skill development.

Research Design

This study took place in the lecture section of an upper-level, plant systematics course at a Midwestern research extensive university during the Spring 2007, 2008, and 2009 semesters. This course was organized primarily around phylogenetic tree thinking. Students were engaged in interpreting and building phylogenies in addition to learning about plant systematics. I used open-ended student responses from two-tiered pre/posttests, a two-part interview series, weekly reflective journal entries, field notes from course observations, and course assessments to learn how 87 upper-level undergraduate science majors enrolled in a plant systematics course interpreted phylogenetic trees and developed tree thinking skills. I utilized all transcripts, field notes, expanded observation notes, and documents in data analysis. I wrote profiles describing each student's reasoning when using phylogenetic trees. Throughout the construction of each student profile, I returned to the data sources to test my interpretations of student responses and find additional supporting evidence. I inductively coded the profiles to identify reasoning students used when reading trees and their reactions to instructional interventions. I compared the coded student profiles to identify themes. Once the themes were identified, I triangulated findings using secondary data sources to ensure the research findings represented accurate interpretations of the data. I wrote rich descriptions of students' tree thinking skills and documented themes that emerged from the data about effective instructional scaffolds.

Findings

I identified 13 major challenges students encounter when developing tree thinking skills: (1) Overcoming prior ideas about organisms and using a tree to draw conclusions; (2) Visualizing how branches can rotate; (3) Reading from the tips rather than nodes; (4) Mapping a species lineage from tip to root of a tree; (5) Comparing patterns of relationships among trees; (6) Lumping organisms on single characteristics rather than looking at them holistically; (7) Ignoring critical data and/or using uninformative evidence to construct a tree; (8) Difficulties transferring empirical data into a tree illustrating evolutionary relationships; (9) Creating consensus nodes to address discrepancies; (10) Altering the format or orientation of the tree alters the relationships depicted; (11) Generating accurate, branching, hierarchical representations; (12) Using trees to reconstructing ancestral states; (13) Comparing representations to identify the most supported tree.

Two instructional interventions were used in the course (e.g., a hypothetical plant exercise and a pipe cleaner phylogeny activity) Students perceived the pipe cleaner phylogeny activity as the most effective instructional intervention. With the pipe cleaner tree manipulative, students could physically bend and rotate the pipe cleaners into new shapes, directions, and different topologies without altering the relationships. Students began manipulating the pipe cleaner trees by swiveling the branches, and came to see that nodes to determine relationships rather than the tips. For example, after the activity he suggested that "*That when studying trees, one should focus on nodes.*" and knew "*trees can be displayed in different formats while still showing the same information.*" Sally discussed the benefits of having a 3D pipe cleaner model. She indicated that this model provided a novel context for phylogenetic trees that was more effective than traditional printed phylogenetic trees in helping instruct how branches could rotate. "This is something you cannot do with a drawing on paper." In the presentation, I will elaborate on how this instructional intervention helped students overcome four main challenges: namely numbers 2, 3, 4 and 7 above

Some instructional resources (e.g., University of California Museum of Paleontology, 2009) have attempted to address some of the listed tree thinking challenges by explaining how scientists interpret and use data as evidence to build phylogenetic trees. However, these resources do not provide opportunities for students to practice tree thinking nor do they provide scaffolds to facilitate tree building skills. Thus, while tree thinking challenges are sometimes acknowledged, they are not always explicitly addressed in ways that help students overcome the challenges and, in turn, improve tree thinking skills. Few studies focus on instructional strategies to help students overcome challenges (Gendron, 2000; Meir et al., 2005). There are numerous published lessons that propose activities using phylogenetic trees or are aimed at helping students develop tree thinking (over 50 published in the *American Biology Teacher* alone). However, none of these activities is grounded in research on how students overcome identified challenges or on how students learn core tree thinking skills. Additionally, published instructional activities (e.g., Gendron, 2000; Meir et al., 2005) assume students are aware that trees contain information on evolutionary histories and can interpret and build these representations. I have found that this is not the case. My study used research-based activities to help students overcome the major challenges associated with tree thinking, something novel to tree thinking instruction. I found that the research-based instructional interventions helped students overcome challenges with tree thinking at the same time they facilitated students' development of core tree thinking skills. By investigating how undergraduates learn tree thinking during three semesters of a plant systematics course, this study adds to our understanding of critical elements necessary for continuing to improve instruction with phylogenetic trees and maximize the potential of evolution education.

References

American Association for the Advancement of Science. (2001). *Atlas of science literacy*. Washington, DC: Author.

Baum, D. A., Smith, S. D., & Donovan, S. S. S. (2005). The tree-thinking challenge. *Science, 310*, 979-980.

Catley, K., M. (2006). Darwin's missing link - a novel paradigm for evolution education. *Science Education, 90*(5), 767-783.

Catley, K. M., & Novick, L. R. (2008). Seeing the wood for the trees: An analysis of evolutionary diagrams in biology textbooks. *BioScience, 58*(10), 976-987.

Cox, R., & Brna, P. (1995). Supporting the use of external representations in problem solving: The need for flexible learning environments. *Journal of Artificial Intelligence in Education, 6*((2/3)), 239-302.

Evans, E. M. (2006). Teaching and learning about evolution. In E. J. Zimmer, E.M., Allison, L., & Disbrow, S. (Ed.), *Virus and the whale: Exploring evolution in creatures small and large* (pp. 25-37). Arlington, VA: NSTA Press.

Gregory, T. (2008). Understanding evolutionary trees. *Evolution: Education and Outreach, 1*(2), 121-137.

Halverson, K. L., Abell, S. K., Friedrichsen, P. M., & Pires, J. C. (2009). Testing a model of representational competence applied to phylogenetic tree thinking, *NARST*. California.

Halverson, K. L., Pires, J. C., & Abell, S. K. (2008). Undergraduates' abilities to use representations in biology: Interpreting phylogenetic tree thinking, *National Association for Research in Science Teaching*. Baltimore, MD.

Meir, E., Herron, J.C., Maruca, S., Stal, D. & Kingsolver, J. (2005). *EvoBeaker 1.0*. Available online at : http://www.simbio.com. Ithaca, NY: SimBiotic Software

Meir, E., Perry, J., Herron, J. C., & Kingsolver, J. (2007). College students' sisconceptions about evolutionary trees. *The American Biology Teacher, 69*(7), 71-76.

National Research Council. (1996). *National science education standards*. National science education standards: National Academy Press.

Novick, L. R., & Catley, K. (2009). Understanding the tree of life: Effects of biology background and cladogram format on tree thinking., *American Educational Research Association*. San Diego.

Novick, L. R., & Catley, K. M. (2007). Understanding phylogenies in biology: The influence of a Gestalt perceptual principle. *Journal of Experimental Psychology: Applied, 13*(4), 197-223.

O'Hara, R. J. (1997). Population thinking and tree thinking in systematics. *Zoologica Scripta, 26*(4), 323-329.

Roschelle, J. (1996). Designing for cognitive communication: Epistemic fidelity or mediating collaborative inquiry. *Computers, communication and mental models*, 15–27.

Schwartz, D. L. (2006). *Learning by producing diagrams.* Paper presented at the Diagrams 2006, Berlin, Heidelberg.

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology, 23*, 515-557.

POSTER SYMPOSIA

Using Visualization to Link Abstract Science and Everyday Experience

Chair: Marcia C. Linn, University of California, Berkeley
Discussant: TBD
Organizers: Ji Shen, Hsin-Yi Chang

Abstract: This interactive poster symposium features research groups investigating how visualizations and aligning instructional approaches promote students' deep understanding of physical sciences. The participating studies take advantage of computerized visualizations to bridge abstract science concepts and students' intuitive ideas of physical phenomena. These studies reveal how the visualizations help students improve their understanding of science over time by employing mixed methods such as data from student performances on pre-post tests and student practices during the learning process. These posters provide insights about how students learn from visualizations and propose effective design approaches to augment the impact of computerized visualizations.

Introduction

A major challenge that educators face is that student learning and understanding of subject areas often occurs at a superficial level (e.g., Krajcik & Blumenfeld, 2006). Many teachers and researchers recognize the difficulty of promoting meaningful learning and deep understanding due to limited time, resources, tools and instructional strategies. However, with the rapid development of technology, research has emerged to provide promising evidence for how advanced technology tools can effectively transform teaching and learning practice to benefit student learning and promote deep understanding (e.g., Blumenfeld, Fishman, Krajcik, & Marx, 2000; Goldstone & Wilensky, 2008; Linn, Clark, & Slotta, 2003; Wieman, Adams, & Perkins, 2008). Specifically, this collection of studies examines the role of computerized visualizations in supporting students' understanding of physical sciences. Computerized visualizations such as simulations and dynamic models allow students access to unseen processes and abstract concepts in science. These external visualizations and models can help students form complex understandings of a given concept or phenomenon (Buckley, 2000). However, the process of student interacting with visualizations to form integrated understanding is not straightforward. Students' prior knowledge may influence their perception of phenomena and understanding of the external models (Rohr & Reimann, 1998). Moreover, students need to integrate multiple types of knowledge and skills in order to make sense of the visualizations and successfully perform their learning tasks using the visualization. Students often need guidance to interact productively with visualizations. In this symposium, eight studies investigated how students developed coherent understanding of science using computerized visualizations with various types of support. This symposium will engage participants in discussing diverse viewpoints concerning the roles, effective strategies, and beneficial features of computerized visualizations to promote deep science learning.

Purpose and Objectives

We organize this interactive poster symposium to provide a platform for the presenters and the audience to discuss how computerized visualizations can promote strong conceptual connections between classroom science and the physical world. Research suggests that many natural science concepts (e.g., atomic interactions, acceleration, electricity) are abstract and challenging for students because they cannot meaningfully connect these concepts to real observations and concrete experiences. A wide range of computerized visualizations has been created to help students learn these difficult concepts. Many of these visualizations show effectiveness in improving students' science understanding. Through the collection of the studies we aim to answer the following questions surrounding the use of computerized visualizations in science classrooms:

- *How can dynamic visualizations make science relevant to students' life?* Students encounter everyday experience such as heat and temperature, electric circuits, and physical motions. The visualizations presented in the symposium aim to embed abstract disciplinary science knowledge (e.g., atomic models, Newtonian mechanics) in contexts that are familiar with students.
- *How can visualizations help students distinguish spontaneous ideas gained from everyday experiences and scientific ideas learned in class?* As students form intuitive ideas to explain observations they make about the world, visualizations can help students distinguish and link the spontaneous ideas from scientific ideas by

providing access to unseen processes (e.g. molecular interactions) and unattainable situations (e.g. frictionless worlds).

- *How to facilitate students in developing deep understanding and inquiry skills necessary in solving complex problems?* The studies in the symposium use complex problems in the physical world such as the mechanism of airbags, global warming, and hydrogen fuel cell cars. Associated dynamic visualizations offer opportunities for students to formulate, investigate and experiment with variables, construct and evaluate explanatory models, and collaborate with peers to tackle complex problems.

To investigate these questions about using visualizations in learning science, the researchers employed different combinations of a variety of scaffolding strategies. These include sequencing physical experiments with virtual experiments, combining students' drawings with computer models, critiquing visualizations, overlaying gameplay dynamics with formalized representations, coordinating multiple visualizations, and embedding key prompts. Through the interactive symposium, we further seek the answers to the question "*what are the criteria of using different supporting strategies under certain conditions in different science content areas*?"

Session Structure and Participating Presentations

The session is planned as an interactive poster session, chaired by Prof. Marcia Linn. She will briefly introduce the session (~5m). Each presenter will then summarize their own research in one minute (~10m). Attendees will then circulate and interact with individual presenters (~50m). Presenters will bring computer-based demonstrations of the technologies used in their research. After the interaction between the presenters and the attendees, the discussant will comment on the presentations (~10m) and moderate a conversation that allows presenters and attendees to share their insights (~15m). The following section will summarize each individual presentation and list participants.

Investigating the Role of Physical and Virtual Experiments in Developing Integrated Understanding of Thermal Conductivity and Equilibrium

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National Kaohsiung Normal University

Understanding science requires students to integrate multiple types of knowledge and abilities to form a coherent structure (National Research Council [NRC], 1996; Olsen, 2003). One indicator of integrated understanding is students being able to integrate scientific concepts with everyday events (NRC, 1996). Indeed, when learning the concepts of thermal conductivity and equilibrium students may show resistance to change ideas stemming from personal experience of heat and temperature (Clark & Linn, 2003; Paik, Cho, & Go, 2007). For example, students often think that metal objects have lower temperatures than wood objects and resist the idea that objects eventually become the same temperature as the room's temperature (Clark & Linn, 2003). A second indicator of integrated understanding is students being able to explain a phenomenon or scientific process in light of its mechanism. For example, when explaining thermal conductivity a core concept involves understanding of heat transfer by collisions of atoms and molecules (American Association for the Advancement of Science [AAAS], 1993). However, many middle or high school students have little or fragmented knowledge of atoms and molecules (Lee, Eichinger, Anderson, Berkheimer, & Blakeslee, 1993; Nakhleh, Samarapungavan, & Saglam, 2005). It is unclear how to best support students in learning the mechanism of heat conductivity and equilibrium at the molecular level.

In this study we used a week-long Web-based Inquiry Science Environment [WISE] module on thermodynamics that has been proven effective to students' science understanding (Clark & Linn, 2003) and argumentation abilities (Clark & Sampson, 2007). We particularly examine one physical and one virtual experiment activities to discern the roles of physical versus virtual experiments in developing different aspects of student understanding of thermal conductivity and equilibrium. In the physical experiment students are guided to choose six objects made of different materials to predict and measure their temperature in the classroom. We hypothesize that this physical experiment provides direct experiences and evidence for students to connect and sort scientific and personal ideas. In the virtual experiment students are guided to change parameters such as different materials to observe what happens to the atoms and molecules when heat transfers from one object to another. We hypothesize that this virtual experiment supports students in building their understanding of the mechanism of heat transfer. We implemented the Chinese version of the module in five eighth-grade classes (n=154) in South Taiwan. Data collected include pre-post test data, and learning process data including students' written responses to the prompting questions embedded in the activities, and students' action and discussion videos when students worked on the activities. Pretest to posttest gains indicate medium to large effect sizes of the module, similar to what was found in the American runs (Chang & Linn, in preparation). In-depth examination of the learning process data indicates the patterns of students' strategies in the physical and virtual experiments, the aspects and extents of student understanding mediated by the physical and virtual experiments, and the relationships between the learning process and pre-posttest phases.

Promoting Links and Developing Students' Criteria for Visualizations by Prompting Judgments of Fidelity

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Chemistry students struggle to bridge molecular, symbolic, and molecular representations of chemical phenomena. For example, students view chemical equations, such as $2H_2 + O_2 \rightarrow 2H_2O$ as math problems to solve instead of breaking and forming bonds among atoms (Krajcik, 1991). Research demonstrates that powerful visualization tools can help students add normative ideas about phenomena on a molecular level (Pallant & Tinker, 2004). However, students need support to connect these ideas to symbolic and everyday ideas, develop criteria for these ideas and sort and refine the links among ideas to build coherent understandings of complex phenomena (Linn & Eylon, 2006). Past studies show that students have rich intuitive abilities to critique representations, do well reacting to representations in design settings but have trouble articulating their ideas (diSessa, 2002). We hope to build upon these existing capabilities to help students link pre-designed, interactive visualizations to the real world and promote the development of criteria for these connections.

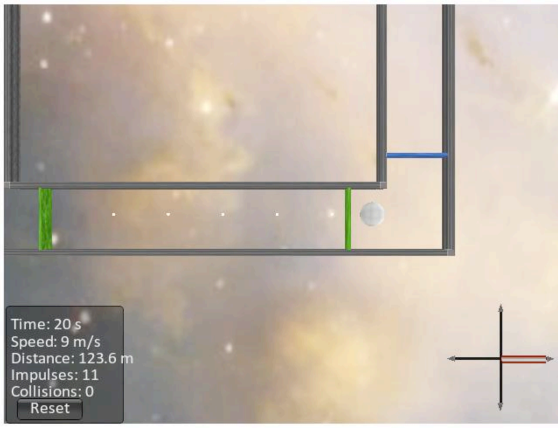
This poster investigates how prompting students to judge and explain how strongly the visualization relates to the real world can help students connect molecular visualizations to macroscopic ideas as well as develop criteria about visualizations. Approximately 140 high school chemistry students from two teachers participated in a week-long technology-enhanced curriculum unit about chemical reactions. As part of this curriculum, students interacted with molecular visualizations from *Molecular Workbench* and greenhouse effect visualizations in *NetLogo*. After each visualization step, students were prompted to judge the visualization as "not at all related", "somewhat related" or "very related" to the real world and then explained their choice. Significant gains from pretest to posttest items demonstrate students made connections among molecular and macroscopic levels. Analyses of students' embedded explanations show that many students judge visualizations as related to the real world because of particular examples, such as specific chemicals or reactions. Many students also articulate ideas about the fidelity, usability, and learnability of the visualizations. Overall, the data suggests that students make connections from the visualizations to the real world but but need support to build from their rich intuitive ideas and develop more sophisticated criteria for visualizations.

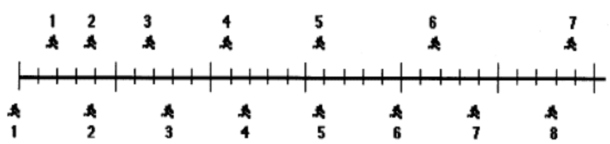
SURGE: Intended and Unintended Learning in Digital Games

Douglas B. Clark, Brian C. Nelson, Cynthia M. D'Angelo, Kent Slack, and Mario Martinez
Vanderbilt University and Arizona State University

Well-designed video games can support learners in building accurate intuitive understandings of the concepts and processes embedded in the games due to the situated and enacted nature of good game design (Gee, 2007). Most commercial games fall short as platforms for learning, however, because they do not help students articulate and connect their evolving intuitive understandings to more explicit formalized structures that would support transfer of knowledge to other contexts. In Thought and Language, Vygotsky (1986) discusses the potential for leveraging intuitive understandings from everyday experience ("spontaneous concepts") with instructed scientific concepts to build robust understandings. The SURGE project (Scaffolding Understanding by Redesigning Games for Education) focuses on integrating and overlaying popular gameplay dynamics with formal physics representations and visualizations (see Figure 1 (a) for a snapshot). The design combines cognitive processing-based design and socio-cognitive scripting with design principles and mechanics of popular commercial video games such as Mario Galaxy, Switchball, Tiger Woods PGA Tour, Orbz, and Portal.

The first SURGE study analyzed 24 university students playing SURGE. The pre-post test data support the potential of games for learning, but also underscore their potential to reinforce alternative conceptions. The game actually resulted in a significant pre-post test decrease ($\chi 2 = 4.75$, $p = .029$) in correct answers for one question by unintentionally focusing students' attention on another physics relationship (we had not yet added all of the intended functionality to the interface relevant to projectile motion and the independence of the x and y components of an object's velocity), but the students demonstrated significant ($p = .037$) gains on the rest of the posttest. In post-interviews, students' understanding of the concepts and vector representations demonstrate the ways in which students' ideas evolve during the game. The results suggest that players learn about the formal instructed concepts in a manner that transfers to Force Concept Inventory items (Hestenes, Wells, & Swackhamer, 1992; Jackson, 2007), but the results also caution that the ideas that students take away from games aren't always the ones intended by the designers. A second study in November 2009 will analyze 330 students in Taiwan and Minnesota playing SURGE. Students will be randomly assigned to conditions that display or remove the overlaid vector representations. Interview data will explore how the students make use of the vector representations and visualizations within the game as well as the ways in which the game connects with students' other interests and identities outside of school.





19. While you and your friend are running, your science teacher takes measurements. Later he makes this drawing. The little stick figures show where both of you are (your positions) at every second of time. You're both running to the right.

Are you and your friend ever running at the same speed?

(A) No.

(B) Yes, at the 2nd second of time (that is, at the 2nd stick figures).

(C) Yes, at the 5th second of time (that is, at the 5th stick figures).

(D) Yes, at the 2nd and 5th seconds of time.

(E) Yes, at some time between the 3rd and 4th seconds.

Figure 1. (a) Screenshot of SURGE environment (b) A sample item from FCI.

How Do Interactive Graphing Tools Help Students Interpret Virtual Experiments about Car Collisions?

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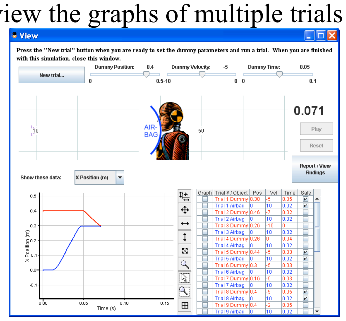
University of California, Berkeley Graduate School of Education

This study examines how experimentation using a visualization featuring coordinated animated and graphical representations of motion can help students reach sophisticated insights about car collisions. Airbags: Too Fast, Too Furious? is a one-week high school physics investigation about airbag safety that addresses students' understanding of motion graphs. The design of Airbags builds on research that recommends using visual representations to scaffold inquiry-based learning (Quintana et al, 2004), particularly investigations concerning motion (White, 1993). Airbags incorporates dynamic visualizations that aim to help students understand events in a car collision that occur too quickly to be observed in real time. The visualizations present coordinated animated and graphical representations that are each designed to help support students' understanding of the other (Ainsworth, 1999; Kozma, 2003).

I designed the final Airbags visualization (Figure 2a) to model the crash test videos (Figure 2b) students observe in previous activities. Students use this visualization to experiment with three motion variables to investigate what factors put drivers at increased risk for injury. The visualization allows students to categorize trial outcomes and view the graphs of multiple trials to aid in the interpretation and comparison of trial outcomes.



(a)

(b)

Figure 2. (a) Experimentation visualization (b) Crash test video used in early activities

Students (n = 168) in five diverse high schools studied Airbags in dyads. Students responded to pretests and posttests on motion graphs and embedded assessments about the airbags situation. We also videorecorded the experimentation of 12 dyads, capturing their discussions and gestures during the experimentation activity. Significant pretest to posttest gains on understanding of motion graphs demonstrate that students were able to generalize knowledge about motion graphs in Airbags to other situations. Reponses to embedded assessments show that many students achieved a sophisticated understanding of the airbags situation that involved the role of threshold

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values in determining collision outcomes. This poster will present case studies that illustrate how the interactive graphing tools helped students interpret their experiments in meaningful ways that extended their everyday understanding of airbags.

Transformative Modeling in Learning Current Electricity: A Case Study of Preservice Teachers

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Research finds that students have many ideas on electricity not aligned with scientific notions (e.g. Eylon & Ganiel, 1990; Thacker, Ganiel, & Boys, 1999; Osborne, 1983; Shen, Gibbons, Wiegers, & McMahon, 2007; Shepardson & Moje, 1994). It is challenging to change these conceptions. Different strategies have been employed by science educators to help students learn current electricity (e.g., Benseghir & Closset, 1996; Shaffer & McDermott, 1992; Gibbons et al., 2003; Shen & Linn, submitted). This paper presents a teaching experiment that incorporates a variety of environments including computerized modeling tools (e.g., WISE, Phet), hands-on activities, role playing, and formative assessments (see Figure 3). The activities are designed based on the transformative modeling framework (TM) used to describe, analyze, and inform learning processes (Shen, submitted). TM delineates learning and teaching as a process of modeling the natural world through chains of operations on materials. At the center of the operations are a set of transformations that alter the nature of physical or symbolic objects by adding or suppressing information (Shen, in press; Shen & Confrey, 2007). The transformed materials, as well as the operations on these materials, render potential for future learning (Shen, submitted).

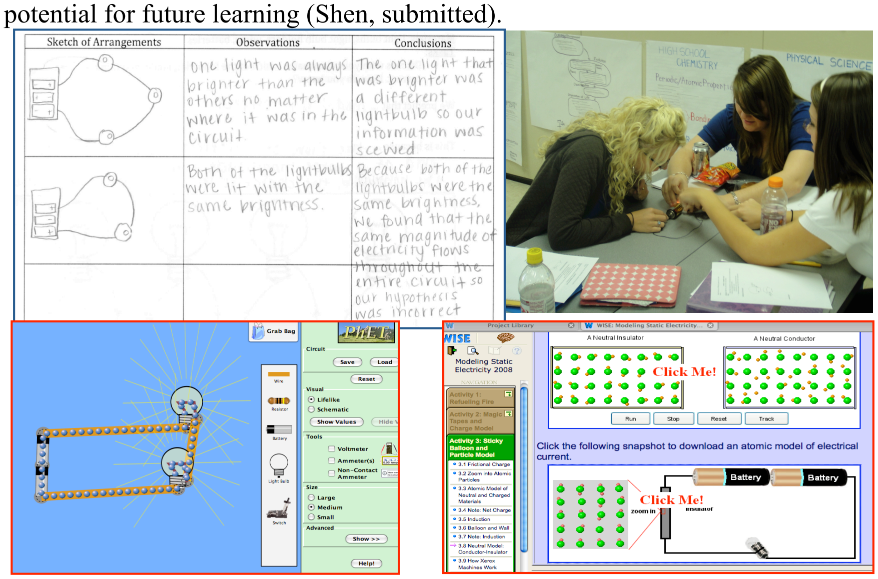

Figure 3. Students' work on current electricity.

The participants include 18 preservice middle grades teachers (17 female, 1 male). Their science background is weak based on the results of a pretest measuring general physics knowledge (25% correct). The teaching experiment lasted 2 weeks (15hours in a total). We collected online responses, videotapes, students' artifacts and formative assessment results to examine the learning processes. Preliminary findings suggest, among many others, the following message. The transformations among different forms of representations of knowledge challenge students to understand the underlying mechanism of scientific processes (e.g., transforming from a physical set-up to a computerized circuit to an electrical diagram to role play). Different models inform each other and together they help students form scientific understanding. The breakdowns of transformative links create conceptual difficulties for students on the on hand, and provide teachable moments on the other hand. The mechanism, types, and characteristics of these transformations and their implications in classroom teaching will be discussed.

Using Interactive Models to Support Content Learning through Scientific Reasoning

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This work examines how students learn scientific concepts related to the greenhouse effect by participating in scientific reasoning activities with an interactive model. A longstanding issue in science education research is the tension between teaching scientific content vs. scientific process or reasoning. Following instruction and experience, students are able to engage in valid scientific reasoning in *familiar or simple* contexts (Chen & Klahr, 1999, Kuhn & Angelev, 1976). However, there is still concern about overtaxing students' cognitive resources when they are required to engage in activities that involve using scientific reasoning strategies to learn *new* scientific content. Models are "dynamic representations and provide a visual explanation of the underlying causal mechanisms and processes underlying scientific phenomena which are not directly observable because of their scale" (Gobert, 2005). Using *interactive* models to teach science can help address the content versus process issue by allowing students to practice reasoning about scientific phenomena in rich contexts. In this study, students use an interactive model to learn about the greenhouse effect. Instruction prompts them to use a control variables strategy as they conduct multiple experiments with the model. The main goal of this work is to measure changes in students' content knowledge and scientific reasoning skills following a model based instruction experience.

In this work, 190 middle school students use an interactive model of the greenhouse effect. Pre-post tests measure content learning prior to and following the instruction experience. A subset of the items was designed to measure scientific reasoning. Additionally, log data documents how students' reasoning strategies change over time. Students engage in "simulated discovery tasks" (Zimmerman, 2000) as they use the model to conduct multiple experiments. They investigate the roles of solar energy, infrared energy, greenhouse gases, clouds, and Albedo in the greenhouse effect. Students are instructed to change only one variable at a time so that their experiments can provide valid information about the variable they are investigating. Supporting students to engage in this type of model-based instruction is an effective instructional strategy (Penner, Lehrer, & Schauble, 1998). Overall, students' understanding of the scientific content improves (t (189)=8.66, $p < .001$). The log data show that they use multiple reasoning strategies. Some closely follow the instruction to engage in the control of variables strategy and use it consistently in their experiments with the model. Some use the strategy after initial random exploration of the model. Others systematically manipulate two variables at a time to make comparisons. Ongoing analyses are looking at the range of reasoning strategies involved in experimentation and evaluating correlations between students' scientific reasoning and changes in their content knowledge. This work informs researchers interested in using model-based instruction that combines content learning and scientific reasoning. A more detailed presentation of the findings will extend the discussion of the complexity of supporting both of these learning goals.

Abstraction and Re-representation in Visualizations: Understanding Where the Learning Occurs

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Graphic representations (i.e., visualizations) have a long history as a tool to promote learning in science. Historically, a "craft-based" approach has been the primary strategy used to design and evaluate visualizations for use in instruction (e.g., Tufte, 1983). That is, heuristics based on practice are used to create representations that communicated, in the designer's eyes, the necessary information for student learning. More recently, a number of frameworks based on current understandings in the learning sciences have been applied to better guide visualization design and to understand why some designs are more effective than others. This paper will present an approach developed from semiotic theory (Hartshorne & Weiss, 1960) and the knowledge integration framework (Linn, 2006) for science meaning-making to develop strategies for visualization development and use in classrooms. Focusing on the knowledge-integration's component of making scientific phenomena visible, the presented work will look at the interplay of phenomena visible in the natural world with unaided senses with the conceptual and phenomenological elements of science learning that live in invisible, abstract layers. Semiotics is used to understand re-representations that move between the same level of abstraction and new representations that move toward or away from abstraction.

Student work in elementary science (Grades 2-5) was used as data source for validating this new approach to understanding student meaning-making through visualizations. A stratified sample of notebooks (M=7) were taken from 7 classrooms (4 Grade 2 and 3 Grade 5) for a total of 45 notebooks. From these notebooks, student entries for all activities relating to two science kits (EDC, 2004; FOSS, 2008), one per grade, were analyzed—a total of 1195 pages. Student entries were coded based on dimensions related to the context of the work (science learning goal, phase of inquiry), and the type of entry (text, graphic, mixed). For the graphic entries, the level of abstraction, how the abstraction was represented in the graphic, and the relationship of the graphic to complimentary text were coded in order to chart the moves in relation the meaning-making goals, as defined by the curriculum. This analysis will provide insight for the design of future, computer-based systems and how they may differ from those currently being designed for later school grades. Better understanding these moves and their role in learning provides new approaches to the creation of computer-based visualizations specifically designed for elementary science contexts.

Exploring Drawing and Critique to Enhance Learning from Visualizations

Helen Z. Zhang
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Many chemistry students struggle to make sense of chemical phenomena at the molecular level (Johnstone, 1993). They have difficulty visualizing a chemical equation (e.g., $2H_2+O_2 \rightarrow 2H_2O$) as a chemical reaction that involves atom rearrangement and bond breaking and formation (Krajcik, 1991). As a result, they cannot form deep understanding of chemical concepts by linking ideas at the molecular, symbolic, and observable levels. Dynamic visualizations have potential to meet this challenge by demonstrating changes at the molecular level. Nevertheless, many visualizations are confusing (Tversky, Morrison, & Betrancourt, 2002), and often students are beguiled by their deceptive clarity (Chiu & Linn, in press). They need support to add ideas at the molecular level and connect with ideas at other levels. My previous research (Zhang & Linn, 2008) has suggested that creating drawings is an effective approach to promote student learning. Yet it requires more instructional time and may not be efficient. Critique may be another candidate to effectively support students' learning. In this study we explore this two ways.

This study reports student learning with a dynamic visualization embedded in an inquiry-based WISE curriculum unit entitled *Hydrogen Fuel Cell Cars* (Linn & Hsi, 2000). In the project, students first learned chemical reactions by interacting with the visualization showing molecular interactions during hydrogen combustion. They then drew four pictures to represent intermediate phases of the reaction (drawing condition), or critiqued two sets of pre-made drawings aiming to demonstrate the same information (critique condition). The drawings to be critiqued were designed to capture various ideas held by students from previous studies (Zhang, 2007). At the end of the project, students need to use integrated ideas about atomic reactions, cars, and fuel economy to analyze the advantage and disadvantage of hydrogen fuel cell cars.

High school chemistry students (N=73) participated in this study (critique condition: n=48; drawing condition: n=25). Both groups of students gained significantly [drawing group: $p<.001$, effect size=2.17; critique group: $p<.001$, effect size=1.73] after the project. Students were able to integrate ideas such as bond breaking and formation with prior knowledge and use these ideas to explain observable phenomena and other chemical reactions. There was no significant difference in the two groups of students' posttest scores after controlling for pretest scores [$t(70)=.17$, $p=.87$]. Further analysis of students' embedded assessments and log files of interaction with the visualization suggests that drawing supports learning by enabling students to distinguish among ideas and recognize gaps in their knowledge. Students are prompted to revisit the visualization for nuanced information. Critique, in contrast, requires students to distinguish their own ideas from the ideas they critique. Students also revisit the visualization to solve conflicts between ideas.

References [Selected]

Ainsworth, S. (1999). The functions of multiple representations. *Computers and Education, 33*(2-3), 131-152.

Blumenfeld, P. C., Fishman, B. J., Krajcik, J., & Marx, R. W. (2000). Creating usable innovations in systemic reform: Scaling up technology-embedded project-based science in urban schools. *Educational Psychologist, 35*(3), 149-164.

Buckley, B. (2000). Interactive multimedia and model-based learning in biology. *International Journal of Science Education, 22*(9), 895-935.

Chen, Z., & Klahr, D. (1999). All other things being equal: Children's acquisition of the control of variables strategy. *Child Development, 70 (5),* 1098-1120.

Chiu, J. & Linn, M.C., (in press) The Role of Self-Monitoring in Learning Chemistry with Dynamic Visualization , A. Zohar, & Y. J. Dori (Eds.), Metacognition and Science Education: Trends in Current Research. London: Springer-Verlag.

Clark, D., & Linn, M. C. (2003). Designing for Knowledge Integration: The Impact of Instructional Time. *The Journal of the Learning Sciences*, 12(4), 451-494.

Clark, D., B., & Sampson, V. (2007). Personally-seeded discussions to scaffold online argumentation. *International Journal of Science Education*, 29(3), 253-277.

Gee, J. P. (2007*). Good video games and good learning: Collected essays on video games, learning, and literacy.* New York: Peter Lang.

Gobert, J. (2005). Leveraging technology and cognitive theory on visualization to promote students' science learning and literacy. In *Visualization in Science Education*, J. Gilbert (Ed.), pp. 73-90. Springer-Verlag Publishers, Dordrecht, The Netherlands.

Goldstone, R. & Wilensky, U. (2008). Promoting transfer through complex systems principles. *Journal of the learning sciences*, 17 (4), 465-516.

Jackson, J. (2007). *Simplified Force Concept Inventory*. In preparation.

Johnstone, A. H. (1993). The development of chemistry teaching: A changing response to changing demand. Journal of Chemical Education, 70(9), 701–705.

Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. *Learning and Instruction*, 13 (2), 205-226.

Krajcik, J. (1991). Developing students' understandings of chemical concepts. In S. Glynn, R. Yeany, & B. Britton (Eds.), The psychology of learning science (pp. 117-147). Hillsdale, NJ: Erlbaum.

Krajcik, J. S., & Blumenfeld, P. C. (2006). Project-based learning in . K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences*: 317-333.

Kuhn, D. & Angelev, J. (1976). An experimental study of the development of formal operational thought. *Child Development, 47 (3),* 697-7006.

Lee, O., Eichinger, D. C., Anderson, C. W., Berkheimer, G. D., & Blakeslee, T. D. (1993). Changing middle school students' conceptions of matter and molecules. Journal of Research in Science Teaching, 30, 249-270.

Linn, M. C. (2006). The knowledge integration perspective on learning and instruction. in . K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 243-264). New York, Cambridge Press.

Linn, M.C., Clark, D.B. & Slotta, J.D. (2003). WISE design for knowledge integration. *Science Education*, *87*, 517-538.

Nakhleh, M. B., Samarapungavan, A., & Saglam, Y. (2005). Middle school students' beliefs about matter. Journal of Research in Science Teaching, 42, 581-612.

Osborne, R. (1983). Towards modifying children's ideas about electric current. *Research in Science & Technological Education*, 1(1), 73–82.

Paik, S.-H., Cho, B.-K., & Go, Y.-M. (2007). Korean 4- to 11-Year-Old Student Conceptions of Heat and Temperature. *Journal of Research in Science Teaching*, 44, 284-302.

Pallant, A., & Tinker, R. (2004). Reasoning with atomic-scale molecular dynamic models. *Journal of Science Education and Technology, 13*(1), 51-66.

Penner, D. E., Lehrer, R., & Schauble, L. (1998). From physical models to biomechanics: A design-based modeling approach. *Journal of the Learning Sciences, 7*, 429–450.

Quintana, C. et al. (2004). A Scaffolding Design Framework for Software to Support Science Inquiry. *The Journal of the Learning Sciences, 13*(3), 337-386.

Rohr, M., & Reimann, P. (1998). Reasoning with multiple representations when acquiring the particulate model of matter. In M. W. van Someren, P. Reimann, H. P. A. Boshuizen & T. de Jong (Eds.), *Learning with multiple representations*. Oxford: Elsevier Science Ltd.

Shaffer, P., & McDermott, L. (1992). Research as a guide for curriculum development: An example from introductory electricity. part ii: design of instructional strategies. *American Journal of Physics*, 60(11), 1003–1013.

Shen, J. & Confrey, J. (2007). From conceptual change to transformative modeling: A case study of an elementary teacher in learning astronomy. *Science Education*, 91 (6), 948-966.

Shepardson, D. P., & Moje, E. B. (1994). The nature of fourth graders understandings of electric circuits. *Science Education*, 78(5), 489–514.

Thacker, B., Ganiel, U., & Boys, D. (1999). Macroscopic phenomena and microscopic processes: Student understanding of transients in direct current electric circuits. American Journal of Physics, 67(7), 525–531.

Tversky, B., Morrison, J. B., & Betrancourt, M. (2002). Animation: Can it facilitate? *International Journal of Human-Computer Studies*, 57, 247-262.

White, B.Y. (1993). ThinkerTools: Causal Models, Conceptual Change, and Science Education. *Cognition and Instruction, 10*(1), 1-100.

Zhang, Z. & Linn, M. (2008). Using drawings to support learning from dynamic visualizations. International Perspectives in the Learning Sciences: Creating a Learning World. *Proceedings of the 8th International Conference on the Learning Sciences*, vol. 3, 161-162.

Zimmerman, C. (2000). The development of scientific reasoning skills. *Developmental Review, 20,* 99-149.

Wieman, C., Adams, W.K., & Perkins, K.K. (2008). PhET: Simulations that enhance learning. *Science*, 322, 682-683.

The Educative and Scalable Functions of Authoring Tools to Support Inquiry-based Science Learning

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Abstract: Specialized authoring tools enable non-programmers to develop computer-based learning environments that reflect a particular task model. Large-scale implementation of novel but pedagogically sound environments is made possible if the resulting environments reflect the intended essential pedagogical features. We explore the balance between constraints and generativity through five teams' experiences with a specialized authoring tool, STOCHASMOS. We hope to spark a critical discussion of the role of specialized authoring tools in scalability. We also suggest that future research examine the educative function of these tools.

Symposium Goals and Overall Focus

There is general consensus over the need to orchestrate learning in the disciplines around rich experiences where students engage in first-hand activities relevant to future application contexts (Edelson, 2001). Yet, such learning environments, often supported through technology, typically require innovative materials that draw on a wealth of intellectual and tangible resources. Thus, transferability and scalability are inseparable from pedagogical considerations and goals. We aim to advance our understanding of issues of scale-up by examining the role of specialized authoring tools (Bell, 1998) in this process.

Specialized authoring tools pose one type of strategy for scaling-up science education reform efforts, by making it easier to produce a wide-range of inquiry-based learning environments that capture the essential features of environments that were developed, studied and found productive within a research context. However, this potential can only be realized if the use of such authoring tools results in the development of new environments that reflect such essential features. This is especially true when these features relate to discipline-specific needs, such as combining molecular diagrams and equations in chemistry, or explicitly supporting the integration of evidence in scientific argumentation. Yet, it is just as important that these tools provide enough flexibility to allow for the creation of new problems, so that a range of curricular topics, learning goals, and learning contexts can be served by these new learning environments, rather than serve the narrow production of isomorphic problems. Thus, there is a tension between the two criteria for effective scale-up: rigidity in the authoring tool that preserves essential features and malleability in the authoring tool that allows for generativity and variation.

We will present case studies from five teacher-researcher teams each working with the same authoring tool, STOCHASMOS (in Greek: reflection), to design different problem scenarios aimed at engaging students in evidence-based reasoning around socio-scientific issues. These teams, each from a different partner country, are part of a broader project called Digital Support for Inquiry, Collaboration, and Reflection on Socio-Scientific Debates (CoReflect, http://www.coreflect.org) funded by the European Commission's Seventh Research Framework Programme (FP7). Each case study explores key affordances and constraints surrounding their use of STOCHASMOS, how this exposes the tension between rigidity and malleability, and what implications there might be for the roles that specialized authoring tools may play in scalability. Mainly we have found that such tools can serve as boundary objects (Star & Griesemer, 1989) and as educative materials (Davis & Krajcik, 2005) that convey pedagogical and technological knowledge. We aim to engage the audience in a critical discussion of these roles and their implications, as we describe in the symposium structure section. Our broader goals are to initiate a conversation in the community on the ways in which authoring tools can foster collaboration and professional development beyond their utility in technical efficiency.

Rationale and Background

The past few decades have been marked with the creation of computer-based learning environments that are intended to help young science learners contend with rich problems. As a field, we have accrued considerable knowledge about the types of representations and modes of interaction that can be incorporated in these learning environments to productively support collaborative scientific inquiry (e.g., Edelson, 2001; Kali, 2006). However, developing such learning environments is very resource intensive. This is especially true, because they often include unique representations, simulations, and interface structures that scaffold novice reasoning. Recent research has examined not only how to develop particular learning environments geared toward overcoming particular learning challenges or toward meeting particular learning goals, but also how to reduce the time and cost involved in developing such learning environments. These initiatives aim to capitalize on existing knowledge and encourage its reuse (Roschelle, Kaput, Stroup, & Kahn, 1998).

Efforts in this direction include, but are not limited to, research on open source (e.g., Scharff, 2002), learning objects (e.g., Graaff, Laat, & Scheltinga, 2004), and authoring tools (e.g., Murray, 1999). Of these three, authoring tools impose the least demands on end-users in terms of requisite programming knowledge, which makes them quite apt for providing non-programmers access to the development of computer-based learning environments. The realm of authoring tools includes a wide spectrum. At one end of the spectrum are general-purpose tools (e.g., Adobe Authorware or Moodle) that only alleviate the need to program, but that do not provide any guidance about the structure of appearance of profitable learning environments for particular disciplines of study. Another genre of authoring tools, midway through the spectrum, are authoring tools that reflect a particular pedagogical approach and/or group of target tasks, so that they provide pedagogical guidance. Thus, end-users can only create a particular class of environments, but this class of environments is open to multiple problem definitions and allows for some flexibility in the design of the flow of interaction. Finally, at the other end of the spectrum are authoring tools that present a fixed structure so that the nature of the activity is preset and development consists only of inserting new content.

In this symposium, we focus on authoring tools of the mid-range genre, which we refer to as specialized authoring tools. As we have noted, the efficacy of specialized authoring tools hinges on the tension between rigidity that preserves essential features and malleability that allows for generativity and variation. We examine how different teams used the same specialized authoring tool to develop different problem-based scenarios in an effort to gauge the extent to which it was possible to develop problems that differ from a prototype in more than just surface features, while not posing too great a departure from a prototype so as to lose its essential pedagogical features.

STOCHASMOS and its Use in the CoReflect Project

The STOCHASMOS Specialized Authoring Tool

The CoReflect project uses a specialized authoring tool called STOCHASMOS (Kyza & Constantinou, 2007) to develop a set of computer-based learning environments that support learners in investigating socio-scientific problems. STOCHASMOS lets teachers or designers build a multi-modal web-based environment that can support learners in coordinating theory and evidence (e.g. analyze data as they relate to hypotheses), in constructing evidence-based explanations and arguments, and in planning, monitoring and evaluating these actions.

Overview of Underlying Pedagogy

STOCHASMOS was designed to develop learning environments that support reflective inquiry. We define reflective inquiry as a set of practices that help the inquirer adopt a critical orientation, such as planning, monitoring and evaluating one's inquiry-related actions (Loh et al., 1998). Based on prior research (Kyza & Edelson, 2005), a key part of supporting this process lies in supporting students in developing and sustaining common ground, and in making sense of data rich environments. STOCHASMOS was designed to help designers implement learning environments that include specific supports for these processes. The tool provides structured workspaces that reflect some of the epistemic games (Collins & Ferguson, 1993) associated with scientific inquiry. These workspaces can be shared between users and are integrated with communication devices such as forums and chats. This is one of the ways that STOCHASMOS makes thinking visible and shared, thus supporting the construction of common ground. The approach to supporting sense-making includes a combination of context-dependent prompts that can compensate for limited background knowledge, and context-independent prompts that can encourage adoption of general data interpretation and management practices.

Underlying Pedagogy as Realized in the STOCHASMOS Authoring Tool

The functions and design features of STOCHASMOS are accessed through tabs (see Figure 1): Project, Templates, Inquiry Environment, Add Group, Review, Group Pairing, Partnership, and Forum. Designers access different functions and design features as the names of the tabs imply. The "Inquiry Environment" tab allows designers to add content to the basic environment the students will use. The "Templates" tab enables the design of template pages that are later accessible to students through the WorkSpace area. These templates can help structure student work around important ideas, such as connecting data to hypotheses. The WorkSpace also provides guidance in the form of prompts and articulation boxes, which are also customizable at the level of access of the individual teacher. The "Add Group", "Group Pairing", and "Partnership" tabs enable teachers to setup collaboration patterns and rules. The "Review" tab allows teachers synchronous and asynchronous access to their students' ongoing inquiry work on STOCHASMOS. Other authoring features, such as a generic graph tool, the customizable glossary, and the history log are accessible from a side menu. Teachers also have the ability to control the timing, presentation, and deactivation of pages in the inquiry environment and the WorkSpace templates, and are thus able to control what their class will have access to, according to their progress.

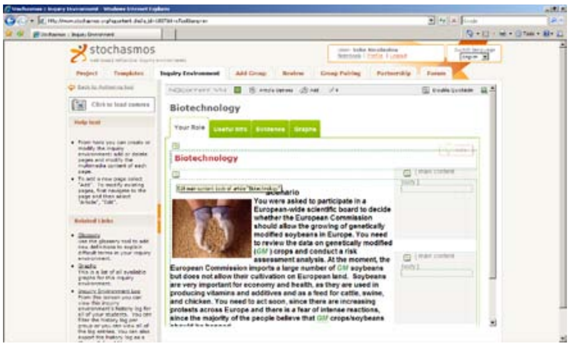

Figure 1. The STOCHASMOS Authoring Tool.

Teachers who choose to create or import an existing inquiry environment have the ability to import WorkSpace templates or create their own templates to accompany the students' investigation. The activation of other features can support the design of a more flexible and customized environment, within the STOCHASMOS framework, to address teaching and learning needs. For example, the teacher has the ability to use the inquiry environment or the WorkSpace environment of the STOCHASMOS platform separately, or use both of them by default. This possibility allows flexibility in the case that a teacher wants to use the WorkSpace area with other web pages that already exist in cyberspace, or even a desktop-based software application. In this case, the image capture tool remains available to enable the user to transfer screen shots of their work from any other application on their computer (e.g. from a database or spreadsheet program). Another customizable feature is the glossary: teachers can add glossary definitions according to the age group and cognitive needs of their students; these definitions are not global and will only appear in the specific inquiry project. The project management features of STOCHASMOS allow teachers asynchronous access to their students' work. This means that a teacher can review a group's work and add comments to their WorkSpace pages, thus providing feedback the students can view and use at the beginning of their next investigation session. Furthermore, the history log of the tool can give teachers information on which inquiry environment pages the students have visited and the time between accessing each of the web-pages stored in the STOCHASMOS system.

The CoReflect Project Structure and Teacher-Researcher Working Groups

The overall goal of the CoReflect project is to advance scientific literacy among youth in Europe by cultivating evidence-based reasoning skills around socio-scientific issues. There are seven partners from different institutions who focus on the development, enactment and study of learning environments that support these overall goals. These partners represent six different European and associate state countries. An eighth partner focuses primarily on dissemination goals of the project. The seven partners who are involved in the design and development aspects lead teacher-researcher teams that are referred to as Local Working Groups (LWG). Each LWG is charged with developing and enacting a problem scenario concerning a socio-scientific issue using the STOCHASMOS platform.

As part of this development process each LWG, based on its local culture, local school structure, national learning goals, group expertise and interests chose a target domain, issue and grade level for its problem scenario. The project conducted a number of meetings that included workshops that introduced the authoring tool, provided instructions on its use, and included some hands-on practice. In these meetings, partners reached some common ground concerning their approaches to science education, inquiry, collaboration, motivation and additional pertinent themes, but, each partner was free to explore their own fine-grained stance and interpretations of these issues. The resultant learning environments span a range of disciplines, such as physics, chemistry and life sciences, as well as a range of ages from elementary through middle to high school levels, and cover different socio-scientific issues such as genetically modified crops, and exploration of extra-terrestrial life.

How the Collective Presentations Fit Together

In line with the different topics, learning goals, and group composition of the different participating design groups, each LWG underwent different design and team collaboration processes. Each LWG interpreted STOCHASMOS in subtly different ways, and orchestrated work around the tool in different ways. This variability makes comparison possible, while the partners' affiliation with the CoReflect project and its broad aims lends a sense of coherence to this comparison that may not have been possible if we were to examine completely unrelated projects. Of particular importance is the shared aspect of teacher-researcher teams, which are not necessarily the norm in every learning-environment design team, but which turned out to be a key point for identifying contributions of specialized authoring tools that extend beyond their technological streamlining utility. Thus, this unique study context provides an opportunity to explore nuances of use and to consider their analytical implications.

Major Issues Addressed by the Collective Work

Any computer-based learning environment design effort entails a process of translating pedagogical ideals and practices into content structures, process flows, and representations in the software. This in turn leads to an explication of often tacit pedagogical approaches, and when diverse teams are involved, such as teacher-researcher collaborations this can be a setting in which these approaches are an object of negotiation. Each LWG contributing to this symposium considered instances where the inbuilt features of STOCHASMOS have facilitated the bringing forth of important pedagogical issues when the LWG was discussing design decisions. Similarly, they considered instances where conceptualized design directions may have been constrained by the authoring tool, as well as the processes that were involved in resolving these dilemmas and their associated solutions. These instances were distilled to a set of analytical points that carried generalizable significance concerning the broader role of specialized authoring tools. This has led us to consider four main issues:

- The importance of exposure of the design teams to past implementations to the efficacious use of specialized learning environments
- The contribution of specialized authoring tools for prompting and guiding pedagogically-focused design discussions.
- Costs and benefits of the inclusion or exclusion of process-flow support in a specialized authoring tool.
- Costs and benefits of the complementary design of offline activities to augment the computer-based learning environment.

Symposium Structure

The symposium will be conducted as a structured poster session. We will open with a 10-minute introduction to the session and to STOCHASMOS. In the next 40 minutes, the audience will be invited to visit the different poster sites around the room. Each poster will present the dilemma or insight encountered by that group pointing to implications about the educative and scalable functions of STOCHASMOS, the authoring tool. Following this, we will reconvene for a 10-minute commentary from a discussant. The remaining 30 minutes will be devoted to a structured discussion with the audience that will draw on the commentary and on a set of analytical questions. We will present a set of overarching questions that arise from the case examples in the various posters, such as:

- Are there pedagogical aspects (such as task flow) that are best left under-determined in specialized authoring tools? Would this maximize tailoring to local contexts?
- Do specialized authoring tools require an accompaniment of prior implementation case-examples in order to produce learning environments that are consistent with the intended vision?
- Should future research examine how authoring tools can suggest the nature of "off-line" activities and supports that can complement and maximize the potential of the computer-based learning environments?

These questions as well as questions gleaned real-time from the discussant's commentary will initiate and guide the closing discussion with the audience.

The session will be chaired by Iris Tabak. Our discussant will be Elizabeth A. Davis.

Potential Significance of the Contributions

This session can help reconceptualize the ways in which specialized authoring tools are conceived of in the learning sciences as conveyors of knowledge with functions beyond those of technical efficiency. In particular, it illustrates various functions that such tools perform in facilitating collaborative design processes in mixed-expertise groups. This reconceptualization can inform the use of specialized authoring tool as well as their future design. In addition, it can initiate a line of research that examines the educative (Davis & Krajcik, 2005) role that specialized authoring tools can play, and how this might affect scalability in terms of broad development and adoption of computer-based learning environments.

Brief descriptions of each of the poster presentations included in the symposium appear in the concluding section below.

A Specialized Authoring Tool in Use: Cases and Lessons Learned

The following set of individual posters present examples of design tensions, dilemmas, insights and serendipitous design plans associated with our use of STOCHASMOS. We aim to synthesize and extrapolate from these cases in order to inform the design of specialized authoring tools, and to better understand the communicative and educative functions of these tools.

Knowledge of prior implementations leverages authoring tool efficacy: The case of the Cyprus University of Technology team (CUT)

The case of Cyprus University of Technology, like most of the cases included in this session, combines issues related to a participatory design process with issues related to the use of a specialized authoring tool. The co-evolution of these processes gave rise to the educative role that such authoring tools might play. Members of the Cyprus University of Technology team were previously involved in the development of the prototype learning environment upon which STOCHASMOS is based. Thus, some of the members of this team entered the new design tasks of the CoReflect project with a rich understanding of the features, structures, and tools encapsulated in STOCHASMOS and the roles that they play in particular problem scenarios. However, this knowledge was not shared by all participants.

This discrepancy surfaced early in the design process when it became evident that considering scientific data with the purpose of creating a base of evidence to service the first-hand investigations of learners in an inquiry-oriented computer-based learning environment differed from the perspective of answering a scientific question or creating typical activities for science lesson. Thus, it became evident to the group leader that the LWG needed to reach some common ground before the design efforts could continue productively. Based on the group leader's general experience in developing computer-based learning environments, and her intimate experience with STOCHASMOS, she introduced written, top-down design guidelines tailored to the affordances of STOCHASMOS. The guidelines were augmented by several presentations of the tool's capabilities and the evolving team design. Gradually, the team came to frame the design alternatives in terms of the best way to take advantage of the tool's functions. This seems to have resulted in strong coherence between the teams' envisioned conceptions of inquiry and pedagogical supports and their implementation using STOCHASMOS. This is exhibited in part by their use of templates to support collaboration, critique and reflection.

The participatory design process was evident in the two-way interaction between teachers and researchers, which in the end took advantage of the expertise and diversity of the LWG members. For instance, the design of the accompanying activity sequence was highly influenced by the epistemology of the enacting teacher: the teacher sought to integrate hands-on experiments with the work conducted on STOCHASMOS to enable students' deep comprehension of prerequisite biological concepts she felt could not be delivered through STOCHASMOS alone. At the same time this collaborative process and the enactment of the designed environment with students allowed the participating teacher to grasp the ideas behind the integration of learning technologies in her teaching and helped her confront newly-realized anxieties over the loss of control of students' actions.

Team: Kyza, E. A., Nicolaidou, I., Terzian, F., Hadjichambis, A., Kafouris, D.

Using STOCHASMOS to scaffold students in discussing key issues while retaining ownership of their learning processes: The case of the Kristianstad team (HKr)

The Kristianstad team had a strong investment in supporting collaborative processes in scientific inquiry using a kind of Fostering Communities of Learners (FCL) approach. Their domain of focus was astrobiology, a content area that entices questions in students in relation to their worldview (Cobern, 1996). The emphasis on fostering a community of learners, and the recognition that worldviews may be quite variable and salient in this context, prompted this team to elicit explicit discussion of presuppositions of science at the onset of the learners' experiences. This suggested particular curricular sequences. STOCHASMOS does not provide direct or explicit support for process-flow. In the case of HKr this proved to be an asset, as they were able to easily maintain their pre-existing commitment to FCL.

Nonetheless, working with the authoring tool enabled them from the start to have an initial image of what the learning environment would look like in practice and what features it might have. Consequently, they decided to employ particular software features to augment and enhance their conceptions of collaborative and inquiry-flow processes. These included three main features: (1) Organizing students in functional triads taking a pre-test of worldviews into consideration, but keeping group functionality foremost (2) Having the teacher use the notes tool to comment on group work between work sessions. A form of teacher-student interaction which the participating teacher had noted was welcomed but novel to her. (3) Using the chat tool and sharing of workplace pages to try to sustain continuous group work and collaboration.

Team: Redfors, A., Rosberg, M., Hansson, L., Lundh, I.

Specialized authoring tool as boundary object: The case of the Ben Gurion team (BGU)

The Ben Gurion University (BGU) team consists of some individuals who have prior experience in developing computer-based learning environments and some who do not. Developing educational software requires one to think of pedagogical moves and instructional supports in terms of software features and interface objects. In creating software "from scratch," this requires one to imagine and envision what these features and consequent user interactions might look like once a prototype is created Such visualization may be difficult or impossible without prior experience. Specialized authoring tools display the main features and software interactions (devoid of content) of the intended learning environment, and provide a concrete object around which pedagogical discussions can occur. This alleviates some of the need to engage in visualization and mental translation of pedagogical moves to software interactions. Some of the team's design discussions used the language of the STOCHASMOS tools and interface features to discuss the problem structure, student activities and supports (e.g., the "role tab", or "the template"). Thus, the translation from pedagogy to interface preceded and guided the design considerations and discussion.

This figured most prominently in considering how to deal with anticipated student difficulties. The team's interpretation of STOCHASMOS and its features was that assistance could be supported mainly through the features of the "template" and the "hints." Often the team would envision ambitious analysis on the part of the student, followed by a wave of strong concern over students' ability to contend with these tasks in light of their current background knowledge and skills This, in turn, was followed by consideration of what forms of scaffolding and guidance could bridge these gaps. Our considerations were framed in terms of "hints" and "templates." When the team did not frame their suggestions in terms of a hint or a template, one of the team members, usually the main hands-on developer of the learning environment, would respond with a question of how the suggestion could be implemented as a hint or template. So, the features of STOCHASMOS acted as a translational device translating pedagogy into interaction with computational media. In this way, STOCHASMOS, facilitated the design process, and served as a boundary object bridging between team members who had prior experience in software development and those who did not. One of the broader implications or questions for the field lies in determining the relative costs and benefits between facilitating the translation process from pedagogy to software interaction and constraining the space of software-realized scaffolding to the authoring tools' existing features.

Team: Tabak, I., Asher, I., Nasser, S., Gnaim, L., Fried, M., Katz, I., Weinstock, M.

Design foreclosure and the proliferation of offline activities

The case of the Leibniz Universität Hannover team (LUH)

In the case of Leibniz Universität Hannover (LUH), issues pertaining to the use of the specialized authoring tool were conflated with issues concerning the participatory design approach adopted in the CoReflect project. The participatory design approach asks to merge different kinds of experiences offered by teachers and researchers. Stringently adhering to the tenets of this approach calls for negotiating and reconciling the different viewpoints. The researchers seemed to provide presuppositions based mainly on published educational research and theory, whereas teachers seemed to draw on classroom experiences and their emergent intuitive theories, as well as their conceptions of best practices that also seemed to be anchored in their prior experiences. The design requirements of using STOCHASMOS made these tacit distinctions surface, because a direct importation of prior best practices into the learning environment was not possible. This instigated an explicit discussion of what activities are desirable and why.

The STOCHASMOS learning environment seemed to project to the participating teachers an image of instruction as based on texts and data sheets inside a computer. This was in contrast to the teachers' strong commitment to hands-on experimentation (wet labs, i.e. laboratory experimentation using chemicals, or biological matter, etc.). This commitment stems from both disciplinary and instructional considerations. Chemistry is an experimental science and there is a longstanding tradition to focus chemical education on hands-on experiments rather than "chalkboard chemistry." From an instructional perspective, the teachers believed that the hands-on experiments provided insights that could not be derived from declarative data sources, and that they would need to engage in experimentation in order to deal well with core concepts. In addition, they believed that the students would explicitly ask for these hands-on activities. Simulations, videos and pictures seemed to be regarded as competing with wet-labs on classroom time, and as offering an instructionally inferior alternative. Therefore, the participatory design team's decision was to provide students with both learning opportunities: hands-on experiments, as well as pictures and descriptions of these experiments inside the STOCHASMOS-based learning environment.

Findings from a pilot study revealed mixed results. Students made little use of the hands-on opportunities, reporting that the STOCHASMOS pages were sufficient for understanding the basal concepts. However, the analysis of the students' learning products revealed a lack of integration of these concepts. The team is currently working on this issue, discussing additional within-STOCHASMOS and out-of-STOCHASMOS activities to foster the integration of scientific concepts mediated by the experiments to be tested in Spring 2010.

Team: Schanze, S., Saballus, U., Neumann, A., Manske, M., Sieve, B., Söhlke, M., Janßen, O.

The case of the University of Thessaly team (UTH)

The University of Thessaly team was dedicated to fostering conceptual change and a scientific approach to the ways in which students explain physical phenomena, focusing on the topic of evaporation and condensation of water. These goals coincided with strong prior commitments to activities that are not explicitly supported in STOCHASMOS. They also had expectations about how students might engage in inquiry. As a result, there were instances where they had a hard time mapping their envisioned curriculum to the authoring tool implementation. For example, they were concerned that STOCHASMOS afforded more degrees of freedom and autonomy than their students were equipped to handle. Consequently, they devised a framework for teacher moves in which the teacher manages the flow of the investigation based on awareness of students' misconceptions, and on the quality of student argumentation. Generally, in CoReflect we adopt a distributed scaffolding stance that posits that support cannot be achieved through a single means, and that offline activities and supports are an essential part of the overall learning environment. Thus, designing offline activities does not in and of itself subvert the essence of intended designs underlying STOCHASMOS. However, one question to contend with is whether there is a point at which a proliferation of offline activities obviates rather than augments the technological supports.

Team: Kollias, V., Matos, A., Davaris, A., Karnavas, A., Daropoulos, A., Zaganas, K., Christodoulopoulos, V., Tsaknia, Th.

References

Bell, B. (1998). Investigate and decide learning environments: Specializing task models for authoring tool design. Journal of the Learning Sciences, 7(1), 65-105.

Cobern, W. W. (1996). Worldview theory and conceptual change in science education. *Science Education, 80*(5), 579-610.

Collins, A. M., & Ferguson, W. (1993). Epistemic forms and epistemic games: Structures and strategies to guide inquiry. *Educational Psychologist, 28*, 25-42.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3-14.

Edelson, D. (2001). Learning-for-Use: A Framework for the Design of Technology-Supported Inquiry Activities. Journal of Research in Science Teaching, 38(3), 355-385.

Graaff, R. d., Laat, M. d., & Scheltinga, H. (2004). CSCL-ware in practice: Goals, tasks, and constraints. In J.-W. Strijbos, P. A. Kirschner, R. Martens & R. L. Martens (Eds.), *What We Know about CSCL and Implementing it in Higher Education* (pp. 201-220). Dordrecht: Kluwer Academic Publishers.

Kali, Y. (2006). Collaborative knowledge building using the Design Principles Database International Journal of Computer-Supported Collaborative Learning, 1(2), 187-201.

Kyza, E. A., & Constantinou, C. P. (2007). STOCHASMOS: A web-based platform for reflective, inquiry-based teaching and learning: Cyprus: Learning in Science Group.

Kyza, E., & Edelson, D. C. (2005). Kyza, E., & Edelson, D. C. (2005). Scaffolding middle-school students' coordination of theory and evidence. Educational Research and Evaluation, 11 (6). *Educational Research and Evaluation, 11*(6), 545-560.

Loh, B., Radinsky, J., Russell, E., Gomez, L. M., Reiser, B. J., & Edelson, D. C. (1998). The Progress Portfolio: Designing reflective tools for a classroom context. In *Proceedings of CHI 98* (pp. 627-634). Reading, MA: Addison-Wesley.

Murray, T. (1999). Authoring Intelligent Tutoring Systems: An Analysis of the State of the Art. International Journal of Artificial Intelligence in Education, 10, 98-129.

Roschelle, J., Kaput, J., Stroup, W., & Kahn, T. M. (1998). Scaleable Integration of Educational Software: Exploring The Promise of Component Architectures. *Journal of Interactive Media in Education, 98*(6).

Scharff, E. (2002). Applying Open Source Principles to Collaborative Learning Environments. In G. Stahl (Ed.), *Computer Support for Collaborative Learning: Foundations for a CSCL Community* (pp. 499-500). Hillsdale, NJ: Lawrence Erlbaum.

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, 'translations,' and boundary objects: Amateurs and professionals in Berkeley's museum of vertbrate zoology, 1907-39. *Social Studies of Science, 19*(3), 387-420.

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For more information about the CoReflect project please visit http://www.coreflect.org

Terra Nova Toward Terra Firma: Data On Games For Science Learning

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Abstract. Much enthusiasm but less data has often accompanied games for science learning. This session brings together several researchers who investigate the potential of games for science learning and invites audience members to consider the evidence, raise their own questions and concerns, and form their own conclusions regarding several current projects. This interactive symposium will combine a structured poster session with a discussion session led by Yasmin Kafai. In particular, the session explores three questions. Does the data support the claims that the games can effectively support valuable science learning? What types of skills, concepts, and processes do the games and virtual worlds most effectively teach? What other data could and should be collected to support more definitive claims?

Session Overview

According to the National Research Council (2005) and international comparison studies (e.g., TIMSS), science is often taught at a superficial level of definitions. Digital games and virtual worlds offer a potential medium to allow students richer access to deeper authentic understandings of science. This session brings together researchers who investigate the potential of games for science learning and invites respondents and audience members to use the evidence to form their own conclusions. The goals of this symposium will be to shed light on the following issues in terms of several current projects:

- Do data support the claim that games can effectively support valuable science learning?
- What types of skills, concepts, and processes can video games and virtual worlds most effectively teach and what types prove more challenging?
- What other data could and should be collected to support more definitive claims?

The format of this interactive symposium will be in three parts. First, each of our poster teams will briefly introduce the major aspects of their projects to the audience. This will be followed by an open time for attendees to explore each of the posters and interact with the presenters, focusing on discussing the major issues and evidence in their projects. This open time will be structured to move attendees in a semi-organized manner through a set of mini-sessions at the posters of their choosing. The final section of the symposium will be devoted to discussion led by Yasmin Kafai and a lively interaction between presenters and attendees focusing on issues of data collection and analysis in research on games for science learning.

The Role of Embodiment and Symbolization in Supporting Physics Learning with Games and Virtual Worlds for Young Children

Noel Enyedy, UCLA, Joshua Danish, Indiana University

Research Goals and Theoretical Framework. Newtonian mechanics is not typically taught to first and second grade students. In fact, these concepts are even difficult to teach to high school students (White, 1993). However, the Semiotic Pivots and Activity Spaces for Elementary Science Project (SPASES) overcame this barrier using technology to transition students from embodied games to scientific modeling. This transition was supported by the use of embodiment as a tool for representing students' ideas (Danish, 2009), and then helping students refine their ideas by progressively symbolizing them and then refining those symbols (Enyedy, 2005).

Game Context and Methods. SPASES was a 15 week, 2 days a week, force and motion unit piloted with children aged 6-9 (n=49). The curriculum leveraged embodiment and symbolization by using motion tracking technology to follow students as they physically enacted their ideas, and then feeding this information into computer simulation tools. Video case studies will be used to demonstrate the process through which the SPASES tools supported learning gains which will be presented using quantitative analyses of a pre- and post-test based on the FCI.

Data Results and Significance. First, we present analyses of the pre- and post-test gains which demonstrate significant improvement on the questions related to forces in 2-dimensions. For example, the proportion of students who accurately predicted the path of a puck that was moving and then struck by a force in a direction perpendicular to it's current motion increased from 0.10 to 0.69. The difference in proportions is significant,($\chi 2$ =24.61(1, N = 39), p<0.0001. We then present analysis of two game activities that supported students in making this shfit from common misconceptions about force to more normative scientific conceptions. In the first game, students used their physical orientation combined with a simple worksheet to refine their understanding of vector arithmetic in 1-dimension. In the second game, students modified their symbols and then used them in a computer simulation to refine and demonstrate their understanding of 2-dimensional motion. The results will demonstrate the role of embodiment and symbolization in supporting young children in engaging with complex science concepts.

Model Based Reasoning & Use in Massively Multiplayer Online Games

Constance Steinkuehler, UW-Madison

Research Goals and Theoretical Framework. (Massively) multiplayer online games (MMOs) have recently emerged as a technology with potential for science education. As simulations of complex systems, they allow participants to digitally inhabit a virtual world and engage in join activity with others. Innovative projects such as Quest Atlantis (Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007) and River City (Ketelhut, Dede, Clarke, Nelson, & Bowman, 2007) offer proof of the concept that such technologies can foster powerful forms of science learning in formal instructional environments. What is even more surprising, however, is that commercial games with no intention to teach may have potential. In a cognitive ethnography of the MMO Lineage, Steinkuehler (2005) observed teens who decided to test every combination of resources available against a given problem, tabulated the results in Excel , created simple mathematical equations to explain them, and then argued with one another about whose model was most accurate. Subsequent studies found that such practices were more prevalent than first suspected: Across a random sample of MMO forum discussions posts, Steinkuehler and Duncan (2009) found that 86% of the discussions were social knowledge construction with 58% focused on complex systems, 11% providing models to explain those systems, and 28% providing evidence to support their claims. The goal of this study was to further this line of research by examining not the finished models that gamers posted to discussion forums but rather the processes and resources they used in order to construct and justify them.

Game Context and Methods. This study was conducted in the context of an after school lab using the online game World of Warcraft to engage adolescent “at risk” males (n=25) in literacy practices. Participants were asked to construct and justify their best model (a “build”) for how the in-game “priest” class could be specialized using the in-game “talent” system (Figure 1). Each was given a laptop to access any online game-related resource materials they chose and instructed to “think aloud” to reveal their problem-solving process. Researchers asked probing questions (“why did you do that?”) during any lapses of thinking aloud and videotaped participants’ activities (including computer use), took fieldnotes, and collected resulting artifacts. Participants also completed a simple pretest and posttest to measure reported prior experience (pretest), interest (pretest/posttest) and beliefs of success (posttest).

Data Results and Significance. Participants used a complex set of multimodal expository and procedural texts as the basis for their problem-solving and solution justification. In order to find the best-fit solution to then given problem of multiple constraints, they made heavy use of both commercially provided and user-generated online modeling tools that enable the individual to review the functional outcomes of various choices among resource allocations before committing to any one “build.” Curiously, the main tools they chose to complete the problem were user-generated and multimodally complex, with concepts articulated not only through “technical verbal language but also mathematical, graphical, diagrammatic, pictorial, and a host of other modalities of representation” that, ironically, typically make reading comprehension in more traditional domains particularly challenging (Lemke, 1998, p.247).

Current Evidence of Engagement, Understanding, and Achievement in the *Taiga* Curriculum in Quest Atlantis.

Daniel T. Hickey, Eun Ju Kwon, & Michael K. Filsecker, Indiana University

Research Goals and Theoretical Framework. Prior annual design research cycles of a 13-hour ecological science curriculum refined the way students drafted and revised in-game assignments, and the way the game and the teacher provided formative feedback. Substantial incremental improvements in scientific discourse, conceptual understanding, and science achievement were obtained (Barab et al., 2007; Hickey, et al., 2009). In this most recent cycle, new insights about participatory assessment (Hickey & Anderson, 2007; Hickey et al., in press) led to new reflective prompts for the assignments, and a 30-screen formative feedback routine was reformulated as FAQs. These and other refinements were coordinated using new insights about consequential and critical engagement (Gresalfi et al., 2009).

Game Context and Methods. The Taiga virtual park is a world in the *Quest Atlantis* MUVE. Students play the role of field investigator, interacting with non-player characters, each other, and their teacher. Players draft and submit “quests” to the ranger/teacher while investigating declining fish populations. The same sixth grade teacher who had implemented Taiga in three previous cycles implemented it in all four of his classes. Impact was examined primarily by analyzing the discourse in submitting and refining quests, and secondarily using an open-ended performance assessment and a random sample of achievement items aligned to targeted standards.

Data Results and Significance. Analysis of initial and final quest submissions, feedback exchanges with the teacher, and log files of FAQ access showed impact of these refinements, and students enlisted more domain formalisms in their quests and did so more accurately. These and other refinements resulted in even larger gains on the performance assessment from the previous year (from 1.4 to 1.6, SD). While still statistically significant, the average achievement gain of 0.5 SD was smaller than the 1.0 SD gain the previous year; this was partly due to one anomalous class whose achievement scores actually declined. We concluded that (1) the new features were promising and worthy of further refinement, (2) the notions of consequential and critical engagement were helpful for coordinating such refinements and for game-based assessment more broadly, and (3) the performance assessment should be refined to more explicitly afford such engagement.

SURGE: Intended and Unintended Science Learning in Games

Douglas B. Clark, Mario Martinez-Garza, Vanderbilt University,
Brian C. Nelson, Cynthia M. D'Angelo, Kent Slack, Arizona State University

Research Goals and Theoretical Framework. This poster considers data from two studies and highlights the potential for both intended and unintended student learning in games. School science, with its focus on explicit formalized knowledge structures, seldom connects to or builds upon students' tacit intuitive understandings. Well-designed commercial video games, however, are exceptionally successful at helping learners build accurate intuitive understandings of the concepts and processes embedded in the games due to the situated and enacted nature of good game play. Most commercial games fall short as platforms for learning, however, because they do not help students articulate and connect their evolving intuitive understandings to more explicit formalized structures that would support transfer of knowledge to other contexts. In *Thought and Language*, Vygotsky (1986) discusses the potential for leveraging intuitive understandings from everyday experience ("spontaneous concepts") with instructed scientific concepts to build robust understandings. The question remains whether or not the intuitive spontaneous concepts developed in games can be successfully leveraged into robust instructed concepts in the format and terminology of academic assessment and across domains recognized as central by the scientific disciplines themselves.

Game Context and Methods. SURGE (Scaffolding Understanding by Redesigning Games for Education) focuses on design principles for connecting students' intuitive "spontaneous concepts" about kinematics and Newtonian mechanics into formalized "instructed concepts." SURGE integrates research on conceptual change, cognitive processing-based design, and socio-cognitive scripting with design principles and mechanics of popular commercial video games such as Mario Galaxy, Switchball, Orbz, and Portal. Students' intuitive "spontaneous concepts" are measured in SURGE through their performance in actual game levels. Their understanding of formal "instructed concepts" is measured using items from the simplified Force Concept Inventory developed by physicist Hestenes and colleagues (e.g., Hestenes, Wells, & Swackhamer, 1992).

Data, Results, and Significance. Our first study analyzed 24 undergraduate and graduate students playing SURGE. The data strongly reinforce the potential of games to help students learn, but also underscore their potential to reinforce alternative conceptions as well as normative conceptions. The game actually resulted in a significant decrease ($\chi 2 = 4.75$, $p = .029$) in students who answered one question correctly by unintentionally focusing students' attention on another physics relationship (we had not yet added all of the intended functionality to the interface relevant to projectile motion and the independence of the x and y components of an object's velocity), but the students demonstrated significant ($p = .037$) gains on the concepts posttest when that question was excluded. The game therefore showed itself to be effective in changing how students thought about questions from the Force Concept Inventory, but care must be taken to ensure that the ideas that students take away from the game are the ones intended by the designers.

Learning Argumentation through a Role-playing Game-based Curriculum

Mingfong Jan & Kurt Squire, University of Wisconsin

Research Goals. Argumentation plays a key social and intellectual role in the construction of knowledge, but how we may socialize students into the practice of argumentation in schools is less explored. To address this issue, this design-based research (Barab & Squire, 2004; Brown, 1992) project investigates three middle school students' experience and their argumentative discourse in a 10-day game-based learning curriculum designed for argumentation.

Theoretical Framework. To teach argumentation, I propose a situated argumentation design framework that foregrounds four aspect of argumentation design: epistemological, cognitive, social, and material. This design framework guides the conceptualization of game-based learning approaches, mainly role-playing simulation, open-ended challenges, authentic resources and tools, in creating a designed experience (Squire, 2006) for dialogic and collaborative arguments.

Game Context and Methods. We designed Saving Lake Wingra, a 10-day game-based learning curriculum for argumentation based on the situated argumentation design framework. The curriculum aims at restructuring classroom discourse for argumentation through three phases. The first phase (days 1- 4) aims at reconditioning classroom discourse patterns from a usually teacher-centered and turn-taking pattern to a student-centered, dialogic, and collaborative format. The second phase (days 5-8) engages students in extended practices of dialogic and collaborative arguments as teams of three professionals. In the last phase (days 9-10), students present arguments collaboratively and individually to argue for the best interest of Lake Wingra.

Data Results and Significance. The results indicate that all three middle school students participating in this study were socially and intellectually engaged in practicing and developing arguments about the future of Lake Wingra. Some constructed claims with supporting evidence and even countered claims proposed by peers, though the degree to which each participant was able to argue differed. Role-playing and open-ended knowledge representation empowered students to express personal opinions supported by evidence. The findings suggest that (1) conceptual understanding plays a key role in constructing evidence-based claims and (2) the situated argumentation design framework can be improved by foregrounding the importance of conceptual understanding in constructing arguments.

Virtual Environment-based Assessments of Science Content and Inquiry: The SAVE Science Project

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Research Goals and Theoretical Framework. The SAVE Science project is focused on creating, implementing, and evaluating assessment modules designed to capture evolving patterns of scientific understanding among middle-school students based on data collected from their interactions in a virtual environment. In this presentation, we report on findings from implementations of our first assessment module. In particular, we focus on how the module can reveal misconceptions held by students about scientific phenomena, and describe student perceptions of virtual environment-based activities designed primarily as assessments rather than as learning environments.

Game Context and Methods. In SAVE Science, students try to uncover likely contributors to a host of problems facing a virtual world. To accomplish this, students must apply knowledge and skills studied in their classroom-based science curricula through multiple assessment quests over the course of a school year. We are looking to see if learning outcomes on district and state assessments by learners in SAVE Science differ from those in control classes not participating in the project. The module in the current study assessing understanding of adaptations and structure/function asks students to investigate possible causes for poor survivability among a flock of sheep recently moved to the farm from a far-distant (and environmentally distinct) location. In completing the assessment task, students can interact with two computer-based characters (a farmer and his brother). For healthy indigenous or failing new sheep, students can measure legs, bodies, and can access weight, age, and gender data.

Data and Results. This presentation will focus on results from our pilot and first year of implementations. We conducted our pilot in spring 2009 with nineteen 7th grade science students who participated in the first *SAVE Science* assessment module, assessing understanding of adaptation of organisms to a local environment. Automatically collected data lends insight to student actions and understanding. For example, all students gathered data before reaching conclusions, indicating that students understand the concept of evidence-based inferences. Some students asked questions of the two non-player characters multiple times, and all observed sheep characteristics. Further, students used their observations to support their responses to questions from the farmer. The data also helped illustrate student misconceptions of inference versus observation and other science concepts. At the same time, students in the pilot study noted a strong sense of engagement while completing the assessment module activities. One student said, “[I] like how the people talk. [I] like the sound. [I] like how you can move yourself around. [IT’S] MORE FUN THAN A REGULAR TEST.” This student’s sensory experience in the virtual world made for an enjoyable, effective learning experience.

Significance. Initial analysis indicates that we are able to differentiate between students who understood and used the appropriate methods in their inquiry from those with had misconceptions about the content or inquiry processes. Further, and perhaps not surprisingly, we found that students perceived the assessments as engaging and game-like (rather than stressful and test-like). The findings, while tentative, provided useful information for the redesign of the first assessment module that we are now implementing in multiple classrooms.

GameBuilder: Does Reduced Software Complexity Allow More Time on Task?

Eric Klopfer, Chuan Zhang, Judy Perry, Josh Sheldon; Massachusetts Institute of Technology

Research Goals and Theoretical Framework. To allow for greater student engagement and learning as a result of involvement with augmented reality (AR) games, several programs are underway in which students, not teachers or researchers, develop their own AR games. Previous tools for developing AR games had very complex user interfaces. As a result, the team developed GameBuilder, an AR editor with a much simpler interface, under the assumption that such a tool would allow for more focus on the game to be built and learning components to be included in the game. This research is designed to test that assumption.

Game Context and Methods. A protocol was developed to test the abilities of middle-school aged children to engage with the game design and content of their games, as opposed to spending effort managing the software. Participants were randomly assigned to two groups, one that would use the more complicated AR game editor, and one that would use GameBuilder. Each group was asked to complete a tutorial on using the assigned software, and then asked to build a simple game, with a topic of their own choosing, using that software. A researcher observed each study participant through both the tutorial and the free design session, and participants were then asked to rate their satisfaction with the software and the experience overall.

Data Results and Significance. Results from the free-design period and surveys show that participants were equally able to use the two pieces of software to develop their own games, after completing the tutorial. It is interesting to note, however, that participants using the more complex game editor, which had a number of features in which they were not trained, did not take advantage of any of these more advanced features. In addition, though the surveys did not reflect any additional dissatisfaction with the tool, the researcher observing use of the more complex software saw that in a number of cases, users inadvertently opened parts of the software they did not mean to and were distracted for some period of time trying to get back to their planned task. This suggests that the simplified interface is beneficial. Further research should test the ability of users to complete basic tasks without the benefit of the initial tutorial.

MUVEs and Meta-Knowledge

Jody Clarke-Midura & Eugenia Garduno, Harvard University

Research Goals and Theoretical Framework. Numerous researchers have emphasized the role of metacognitive processes in inquiry learning (White & Frederiksen, 1998, 2005; Kuhn, Black, Keselman, & Kaplan, 2000; Kempler, 2006; Kuhn & Pease, 2008). As an example, White et al offer a framework for inquiry learning, the meta-knowledge framework, which contains four primary processes: theorizing, questioning and hypothesizing, investigating, analyzing and synthesizing (White & Frederiksen, 1998; White, Frederiksen, Collins, in press). As part of this framework, they claim there is a meta-processing level where one evaluates not only what process should be carried out but how well it is being carried out. Similarly, research on games and multi-user virtual environments (MUVEs) suggest curricula delivered via these technologies have the potential to offer more authentic science inquiry learning that reflect the processes in White et als framework (Gee, 2003; Dede, 2009, Clark et al, 2009). We are studying how curricula delivered via immersive technologies have the potential to create learning experiences that (1) allow for authentic inquiry learning (2) enable metacognitive processes laid out by White et al. The research questions we will address in this poster are: what aspects of learning influence students' metacognitive processes? What aspects of MUVEs allow for students to engage in metacognitive processes?

Game Context and Methods. In order to answer our research questions, we conducted a series of studies in 2008. We used a MUVE-based science curriculum, River City, with 5218 middle school students within classes taught by 87 teachers. MUVEs are online digital contexts where multiple participants can communicate and collaborate on shared challenges. A participant takes on the identity of an avatar, one's digital persona in a 3-D virtual world, and communicates via text chat and non-verbal gestures. In this particular curriculum, students take on the role of a scientist and investigate a disease outbreak in a virtual city.

Specific instruments have been developed to measure metacognitive processes explicitly in the context of science inquiry (Kempler, 2006). The constructs measured by these instruments are often referred to as describing children's "thoughtfulness of inquiry" (Patrick et al, 2000; Fredricks, Blumenfeld & Paris, 2004). We used a scale developed by researchers at the University of Michigan to measure the extent to which students employ deep-level learning and self-regulatory strategies in inquiry-based science (Kempler, 2006). The University of Michigan studies reported an internal consistency reliability of .79 (Kempler, 2006). Students were administered surveys online prior to and after participating in the curriculum. The surveys contained two sections: (1) an affective sub-scale, which measured their thoughtfulness of inquiry (TOFI); and (2) a content sub-scale, which measured their inquiry and content knowledge. Multiple-choice were analyzed using multi-level regression. Open-end responses were first coded using open coding, allowing codes to emerge inductively from participants (Strauss & Corbin, 1998). A second round of coding was done to search for themes related to the research questions (Geertz, 1973).

Data Results and Significance. We found that students who felt like a scientist (t(3625)=6.99, p=.0001), felt like they were conducting an experiment (t(3625)=6.28, p=.0001), and enjoyed working as part of a team of scientists (t(3625)=2.74, p=.001) were more thoughtful of their inquiry. We found that teachers' self-identified teaching styles, in terms of the types of activities conducted in science class in general, had no significant effect on students' thoughtfulness of inquiry. Furthermore, a teacher's prior experience with teaching the *River City* curriculum showed no significant effect on students' thoughtfulness of inquiry. In this poster we will present more detailed results of our studies, including case studies of students who demonstrated high and low thoughtfulness of inquiry in the curriculum.

Metacognition is an important component of inquiry learning. As research on games and MUVEs in science education grows, it is important for researchers to understand what variables and design features help foster metacognitive and inquiry processes.

References

Barab, S. A., Sadler, T., Heiselt, C., Hickey, D., & Zuiker, S. (2007). Relating narrative, inquiry, and inscriptions: A framework for socio-scientific inquiry. *Journal of Science Education and Technology, 16*(1), 59–82.

Barab, S., Sadler, T., Heiselt, C., Hickey, D., & Zuiker, S. (2007). Relating narrative, inquiry, and inscriptions: A framework for socioscientific inquiry. *Journal of Science Education and Technology, 16,* 59-82.

Barab, S.A. & Squire, K.D. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences, 13*(1), 1-14.

Bargh, J. A., & Schul, Y. (1980). On the cognitive benefits of teaching. *The Journal of Educational Psychology*, 72(5), 593-604.

Brown, A. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of Learning Sciences*, *2*(2), 141-178.

Danish, J. A. (2009). BeeSign: a Design Experiment to Teach Kindergarten and First Grade Students About Honeybees From a Complex Systems Perspective. Paper presented at the annual meeting of the American Educational Research Association.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science,* 323, 5910 (2nd Jan), 66-69.

Enyedy, N. (2005). Inventing Mapping: Creating cultural forms to solve collective problems. Cognition and Instruction, 23(4), 427-466.

Fredericks, J., Blumenfeld, P. & Paris, A. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, 74(1), 59-96.

Geertz, C. (1973). *The interpretation of cultures*. New York: Basic Books.
Gresalfi, M., Barab, S., Siyahhan, S., & Christensen, T. (2009). Virtual worlds, conceptual understanding, and me: designing for consequential engagement. *On the Horizon*, *17*(1), 21-34.
Hestenes, D., Wells, M., & Swackhamer, G. (1992) Force Concept Inventory. The Physics Teacher, 30, 141-158.
Hickey, D. T., & Anderson, K. T. (2007). Situative approaches to student assessment: Contextualizing evidence to support practice. (P. Moss, Ed.)*Yearbook of the National Society for the Study of Education: Evidence and Decision Making*, *106*(1), 264–287.
Hickey, D. T., Honeyford, M. A., Clinton, K. A., & McWilliams, J. (inpress). Participatory assessment of 21st Century proficiencies. In V. J. Schute & B. Becker (Eds.),*Innovative assessment in the 21st century: Supporting educational needs*. Springer.
Hickey, D. T., Ingram-Goble, A. A., & Jameson, E. M. (2009). Designing assessments and assessing designs in virtual educational environments. *Journal of Science Education and Technology*, *18*(2), 187-208.
Kempler, T. M. (2006). Optimizing students' motivation in inquiry-based learning environments: The role of instructional practices. *Unpublished doctoral dissertation*, University of Michigan, Ann Arbor.
Ketelhut, D. J., Dede, C., Clarke, J., Nelson, B., & Bowman, C. (2007). Studying situated learning in a multi-user virtual environment. In E. Baker, J. Dickieson, W. Wulfeck, & H. O'Neil (Eds.), *Assessment of problem solving using simulations*. Mahwah, NJ: Lawrence Erlbaum Associates.
Klopfer, E. (2008). *Augmented Learning: Research and Design of Mobile Educational Games*. Cambridge, MA: MIT Press.
Kuhn, D., & Pease, M. (2008). What needs to develop in the development of inquiry skills? *Cognition and Instruction*, 26(4), 512 - 559.
Kuhn, D., Black, J., Keselman, A., & Kaplan, D. (2000). The development of cognitive skills to support inquiry learning. *Cognition and Instruction*, 18(4), 495-523.
Lemke, J.L. (1998a). Multiplying meaning: Visual and verbal semiotics in scientific text. In J.R. Martin & R. Veel (Eds.), *Reading Science*, (pp. 87-113). London: Routledge.
Patrick, H., Middleton, M., Taines, C. (2000). Urban Students' Motivation, Collaboration, and Thoughtfulness During Science Inquiry. *Paper presented at AERA 2000. References*
Squire, K. D. (2006). From content to context: Video games as designed experiences. *Educational Researcher, 35*(8), 19-29.
Steinkuehler, C. & Duncan, S. (2009). Informal scientific reasoning in online virtual worlds. *Journal of Science Education & Technology*. DOI: 10.1007/s10956-008-9120-8.
Steinkuehler, C. (2005). *Cognition and learning in massively multiplayer online games: A critical approach*. Unpublished dissertation. University of Wisconsin–Madison.
Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Thousand Oaks: Sage.
Vygotsky, L. S. (1986). Thought and language (Abridged from 1934; A. Kozulin, Trans.).Cambridge, MA: MIT Press.
White, B. (1993). Thinker tools: Causal models, conceptual change, and science education. Cognition and Instruction, 10(1), 1-100.
White, B., & Frederiksen, J. (1998). Inquiry, Modeling, and Metacognition: Making Science Accessible to All Students. *Cognition and Instruction*, 16(1), 3-118.
White, B., & Frederiksen, J. (2005). A Theoretical Framework and Approach for Fostering Metacognitive Development. *Educational Psychologist*, 40(4), 211-223.
White, B., Collins, A., Frederiksen, J. (in preparation). The Nature of Scientific Meta-Knowledge.

Energy across the Curriculum: Cumulative Learning Using Embedded Assessment Results

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Abstract: This symposium reports research investigating the design and implementation of curriculum, assessment, and professional development to promote cumulative understanding of energy. Using energy as a core idea, we link topics in 6th and 7th grade including thermodynamics, plate tectonics, global climate change, and photosynthesis. We explore new forms of assessment called MySystem and Energy Stories to capture cumulative understanding. Synthesis of findings across studies illustrates the trajectory of student learning and clarifies the elements of the curriculum that promote coherent views.

Symposium Goals

This symposium synthesizes research exploring cumulative learning of energy concepts across disciplinary project, reflecting the conference theme, *Learning in the Disciplines*. We define cumulative learning following the *Taking Science to School* report that calls for organizing the curriculum around a few key ideas that "connect to many related scientific ideas" (Duschl, Schweingruber, & Shouse, 2007). Using energy transfer and transformations as a core idea, we link topics in 6th and 7th grade including thermodynamics, plate tectonics, global climate change, and photosynthesis. To address this research question the eight posters investigate the design of curriculum and new assessment techniques to emphasize cumulative learning. We also study the impact of professional development and explore effective methods for documenting cumulative learning.

The current curriculum is fragmented and incoherent. The most commonly used middle school science textbooks cover too many topics and neglect connections between topics (Linn, Lewis, Tsuchida, & Songer, 2000; Stern & Roseman, 2004). Furthermore, studies show that textbooks introduce the same topics year after year and neglect links from one year to the next (Roth & Garnier, 2006; Schmidt, McKnight, Valverde, Houang, & Wiley, 1997). High-stakes tests reinforce this practice and reward recall of isolated ideas (Au, 2007). Critics argue that widespread use of multiple-choice items deters development of coherent arguments (National Research Council, 2003).

Our assessments, curriculum materials, and professional development are aligned using the patterns and principles developed to support knowledge integration (Kali & Ronen, 2005; Linn, 2006). We design curriculum using the Web-based Inquiry Science Environment (WISE), a technology-enhanced software system (see Figure 1) that both delivers instruction and keeps track of student responses (see Slotta & Linn, 2009). We incorporate technology tools, visualizations, and simulations created by the Concord Consortium. The WISE system of delivery ensures that teachers can track student progress in real time with embedded assessments, and allows instruction and assessment to be integrated. It supports numerous forms of teacher-student and peer-to-peer learning including interactions with probeware, visualizations, simulations, and virtual experiments.

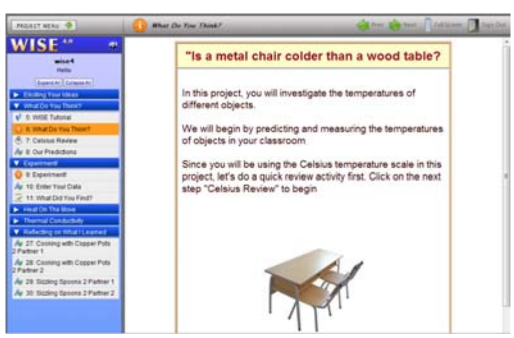


Figure 1. The Web-based Inquiry Science Environment for Thermodynamics

To measure the cumulative learning of energy ideas, we are exploring two new forms of assessment: Energy Stories and MySystem (see Figure 2). Energy Stories ask students to create explanatory narratives about energy phenomena related to the project, such as how plants use light to grow. MySystem, a computer-based modeling environment, enables students to visually represent connections between energy sources, energy transformations, and energy transfer.

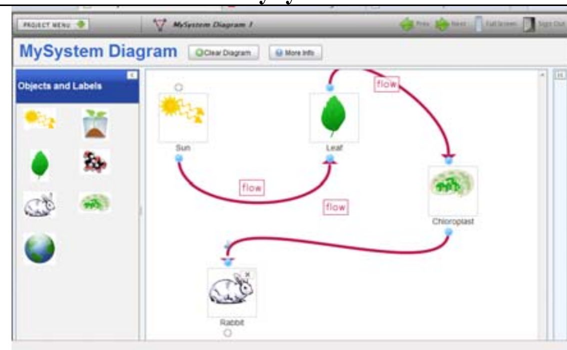
Energy Stories	MySystem
	

Figure 2. Examples of Energy Stories and MySystem from the Photosynthesis Project

We are implementing the units in the classrooms of twenty middle school teachers and study approximately 1500 students annually. These studies provide evidence in support of organizing the curriculum around core ideas, and explore affordances of incorporating the real world activities and connecting to students' everyday experiences. The symposium will be chaired by Marcia Linn, and discussed by Doug Clark.

Promoting Cumulative Learning

Marcia Linn, University of California, Berkeley; and Chad Dorsey, Concord Consortium

Today most students are tested on the topics they studied in the latest unit and often quite superficially. There is seldom the expectation of applying concepts learned in prior units to the next topic or course. To remedy this situation, Cumulative Learning using Embedded Assessment Results (CLEAR) is leveraging cyberlearning to make science learning more cumulative. Defining cumulative learning raises many issues such as: What sorts of ideas should be retained? What sort of understanding do we desire of students after several years of instruction? How do students use the knowledge gained in one day, topic, or course when they encounter the next day, topic, or course? How can instruction enable students to appreciate the ubiquitous role of fundamental science concepts like energy? How can we help students understand the dependencies and connections across science topics and disciplines? From our prior work on knowledge integration we know that students come to science class with a repertoire of disconnected and often contradictory ideas. We want to spur students to develop more coherent ideas. We would like to enable students to integrate their ideas and promote the most fruitful, generative, and useful ideas. We hope to help students distinguish new ideas from existing ideas and reconcile discrepancies with scientific evidence. We expect that cumulative learners will test and refine their ideas by applying them in situations they encounter in their lives. Ideally cumulative learners would continue to expand, refine, and integrate their understanding all during their lives. This poster defines key features of instruction and assessment for cumulative learning and provides case studies from student work to illustrate how students respond. We argue that all students can become cumulative learners.

Teacher Perspectives on Cumulative Learning

Libby Gerard, University of California, Berkeley

This study explores how teachers use the CLEAR curriculum and assessment materials to foster cumulative learning. What ideas do teachers link? What parts of the curriculum do they revisit? What do they learn about student thinking from the new assessments? And how does that information help guide their teaching?

We report on how the 16 teachers implemented CLEAR inquiry projects (see Table 1). Each project takes between five and fourteen fifty-minute class periods. Energy Stories, MySystem, and other activities are embedded in each project to serve as learning events and assessments. All teachers have a minimum of four years of prior experience teaching with technology-enhanced inquiry science curriculum.

Table 1. Participants, Grade and Projects Taught

Participants (n)	Grade	Projects
10	6th	Eliciting Ideas, Thermodynamics, Plate Tectonics, Global Climate Change
6	7th	Eliciting Ideas, Photosynthesis

Teachers were interviewed at the beginning of the year and after implementing a project in their classroom. They responded to questions about their views of cumulative learning, teaching, and assessment strategies. All teachers also participated as partners in a five-day workshop, in which they used student assessment data from Energy Stories and MySystem to inform the design of CLEAR curriculum projects. Teachers responded in writing at the end of each day of the workshop to four reflection questions focused on analysis of student data, ideas for the curriculum, and anticipated support needs for classroom implementation. The impact of the emphasis on cumulative learning is apparent (see Table 2). Teachers have begun to revisit student ideas when teaching non-CLEAR topics.

Table 2. Data Sources and Teachers' Views

Data Source	**Teachers' Views**
Baseline interview, Workshop Reflections	Eager to prioritize students' cumulative learning about energy.
	Have done little to support cumulative learning in past due to use primarily of textbook for instruction
	Surprised when analyzing student Energy Stories and MySystem by students' non-normative energy ideas
	Plan to revisit student ideas about energy transformations in CLEAR and non-CLEAR topics
Post Project Interviews	Guided students to revisit ideas from CLEAR virtual experiments and simulations when teaching energy in other contexts
	Added embedded assessments from CLEAR projects to teacher generated end-of-unit and end-of-semester tests to assess students' cumulative learning about energy
	Energy Stories and MySystem provide a valuable summative assessment of the connections students can make whereas explanation questions capture more of learning process
	Energy Stories and MySystem are more open ended than traditional explanations, so they showed how students *apply* what they learned
	Energy Stories generated longer answers from students than traditional explanations because had to explain the whole journey of energy from one point to the end
	MySystem and Energy Stories forced students to assess their own understanding and identify gaps more so than specific explanation items
	Students needed more icons in MySystem (e.g. for energy lost)
	Students needed opportunities to see other MySystem and Energy Stories in a different topic before doing their own because they lack experience using systems and stories in science

Teachers report revisiting elements of the CLEAR units such as virtual experiments and simulations to make connections to new topics. For example, when teaching the Plate Tectonics project, one 6th grade teacher commented that she frequently referred back to a simulation of conduction in the Thermodynamics project to help students understand why heat moves from the core to the mantle and to the Earth's plates. Teachers see the potential of MySystem and Energy Stories as assessments. For example, one teacher remarked:

> "*the MySystem forces [students] to make choices, to ask what direction is energy moving…and have a conversation, you get kids saying well I don't think that should be there, and well why not, and then they have to explain it which really makes them assess what they know and don't know. A lot of times students think they get it but they don't so MySystem diagrams help because it's not just answer a question but create something and then they have to explain it again in the story.*"

Teachers also offered valuable ways to improve the diagrams such as adding icons and giving students a model of an Energy Story and MySystem to critique prior to generating their own. Teachers' views on cumulative learning and assessment can improve the quality of curriculum materials by identifying which ideas from a project students use to help them understand a new topic. Teachers' views can also help us understand how Energy Stories and MySystem can be strengthened and embedded in the projects to guide students to monitor their understanding.

Eliciting Energy Ideas in Thermodynamics

Hilary Swanson, University of California, Berkeley

To explore the impact of typical instruction on student ideas about energy, we asked students to articulate their ideas in assessments administered early in the school year. This embedded activity elicited ideas, the first step in the knowledge integration framework (Linn, 2006). Students articulate their repertoire of ideas and develop criteria to guide the construction of coherent approaches to understanding scientific phenomena. Pretests show that although eighth grade students had greater technological fluency and higher literacy levels than sixth graders, their ideas about energy were not significantly more coherent than the sixth graders' ideas.

Students then participated in a four-day WISE project on thermodynamics, working in dyads (N= 49 dyads). Assessments embedded in the activity were scored using the knowledge integration rubric. In addition a list of specific ideas consistent with Minstrel's facet analysis was identified (Minstrell, 1992). Seventy-four percent of the responses to the first thermal equilibrium prompt were normative, whereas ninety-three percent of responses to a final assessment were normative. For example, on the final assessment, most students correctly identified the sun as the original energy source, and conduction as the means of heat transfer from an object heated by the sun to an object in contact with it. However, some students explained their reasoning by arguing that heat rises. They would correctly or incorrectly answer questions about conduction based upon the relative orientation of the heat source (i.e., hot cup *on top* of counter vs. hot asphalt *under* bare feet). This non-normative idea elicited by the WISE project will be leveraged by the teacher in subsequent projects, which contrast types of energy transfer as they are introduced.

Redesigning Plate Tectonics for Cumulative Learning

Elissa Sato, University of California, Berkeley

Plate tectonics is currently taught as an earth science unit in sixth grade in the state of California. It has traditionally been a difficult concept for middle school students (Gobert & Clement, 1999), requiring students to learn about abstract processes and phenomena that lie outside of their direct experience and to integrate spatial, causal and dynamic information (Gobert, 2000). The California state standards require students to learn that various geological phenomena are different manifestations of a plate movement (Curriculum Development and Supplemental Materials Commission, 2003). To leverage the unifying concept of energy we frame plate tectonics as a disciplinary context for learning about thermal energy transfer by convection. We sought to make connections between previous instruction on energy, students' existing knowledge, and current instruction featuring convection without fragmenting the curriculum. We report on initial teacher concerns: many sixth grade earth science teachers felt it would be difficult to integrate more in-depth coverage of convection into the plate tectonics curriculum when instruction typically focused on geologic events and features on a mechanistic level. Some teachers also questioned how emphasizing energy concepts in plate tectonics would help students make connections with energy concepts in other domains given the abstract nature of the topics.

To investigate students' understanding of energy concepts in plate tectonics, we conducted two pilot studies (N=100) in six middle school classes taught by the same teacher. After completing an existing plate tectonics project, students were asked to write stories about and draw or annotate diagrams to describe how energy causes changes in the mantle, where the energy came from, where the energy goes, and how the energy moves and changes form. Student responses were analyzed using a grounded coding methodology. Most students correctly identified the core as the source of thermal energy within Earth, although several responses attributed the Sun as being the source. Most students were unable to describe the process of convection. Many instead described thermal energy transfer within Earth as a series of pressure-induced bursts of energy escaping from the core without any flow of matter involved. Many students also isolated the movement of thermal energy within Earth as being limited to heat transfer from the core to the mantle.

These results informed the subsequent redesign of the Plate Tectonics project. Based on these studies we strengthened the convection component of the curriculum and the connections between convection and other concepts in plate tectonics and other disciplines. We incorporated multiple activities to help students make connections between the surface and sub-surface processes, as well as between concrete, mechanistic processes and abstract processes involving energy. Whereas the processes involved in convection were described in a single paragraph in the original project, we expanded the section to allow students to explore and visualize the process of convection at both macro- and micro- levels, to contextualize their understanding of convection to plate tectonics, and to extend their understanding of the principles involved in convection to other contexts such as lava lamps and hot air balloons. Preliminary results suggest that the revised project is effective in supporting students' learning of convection and its underlying processes. Students increased their understanding of the processes underlying convection, made connections between thermal energy transfer and surface geologic processes, and reasoned how concepts underlying convection can manifest in different contexts. Many students made references to the role of conduction as an additional means of thermal energy transfer in Earth, suggesting that students were making connections to energy concepts encountered in previous instruction. Future iterations of the Plate Tectonics project will focus on supporting students in building on previous instruction by incorporating activities that will help them better distinguish between conduction and convection.

Redesigning Global Climate Change for Cumulative Learning

Tammie Visintainer and Vanessa Svihla, University of California, Berkeley

To strengthen cumulative learning we redesigned an existing Global Warming project, incorporating concepts of energy and increasing the personal relevancy of the project for students by building on their initial ideas. The goal of the new project design is to present information in a way that will more effectively facilitate an understanding of the relationship between the mechanisms associated with global climate change and student's energy consumption. The new project explores ways to leverage energy stories, advisory roles, and energy consumption surveys to better elicit students ideas based on their everyday experiences. In this way we can push our thinking of cumulative learning beyond the bounds of the science classroom by incorporating how students' social and cultural backgrounds inform their ideas about science phenomena such as global climate change, and the evidence that they use to support these ideas.

A pilot study was conducted in the Spring of 2009 involving four classes of middle school students taught by the same teacher prior to making revisions of the Global Warming project. Students were asked to write stories and draw energy pathways that included where energy comes from and goes, how it changes form, and how energy travels from place to place. Student responses were analyzed using a grounded coding methodology. The majority of students said energy goes to plants, animals, or the ground, and many said that energy travels through the food chain. Most students only referred to energy in the forms of ultra violet and infrared radiation and had difficulty describing mechanism by which energy changes form. No students mentioned human contributions or the role of their energy consumption when describing how energy affects the atmosphere. Revisions to the existing Global Warming project incorporated findings from this pilot study.

We then conducted a pilot study of the new Global Climate Change project in February 2010 with four classes of 6th grade students, including pre and post interviews with five students. Initial analyses of open-ended responses and interviews suggest that the majority of students believe that pollution or gases cause global climate change and that human actions are sources of this pollution. Students cited ice melting, environmental damage, and temperatures rising as evidence of the occurrence of global climate change. Understanding the specific mechanisms driving global climate change as well as the energy transformations that occur during these processes continue to provide challenges for students. Students commonly mentioned exhaust from vehicles as causes of global climate change, but litter which is tangible to 6th graders as a source of pollution, was also commonly mentioned. Students also tended to group all types of environmental issues together (e.g. ozone layer depletion, acid rain) as causes of or evidence of global climate change.

Further redesigns of the Global Climate Change project will build on students' ideas about the causes of global climate change and the evidence they cite to support their ideas. Activities intended to make explicit the mechanisms behind global climate change and why certain types of pollution contribute to this phenomenon while others does not will be added including comparing and researching different human actions. Likewise, activities will be added to make explicit the energy transformations that occur as energy travels from the sun through different pathways to end products (e.g. food sources, electricity) that are tangible to middle school students. Additionally, students will take home and discuss with their families an Energy Consumption Survey containing items that middle school students can relate to such as transportation to school and recycling and then complete an on-line activity related to the project in school. By examining global climate change from an energy consumption perspective and incorporating activities that make explicit the mechanisms and energy transformations involved with this issue, it is our hope that we will increase students' awareness of how their lives connect to greater science phenomena.

New Assessments of Cumulative Learning in Photosynthesis

Kihyun (Kelly) Ryoo, University of California, Berkeley

The role of energy in photosynthesis challenges students because of its complexity and abstract nature. We designed the photosynthesis project using animations, simulations and virtual experiments to make the role of energy more comprehendible. We report on student learning from pretest to posttest and the potential advantages of using the new assessments, Energy Stories and MySystem (Figure 2). Two middle school teachers taught photosynthesis to eight classes of seventh grade students (N=220) using our CLEAR curriculum for approximately two weeks. Students generated pre- and post-project Energy Stories and MySystem diagrams about how energy is involved in photosynthesis. New extended Knowledge Integration rubrics were developed to score the Energy Stories and MySystem. The rubrics have seven levels including full link (one scientifically valid link between energy source, energy transformation, energy storage, and energy transfer), complex link (two scientifically valid links), and advanced complex link (three or more scientifically valid links). In addition to the Knowledge Integration score, we also captured the specific ideas students generated in their Energy Stories and MySystem.

Overall, paired t-tests revealed that students showed significant improvement in their understanding of energy concepts in photosynthesis in both narrative explanations and visual representations (Figure 3). On the pre-project Energy Stories, students demonstrated a limited understanding of energy concepts in photosynthesis (M = 3.96, SD = 1.12). Twenty-eight percent of the students listed fragmented ideas about energy in photosynthesis, such as "the light energy moves to the plant." Although 40% of the students provided one scientifically valid link between energy ideas, most identified the sun as the energy source for photosynthesis but were unable to describe energy transformation and energy transfer during photosynthesis. They also presented a wide range of alternative ideas related to energy in the Energy Stories, such as "plants releasing energy through oxygen" or water as the energy source for photosynthesis. On the post- project Energy Stories (*M*= 5.02, *SD*=0.78), students showed a significant gain ($t(219) = 10.26$, $p < 0.05$) and this effect was large (Cohen's $d = 1.10$), meaning that they provided two or three scientifically valid connections between ideas. Students not only articulated more integrated ideas about energy sources, transformation, and transfer in photosynthesis, but they also provided more detailed examples of this process.

Consistent with the results of Energy Stories, on the pre-project MySystem, students showed some relevant ideas about energy sources in photosynthesis but did not make any correct links between ideas ($M = 3.41$, $SD = 0.94$). Many students made arrows between irrelevant ideas or provided incorrect labels for correct links (Figure 3). By the post-project MySystems, students demonstrated a more coherent understanding of energy flow in photosynthesis by providing more correct links between energy concepts and elaborated descriptions for each link ($t(109) = 14.71$, $p < 0.05$), and this effect was large (Cohen's $d = 1.38$). Students demonstrated a more coherent understanding of energy flows in photosynthesis by linking different energy concepts and elaborated descriptions for each link ($M = 4.86$, $SD = 1.10$). These results show how a technology-enhanced inquiry curriculum can improve students' integrated understanding of abstract concepts in science and potential advantages of explanatory narrative and visual representation as an assessment tool to document student progress in understanding energy concepts.

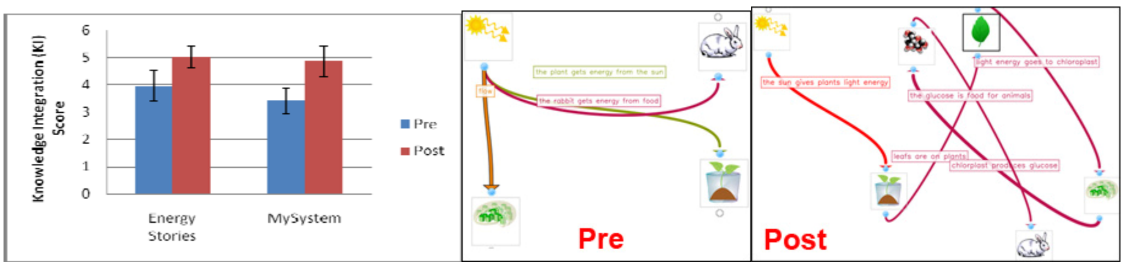


Figure 3. Knowledge Integration Scores of Energy Stories and MySystem on the Pre- and Post-tests

Measuring Cumulative Understanding: Item Formats

Hee-Sun Lee, Tufts University & Ou Lydia Liu, ETS

To measure the learning progression of science ideas, assessment developers have used student alternative conceptions to create multiple-choice items (Alonzo & Steedle, 2009; Briggs, Alonzo, Schwab, & Wilson, 2006; Sadler, 1998; Treagust, 1988). In contrast, we designed multiple-choice items where choices represented various levels of knowledge integration: non-normative ideas, fragmented normative ideas, and integrated normative ideas in order to study whether multiple-choice items can measure students' ability to reason with an increased number of normative and relevant ideas in scientific problems (Lee, Liu, & Linn, in press).

For this study, we selected 10 multiple-choice items from released TIMSS item sets (International Association for the Evaluation of Educational Achievement, 1995, 1999, 2003). These items addressed energy sources, transformation, transfer, and conservation concepts embedded in middle science topics such as heat conductivity, food web, water cycle, plate tectonics, chemical reactions, digestion and respiration. We created a paired item format by adding an explanation part to each of the ten selected multiple-choice items. We designed the explanation part either as selection of an explanation from six choices that represent common student knowledge integration explanation patterns found from a previous study (Lee & Liu, 2010) or as generation of open-ended explanations after a generic prompt, "Explain your choice." We created two online test forms each of which included 10 paired items with alternating selection and generation explanation parts and randomly assigned the two test forms to 794 sixth and seventh grade students.

We used descriptive statistics and a Rasch analysis based on the Partial Credit Model to investigate the compatibility between selection and generation of explanations in measuring knowledge integration. Results show that (1) there appears no systematic advantage for selection explanation items over generation explanation items on the preceding multiple-choice items, (2) student performance on selection explanation items is more aligned when correct answers were chosen in the preceding multiple-choice items than when incorrect answers were chosen, and (3) locations of item thresholds for the fragmented normative idea and the integrated idea explanations are different between generation and selection explanation items. As a result, knowledge integration levels were measured higher when using selection explanation items than generation explanation items. These results indicate that the ability to select an explanation in multiple choice items is not the same as the ability to write one's own explanation. Therefore, relying on multiple choice items to measure knowledge integration will not be accurate and may overestimate students' knowledge integration ability.

Measuring Cumulative Learning Across Disciplines

Vanessa Svihla University of California, Berkeley

Prior research has established effective and reliable ways to measure the coherence of student's repertoire of energy ideas with respect to specific contexts (Lee, et al., in press; Liu, Lee, Hofstetter, & Linn, 2008) and there are promising options for extending these methods of measurement to new open-ended assessment formats (specifically, Energy Stories and MySystem (Ryoo, this session). This poster explores cumulative learning for dyads and methods for resolving individual trajectories of cumulative learning.

Initial analysis of two projects shows that dyads add new ideas and form new scientifically valid links between ideas as they complete a project. For each project, dyad performance on a late, integrative question was modeled as a linear combination of two prior questions, an early question asking students to explain a phenomenon after learning about a type of heat transfer e.g., (conduction or convection) and a later question asking students to provide a more mechanistic explanation of the phenomenon (e.g., conduction relates to rate of heat transfer or heat energy is related to density). A full score on the integrative question would require students to link the description of the heat transfer to the cause.

For the thermodynamics project, modeling the integrative question as a linear combination of prior answers resulted in a significant increase over using the mean (F (2,59)= 6.98, $p<0.05$) and a positive but not strong relationship ($r^2=0.191$). For the plate tectonics project, modeling the integrative question as a linear combination of prior answers resulted in a significant increase over using the mean (F (2,62)= 18.28, $p<0.05$) and a positive relationship ($r^2=0.371$). Including student pretest scores related to thermodynamics does not explain significant variance (F (2, 59)=0.994, $p>0.05$). This finding suggests that regardless of starting point, students have potential to learn using these projects, and supports our assertion that all students may become cumulative learners. For the global climate change project, much of the learning is dependent on understanding models in the project. In this case, the integrative question can be modeled as a linear combination of pre-test scores and score on a question reflecting on the first of a series of climate models (F (2,64)= 7.70, $p<0.05$) and a positive but not strong relationship ($r^2=0.194$).

Exploring student learning across projects is challenging because students work in different dyads for each project. One approach to analyzing such data is to apply a 2-mode affiliation network approach, identifying clustering across individuals and events (Field, Frank, Schiller, Riegle-Crumb, & Muller, 2006). We are developing models of individual student performance taking into account their various memberships in dyads during the course of the school as they completed CLEAR projects, allowing us to explore the extent to which each individual ensures the relative success of a dyad in reaching coherent understanding of energy transformation. Alternatively, this may be framed as exploring benefits of heterogeneous pairing (Gerard, Tate, Chiu, Corliss, & Linn, 2009; Madhok, 1992; Varma, 2008).

Conclusions

Through these studies, we have demonstrated a design-based approach, incorporating findings from teachers as well as evidence from student pilot data that highlight ways to support cumulative learning of energy ideas. Findings from this initial year of the study include the following:

- Teachers were empowered to support their students in becoming cumulative learners by helping them make further connections across CLEAR and non-CLEAR projects
- Teachers endorsed using personal relevance as a means to increase cumulative learning, a perspective currently being empirically tested
- Pretests show little difference between sixth and eighth grade students in terms of coherence of ideas about energy
- Students show an increase in percent normative ideas over the course of a project
- Students achieve significant gains in developing coherent ideas related to energy across projects

Taken together, empirical evidence from these studies suggests that designing for cumulative learning is promising, but that traditional measures are insufficient for assessing it. Furthermore, cumulative learning as we have framed it provides a means to curricular efficiency, allowing students to learn about a core idea in science with increasing depth. This research, which is in its inaugural year, has potential as an exemplar for practical ways to address challenges common to many educational systems.

References

Alonzo, A. C., & Steedle, J. T. (2009). Developing and assessing a force and motion learning progression. *Science Education, 93*(3), 389-421.

Au, W. (2007). High-Stakes Testing and Curricular Control: A Qualitative Metasynthesis. *Educational Researcher, 36*(5), 258.

Briggs, D., Alonzo, A., Schwab, C., & Wilson, M. (2006). Diagnostic Assessment With Ordered Multiple-Choice Items. *Educational Assessment, 11*(1), 33-63.

Curriculum Development and Supplemental Materials Commission (2003). *Science Framework for California Public Schools Kindergarten Through Grade Twelve*. Sacramento, CA: California Department of Education.

Duschl, R., Schweingruber, H., & Shouse, A. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8*: National Academies Press.

Field, S., Frank, K., Schiller, K., Riegle-Crumb, C., & Muller, C. (2006). Identifying positions from affiliation networks: Preserving the duality of people and events. *Social Networks, 28*(2), 97-123.

Gerard, L., Tate, E., Chiu, J., Corliss, S., & Linn, M. C. (2009, July). *Collaboration and knowledge integration.* Paper presented at the CSCL, Rhodes, Greece.

Gobert, J. (2000). A typology of causal models for plate tectonics: Inferential power and barriers to understanding. *International Journal of Science Education, 22*(9), 937-977.

Gobert, J., & Clement, J. (1999). Effects of student-generated diagrams versus student-generated summaries on conceptual understanding of causal and dynamic knowledge in plate tectonics. *Journal of Research in Science Teaching, 36*(1).

International Association for the Evaluation of Educational Achievement (1995). *TIMSS 1999 science items: Released set for population 2 (seventh and eighth grades)*. Chestnut Hill, MA.

International Association for the Evaluation of Educational Achievement (1999). *TIMSS science items: Released set eighth grade*. Chestnut Hill, MA.

International Association for the Evaluation of Educational Achievement (2003). *TIMSS science items: Released set for eighth grade*. Chestnut Hill, MA.

Kali, Y., & Ronen, M. (2005). *Design principles for online peer-evaluation: Fostering objectivity.*

Lee, H.-S., & Liu, O. L. (2010). Assessing Learning Progression of Energy Concepts Across Middle School Grades: The Knowledge Integration Perspective. *Science Education.*

Lee, H.-S., Liu, O. L., & Linn, M. C. (in press). Validating measurement of knowledge integration in science using multiple-choice and explanation items. *Applied Measurement in Education.*

Linn, M. C. (2006). The knowledge integration perspective on learning and instruction. In K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 243-264). New York: Cambridge University Press.

Linn, M. C., Lewis, C., Tsuchida, I., & Songer, N. (2000). Beyond fourth-grade science: why do US and Japanese students diverge? *Educational Researcher, 29*(3), 4-14.

Liu, O., Lee, H., Hofstetter, C., & Linn, M. C. (2008). Assessing Knowledge Integration in Science: Construct, Measures, and Evidence. *Educational Assessment, 13*(1), 23.

Madhok, J. (1992). *The effect of gender composition on group interaction*.

Minstrell, J. (1992). Facets of students' knowledge and relevant instruction. In R. Duit, F. Goldberg & H. Niedderer (Eds.), *Research in physics learning: Theoretical issues and empirical studies* (pp. 110-128). Kiel: IPN.

National Research Council (2003). *Knowing what students know*. Washington, D.C.: National Academy Press.

Roth, K., & Garnier, H. (2006). What science teaching looks like: An international perspective. *Educational Leadership, 64*(4), 16.

Sadler, P. (1998). Psychometric models of student conceptions in science: Reconciling qualitative studies and distractor-driven assessment instruments. *Journal of Research in Science Teaching, 35*(3), 265-296.

Schmidt, W., McKnight, C., Valverde, G. A., Houang, R. T., & Wiley, D. E. (1997). *Many visions, many aims.* Dordrecht, The Netherlands: Kluwer.

Slotta, J., & Linn, M. C. (2009). *WISE Science: Web-Based Inquiry in the Classroom*. New York: Teachers College Press.

Stern, L., & Roseman, J. (2004). Can middle-school science textbooks help students learn important ideas? Findings from Project 2061's curriculum evaluation study: Life science. *Journal of Research in Science Teaching, 41*(6), 538-568.

Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education, 10*(2), 159-169.

Varma, K. (2008, June). *Supporting Students' Experimentation Strategies with Dynamic Visualizations.* Paper presented at the 8th International Conference of the Learning Sciences, International Perspectives in the Learning Sciences: Cre8ting a Learning World, Utrecht, The Netherlands.

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Abstract: This paper explores the role of technologies in supporting informal science learning from seven perspectives. Together, the authors ask a common question: How can learning technologies—tools, spaces, and places—be designed to support learners within and across environments? Eight exemplars are offered to answer this question through an analysis of a specific instance of technology in a non-school environment. Collectively, the authors examine the role of tools that support: access to and distribution of information; scaffolds to help learners tackle complex tasks and deeper understandings; bridging learning across contexts; feedback and reflection; extension of learning experiences in a temporal way; aggregations of visible knowledge, social interaction, facilitation of social practices, personalized learning, and the breakdown of epistemic authority. The authors and two discussants reflect on the methodological innovation, technological advancement, and collaborations needed to move research in this area forward.

Introduction

This paper explores the role of technologies and tools in supporting informal science learning. Authors come from a variety of perspectives: university learning sciences programs, training programs for designers and museum professionals, informal learning institutions, and technology development. From eight different perspectives, the authors ask and answer a set of common question:

> How can learning technologies—tools, spaces, and places—be designed to support learners within and across environments? How do these studies of learning technologies provide insight into how to support learners, not only within settings but also across environments? How can these learning technologies support field-level collaboration across institutional lines of practitioner, researcher, and evaluator?

The authors answer these questions by presenting analyses of technology use, development, and research in non-school environments. In their analyses, the authors examine the role of tools that support various learning processes in informal spaces, including:

- access to, and distribution of, information
- scaffolds to help learners tackle complex tasks and deeper understandings
- bridging learning across contexts
- feedback and reflection
- extension of learning experiences in a temporal way
- aggregations of visible knowledge
- social interaction
- facilitation of social practices
- personalized learning
- the breakdown of epistemic authority

These exemplars of technologies are also designed specifically to reflect learning and teaching in informal spaces, reflecting visitors' expectations and mirroring norms of behaviors in informal environments.

Background

This session work is part of a National Science Foundation funded community-building project, *Building Capacity and Collaboration at the Intersection of the Learning Sciences and Informal Science Education* (Intersection). The Intersection project brings together international researchers to advance research and practice related learning outside of school. The goal of the Intersection project is to develop a community that will further the aims of both the informal science education and the learning sciences fields by building on key publications over the last decade, including *How People Learn* (NRC, 1999), *The Cambridge Handbook of the Learning Sciences* (Sawyer, 2006), the latest NRC consensus volumes *Learning Science in Informal Environments: People, Places, Pursuits* (NRC, 2009), and *Surrounded by Science* (NRC, 2010). These books summarize what we currently know about the processes, content, and contexts of human learning in science inside and outside of formal schooling.

The Intersection project's community building efforts include knowledge sharing and writing projects accomplished through online forums, a website for sharing ideas, and a face-to-face workshop held in August 2009. The intellectual work and conversations that happen through the workshop meeting and in the online spaces highlight synergies, challenges, and opportunities that arise when the informal science learning and learning sciences professionals work together. The Intersection project participants are conducting studies and writing papers that make progress in four key areas:

1. Understanding the concepts of learning and engagement
2. Equity, access, and methodology in informal learning
3. Informal learning pedagogy
4. Tools and technologies that support informal science learning

This interactive symposium is a collaborative effort between a subgroup of researchers and practitioners who are participating in the Intersection grant activities focused on the last key area, tools and technologies that support informal science learning

The authors in this symposium are members of the subgroup interested in applying learning sciences and informal science, technology, engineering, and mathematics (STEM) education methodologies and theories in order to study how to facilitate learning, most broadly considered, with technologies in out-of-school environments. In addition to participating in the workshop and online forums discussed above, the technologies subgroup has formed a special interest networking group and a wiki to begin to synthesize what is known about learning with technologies outside of school. This subgroup cuts across research groups, involves emerging and established leaders, and includes both informal learning institutions and universities. (Note: this work is occurring with additional colleagues.)

The authors have organized this paper to share the findings from their work with the broader learning sciences field. They offer eight diverse designs and studies of technology-supporting learning to better understand how pedagogy can be conceived in out-of-school environments. An author or small team of authors presents each of the eight perspectives below; the authors present findings from an empirical study or set of studies. Then, together, the authors engage the audience in conversations across the studies towards deeper conceptual understandings about the nature of learning with technology that occurs on school fieldtrips, in museums, in homes, in afterschool clubs, and similar places.

Symposium structure

The symposium session will start with a brief introduction by the chair, Heather Zimmerman. Next, the first authors of each of the eight posters (David Kanter, Kirsten Ellenbogen, Leilah Lyons, Steve Zuiker, Tom Satwicz, Heather Zimmerman, Matthew Brown, and Sandy Martell) will provide a two-minute fire-hose presentation of their topic. The bulk of the remaining time will be spent in small group conversation between the audience and presenters. The groups will come back for broader discussion, sparked by initial comments by the two discussants, Sherry Hsi from the Lawrence Hall of Science (an interactive science center in California) and Brian K. Smith from the Rhode Island School of Design. The discussants will make comments on posters in regard to connections to educational practice in informal institutions, learning theory, and the National Research Council new report, *Learning Science in Informal Environments: People, Places, and Pursuits* (Bell, Lewenstein, Shouse, & Feder, 2009). After the discussants' remarks, the time remaining will be spent on full group discussions. Final questions to seed this group, if questions do not arise naturally, include:

> What types of methodological innovation are needed to move our understanding of the learning here forward? What types of technological innovation and collaboration are needed to realize the potential these authors put forth*?*

Exemplars

Exemplar 1: Using the demand for data in a project-based science curriculum to bridge high school biology classrooms and an informal science center by David E. Kanter, Temple University

This analysis reflects on work conducted as part of a National Institutes of Health Science Education Partnership Award titled, "Supporting Student and Teacher Inquiry in Bioscience," a partnership between Northwestern University (Learning Sciences) and Chicago's Museum of Science and Industry (MSI). The work resulted in a project-based high school biology curriculum, "Disease Detectives," and related software, "Village Park Mystery," closely coupled to the museum's "Live from the Heart," a videoteleconference to a real-time coronary artery bypass graft procedure, experienced by the high school students in the informal museum setting. To address the mystery of what was wrong with the people in Village Park, the curriculum and software were designed to help students reason through real data including patient case files, medical images like angiograms, and a virtual cell laboratory, that they would ultimately "invent" Coronary Artery Disease (CAD), requiring and learning cell biology standards along the way. (The term "invent" is used as per Karplus to describe students' conceptual "invention," the middle of the original three-phase inquiry cycle.)

Students complete the project by devising a public health plan for Village Park, defended by data about the characteristics of individuals whose CAD (or lack thereof) would benefit from invasive procedures or non-invasive treatments. It is in completing this part of the project that high school students collect first-hand information from medical professionals about the relative merits of the invasive fix for CAD they are seeing via videoteleconference with other possible interventions for CAD, both invasive and non-invasive. In this way, by coupling the technology in the informal space to a project-based science curriculum for the formal classroom, the learning possible with the existing informal technology in extended insofar as the specialized data, only available in the informal setting, can learned as integral to students' ongoing investigation in the classroom, and as such might be expected to be learned more deeply. We present such changes in students' meaningful understanding of science concepts. On this basis, we emphasize the utility of altering the pedagogy that frames the use of even existing informal technologies to better support science learning.

Exemplar 2: Rain Table: Visualization technology using complex datasets that allows learners to control and follow water flow across the Earth's surface by Kirsten Ellenbogen and Molly Phipps, Science Museum of Minnesota

Water movement across the Earth's surface is among the most misunderstood concepts in earth science (e.g., Coyle, 2006). Concepts like "rivers always flow south" and "curving of water flow due to the Earth's spin" are common issues that emerge in everyday science experiences. One of the best ways to understand water flow is to watch the movement of water across the Earth's surface. However, this is not possible in most lab settings and physical models cannot capture the intricacies of unrestricted stream flow across large areas.

To overcome these obstacles, the Science Museum of Minnesota and the National Center for Earth-Surface Dynamics initiated a partnership with the Electronic Visualization Laboratory of the University of Illinois at Chicago to create a new visualization technology using complex datasets that allows learners to control and follow water flow across the Earth's surface. Using touch screen technology, Rain Table allows users to make rain with their fingertips, producing tens of thousands of raindrops that then flow down and across digital elevation models of real landscapes in ways highly analogous to actual landscape processes. (See an early prototype of Rain Table at http://www.youtube.com/watch?v=rc5I774Mnh4.)

Learning research on the Rain Table at the Science Museum of Minnesota has focused on public conceptions of the directional flow of water on the Earth's surface. Pre- and post-interviews with museum visitors were conducted using a large two-dimensional, non-interactive floor map of the world or Rain Table. Additionally, visitors were video recorded as they used Rain Table. Findings were analyzed with an eye toward understanding the directional flow in:

- Interactive and non-interactive contexts
- High and low elevation areas
- A de-contextualized situation
- A problem-based learning situation (e.g., avoiding run off from a factory when choosing a location for a house)

Findings were also considered in light of the museum visitor's age, the social grouping in which they explored the exhibit, and motivations for coming to the museum.

Exemplar 3: Mobile devices transforming the museum experience: Opportunistic user interfaces to exhibits by Leilah Lyons, University of Illinois at Chicago

The nature of learning in informal environments is individual, idiosyncratic, and opportunistic—suggesting technology employed in these settings should also take on these characteristics. For this reason, mobile devices have been a popular platform in museums (Tallon & Walker, 2008). In the tradition of audio guides, most implementations focus on delivering information to visitors, and many research projects have capitalized on devices' computational abilities to try to customize that delivery, inferring the desired content from the visitor's location (e.g., Abowd, et al., 1997), focus of attention (e.g., Bruns, Brombach, Zeidler, & Bimber, 2007), time spent in different areas (e.g., Benta, 2005), or user-provided preferences (e.g., Chou, Hsieh, Gandon, & Sadeh, 2005). The emphasis has been on individualizing output experiences, but mobile devices also permit the individualization of input experiences.

This analysis explores mobile devices as opportunistic user interfaces to exhibits, giving visitors opportunities to interact bidirectionally with an exhibit through their personal devices (Lyons, 2009). This approach is distinct from other innovative uses of mobiles in museums that view the museum as a whole as an interactive space, usually framed as a scavenger hunt (e.g, Yatani et al., 2004; Klopfer et al. 2005; Yiannoutsou et al., 2009). Rather, mobiles used as opportunistic user interfaces are intended to enhance visitor interactions with a single exhibit at a time. In this fashion, computer-based exhibits can be scaled up to support multiple simultaneous users, transforming the traditional single-user kiosk experience into a collaborative learning opportunity. The semi-private setup allows visitors to transition from peripheral to central roles in the shared experiences, and offers the promise of customized scaffolding to support user interactions with exhibits.

Exemplar 4: Cyber-stretching: The Taiga biome around kids' worlds by Steven J. Zuiker, Learning Sciences Lab, National Institute of Education, Singapore

Science education takes place in functional learning environments in and out of school settings (Scribner & Cole, 1973), and increasingly through designed spaces that cut across these settings. *Quest Atlantis* (QA) is a virtual space that leverages cyber-infrastructure and the technologies and methodologies of videogames to design for transformative play in these functional ways (Barab et al., 2009). Learners from a variety of countries, including Singapore, develop scientific knowledge through participation in QA activities and practices.

One popular unit engages learners as field investigators exploring water quality issues in the Taiga biome (Barab, Zuiker, et al., 2007). Highlighting the confluence of informal science education and learning sciences, these QA experiences are shaped by the diversity of cultural-historical backgrounds as much as the demands of QA's quests, missions, and units. Leveraging this diversity as a resource for learning is a central focus of the QA design. However, it remains unclear whether, and how, interactions provoke learners to think about themselves as systematic yet distinctive knowers and users of, and occasionally contributors to, science.

This analysis considers how the QA Taiga unit facilitates and, at times, frustrates social practices of meaning making in lived, albeit virtual, experiences. The analyses draws on case studies of Singaporean youth engaging QA in after-school programs and at home and contrasts them with other less informal school-based instances where teachers and students agreed that their classroom would function under a set of dramatic conventions that work to shift epistemic authority.

Exemplar 5: Understanding the pieces of knowledge in informal learning environments by Tom Satwicz, University of Washington

What role do informal learning environments play in life-long learning? Bruner (1996) speculated that many of life's experiences provide us with an intuitive understanding of more complex scientific theories. For instance, a young child playing with a seesaw develops an initial understanding of the rule of the lever, which may later be developed into a formal abstract algebraic form. Other work has argued that initial experiences result in small bits of functional knowledge that when overextended lead to misconceptions (Smith, diSessa, & Roschelle, 1993). Given the importance of prior knowledge in supporting new learning, informal learning environments offer important initial encounters with elements of more complex theories.

This analysis explores how artifacts, particularly new technologies, present in a variety of informal learning environments, provide representations of knowledge elements that may be later used in STEM learning. The analysis utilizes a framework that combines a knowledge in pieces perspective (diSessa, 1996) with Distributed Cognition (Hutchins, 1995) to analyze video recordings of young people playing commercially available video games. It is then argued that embedded into many games are elements of STEM knowledge that may be productively utilized in formal educational settings.

One case in particular explores a six year old boy's initial understanding of probability as evidenced by his talk-in-interaction while playing a mini-game on the popular website Webkinz. The analysis demonstrates that initial knowledge fragments are present in a combination of cognitive, social, and material resources that are coordinated in the service of solving a complex task.

Exemplar 6: Using digital photography on an Internet portal to extend and enrich outdoors learning experiences by Heather Toomey Zimmerman, Robert Jordan, Jennifer Weible, and Chris Gamrat, The Pennsylvania State University

This analysis reports on a research and design project that created an Internet-based photograph-sharing portal for a nature center and its visitors. The nature center has diverse programs, including an overnight school for fifth graders, outdoor trails for the general public, presentations for family audiences, and a visitors' center with exhibitions and live animals. The goal of the photograph-sharing website was to enrich existing programming in two ways. First, the portal allows visitors to extend and connect learning experiences across time and space (i.e., home, the center, and other Internet-enabled places). Second, photographic documentation of the center, with the ability to share and view others' photographs, allows visitors to focus observations of their community on ecology related phenomena and increase curiosity about ecological concepts.

Theoretically, the design work and resulting research build from a distributed intelligence and cognition frame (Pea, 1993; Hutchins, 1995), a "making thinking visible in a shared community" principle (Bell, 1997) from a knowledge integration perspective (Linn, 2006), and a model of family learning where parents and children work together to make sense of new content that they observe (Zimmerman, Reeve, & Bell, in press).

This project started with formative research on how Association of Science-Technology Centers' (ASTC) institutional members (i.e., science centers) use web 2.0 and related technologies with their members, especially families. This included a textual analysis with quantitative coding of 342 ASTC science center's websites. These findings on current educational practice with web 2.0 technologies, especially the role of photographs in science learning institutions, were used to design a new portal that encouraged visitors to share their experiences at the nature center from late winter to early spring as the center's grounds and trails changed with the seasons' change. The visitors could share their observations through photographs and writing a brief statement. The pilot study of the portal's use includes family and adult visitors groups that attended the nature center on weekend days. Methods include interviews, observations of groups using the portal, and analysis of visitor created digital artifacts. We report on the formative research, the design elements, and the pilot study of the portal being available to the membership of the nature center, both onsite and online.

Exemplar 7: Innovative Tools and Student Perceptions of Technology: Owl Tracking and GIS Mapping with Fifth and Sixth Graders by Sandra Toro Martell, University of Wisconsin-Milwaukee

Media representations and digital technologies can be used in conjunction with traditional hands-on approaches to promote engagement in authentic science activities in informal settings (Bell, Lewenstein, Shouse, & Feder, 2009). Previous studies have demonstrated that advanced technologies can help people "learn to see" in specific disciplines (Stevens & Hall, 1998), support visitor-to-visitor knowledge communication, and allow for new forms of knowledge communication among unacquainted visitors and beyond the actual museum visit (Stevens & Martell, 2003; Knipfer et. al, 2009).

This descriptive study builds upon these understandings by showing how urban fifth and sixth grade students' use of innovative technological tools informed their understanding of technology and their own learning across settings. Data from two sets of students over two years include student interviews, post-museum visit questionnaires, and videotaped observations of group activities around GIS Mapping in a school lab setting and use of owl tracking radar in a museum and outdoors.

This analysis sheds light on how these different resources can help children build understandings of scientific practices and discusses implications for both learning sciences researchers and informal science education practitioners in terms of the design and development of curricula that features both traditional and innovative technological tools.

Exemplar 8: Take a Stand: Creating an immersive social experience with people tracking, 3D game technology, and interactive storytelling by Matthew Brown and Ben Loh, Inquirium and Joyce Ma, Researcher/Evaluator.

This analysis presents the design and formative evaluation of Take A Stand, an interactive immersive exhibit installed at the Illinois Holocaust Museum and Education Center. The exhibit aims to teach young visitors the universal lessons related to the Holocaust (i.e., the power of one's actions, the challenges of standing up for others, and the importance of dealing with bullying) in the safety of an age-appropriate, simulated world. Using a computer vision-based people tracking system married with modern 3D video game technologies and a massive display, Take a Stand physically immerses visitors in a game-like narrative that places them in the role of bystanders in a socially fraught situation where they must decide whether and how they might want to act. Through their interactions, visitors experience personal agency and a sense that their actions can make a meaningful difference.

The formative evaluation considers two types of visitors: (a) 8-11 year old students who come as part of their school field trip (the target audience), and (b) casual museum visitors who visit apart from a larger organized group (the secondary audience). The study involves observation and informal interviews of approximately 120 visitors and their facilitators during the exhibit experience, which included an exhibit play as well as a docent-led introduction and debrief session.

The analysis discusses: (1) design goals and challenges, (2) technical implementation, (3) affective and cognitive goals, and (4) affordances of the technology for supporting new forms of informal experiences and learning. Implications are given based on this example on how to design simulated worlds to support informal science learning.

Symposium significance

The dual focus of this session, on the design of learning environments and the study learners engaged with technologies in out-of-school time, advances theoretical constructs and design principles of interest to learning scientists and informal science educators. This work adds empirical accounts to address outstanding questions in the recent NRC document (2009) about the nature of learning with media. Additionally, it adds needed out-of-school perspectives to learning sciences fields where the school-based accounts of learning with technologies often dominate the learning technologies discussions.

Discussants

Sherry Hsi from the Lawrence Hall of Science and Brian K. Smith from the Rhode Island School of Design will each present short remarks on the impact of this work on the learning sciences field and on educational practice in non-school environments.

References

Abowd, G., Atkeson, C., Hong, J., Long, S., Kooper, R., & Pinkerton, M. (1997). Cyberguide: A mobile context-aware tour guide. *Wireless Networks*, 3(5), 421-433.

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning science in informal environments: People, places, and pursuits.* Washington, D.C.: National Academies Press.

Benta, K. I. (2005). Affective aware museum guide. In *Proceedings of IEEE International Workshop on Wireless and Mobile Technologies in Education* (WMTE '05), Nov. 28-30, 2005, (pp. 53-55).

Bruner, J. (1996). *The culture of education*. Cambridge, MA: Harvard University Press.

Bruns, E., Brombach, B., Zeidler, T., & Bimber, O. (2007). Enabling Mobile Phones To Support Large-Scale Museum Guidance. *Multimedi*a, 14(2), 16-25.

Chou, S. C., Hsieh, W. T., Gandon, F., & Sadeh, N. (2005). Semantic Web technologies for context-aware museum tour guide applications. In *Proceedings of the 19th International Conference on Advanced Information Networking and Applications* (AINA '05), March 28-30, 2005, (pp. 709-714).

Coyle, K. (2006). *Environmental Literacy in America: What Ten Years of NEETF/Roper Research and Related Studies Say about Environmental Literacy in the U.S.* Washington, DC: The National Environmental Education & Training Foundation.

diSessa, A. (1996). What do 'just plain folks' know about physics? In D. R. Olson & N. Torrance (Eds.), *The handbook of education and human development* (pp. 709-730). Malden, MA: Blackwell Publishing.

Hutchins, E. (1995). Cognition in the wild. Cambridge, MA: MIT Press.

Kanter, D. E. and M.A. Schreck (2006). Learning Content Using Complex Data in Project-based Science: An Example from High School Biology in Urban Classrooms. New Directions in Teaching and Learning, 108, 77-91.

Klopfer, E., Perry, J., Squire, K., & Jan, M. (2005). Mystery at the Museum – A Collaborative Game for Museum Education. In Proceedings of Proceedings of the conference on Computer Supported Collaborative Learning (CSCL '05), Taiwan, (pp. 316-320).

Knipfer, K., Mayr, E., Zahn, C., Schwan, S., & Hesse, F. W. (2009). Computer support for knowledge communication in science exhibitions: Novel perspectives from research on collaborative learning. Educational Research Review. 4(3), 196-209.

Linn, M. C. (2006) The knowledge integration perspective on learning and instruction. In R. K. Sawyer (Ed.) *The Cambridge handbook of the learning sciences* (pp. 243-264). New York: Cambridge University Press.

Lyons, L. (2009). Designing Opportunistic User Interfaces to Support a Collaborative Museum Exhibit. In *Proceedings of the 8th International Conference on Computer Supported Collaborative Learning*, Rhodes, Greece, June 8- 13, 2009, (pp. 375-384). ISLS.

National Research Council, 1999. (Bransford, J. D., Brown, A. L. & Cocking, R. R. (Eds.). *How people learn: Brain, mind, experience, and school.* Washington, D.C.: National Academies Press.

National Research Council, (2010). *Surrounded by Science*. Washington, D.C.: National Academies Press

National Research Council, (2009). Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A., (Eds.) *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington, D.C.: National Academies Press

Pea, R. (1993). Practices of distributed intelligence and designs for education. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 47-87). Cambridge: Cambridge University Press.

Sawyer, R. K. (Ed.), (2006) *The Cambridge Handbook of the learning sciences*, New York: Cambridge University Press.

Smith, J. P., diSessa, A. A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *The Journal of the Learning Sciences*, 3(2), 115-163.

Stevens, R. & Hall, R. (1998). Disciplined perception: Learning to see in technoscience. In M. Lampert & M. L. Blunk (Eds.), *Talking mathematics in school: Studies of teaching and learning*. New York: Cambridge University Press.

Stevens, R. & Martell, S. T. (2003). Leaving a trace: Digital meta-exhibits for supporting visitors to represent and exchange their ideas about museum exhibits. *Journal of Museum Education 28*(2), 25-31.

Tallon, L., & Walker, K. (2008). Digital Technologies and the Museum Experience: Handheld Guides and Other Media. Lanham, MD: Altamira Press.

Yatani, K., Sugimoto, M., & Kusunoki, F. (2004). Musex: A System for Supporting Children's Collaborative Learning in a Museum with PDAs. In *Proceedings of the 2004 IEEE International Workshop on Wireless and Mobile Technologies in Education*, Taoyuan, Taiwan, (pp. 109-113). IEEE Computer Society.

Yiannoutsou, N., Papadimitriou, I., Komis, V., & Avouris, N. (2009).”Playing with” museum exhibits: designing educational games mediated by mobile technology. In *Proceedings of the 8th International Conference on Interaction Design and Children,* Como, Italy, (pp. 230-233). ACM.

Zimmerman, H. T., Reeve, S. & Bell P. (in press). Family sense-making practices in science center conversations. Science Education. DOI 10.1002/sce.20374

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POSTERS

FormulaT Racing: Combining Gaming Culture and Intuitive Sense of Mechanism for Video Game Design

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Abstract: While video games are typically labeled either commercial or educational, little has been done to amplify the educational value of popular commercial games. Using data from a pilot study of children playing commercial games we have developed a prototype video game called FormulaT Racing. This game is designed to fit into gaming culture while simultaneously providing an environment that draws on players' intuitive beliefs to move them to a qualitative understanding of basic kinematic principles.

Introduction

Video games constitute an important part of the lives of youth in today's world. The PEW Internet and American Life Project claims that as many as 97% of American youth play video games and 50% play games daily for an hour or more (Lenhart et al., 2008). Although much has been written about the potential for video games to serve as powerful learning environments in science (Gee, 2003; Kafai, 1996), these games are typically dubbed "educational" or "serious" and are not embraced by the mainstream audience.

We believe that commercial video games are an untapped domain ripe with educational potential. In an effort to increase the educational value of commercial video games we have designed a prototype game we call FormulaT Racing. While others have attempted to build "games" to teach kids about kinematic principles, our game is different in that it was designed to foreground kinematic principles while still being consistent with current video game culture. Specific design components of FormulaT Racing are based on an analysis of a previous ethnographic study of children playing commercial racing video games. In this study we uncovered features of games that instantiated the player's intuitive schema of velocity, acceleration, and momentum. These design components were then altered and adapted in our design of FormulaT Racing.

Theoretical Framework and Method

Our attempt to create a design framework for increasing the educational potential of popular commercial video games proceeds in three phases. The first phase of this work was a study involving ethnographic observations and semi-clinical interviews of participants playing Burnout Paradise on the XBox 360, and Mario Kart Wii on the Nintendo Wii. These interactions were videotaped, transcribed, and coded inductively in an iterative process over multiple passes. To uncover the game designs that activate players' intuitive theories of motion we created an analytical framework that utilizes Roschelle's (1991) concept of registrations and diSessa's (1993) sense-of-mechanism. Roschelle (1991) describes registrations as, "the way students carve up their sensory experience, give labels to parts, and assign those labeled parts significance" (p. 9). In our study, a player may develop a registration of "turning" as a combination of a specific manipulation of the controller as it relates to on-screen action. To analyze how players label registrations, we borrow diSessa's (1993) notion of sense-of-mechanism. In diSessa's well-known framework, knowledge elements are composed of phenomenological primitives (p-prims). While playing racing games players commonly instantiated Ohm's p-prim (that more force yields greater result) by "mashing" the gas button even when their vehicle was at its top speed.

In the second phase of our overall research plan we are constructing a prototype racing game that incorporates a specific design framework developed from the analysis of the ethnographic study. In the study, players attended to three key design components: the spatial relationship between the player car and other vehicles or features on the screen as a representation of velocity, the tendency to assume acceleration was a static property of the player's vehicle, and the importance of the analog nature of the controller. FormulaT Racing is designed to look and feel like a typical commercial racing game while incorporating specific and subtle design tweaks meant to move these intuitive theories of kinematics to a more expert-like understanding.

FormulaT Racing Design

FormulaT Racing was created in the agent-based software NetLogo (Wilensky, 1999). The ability to easily look "under the hood" and quickly manipulate code makes NetLogo an ideal programming environment for a video game prototype. FormulaT Racing is a microworld (Edwards, 1995) designed to cue the same registrations and p-prims found in popular commercial racing games. Specific design features of FormulaT Racing include the use of a motion-sensitive analog controller, external cues as a context for velocity and acceleration, the use of formal terminology, "just-in-time + 1" feedback, action-oriented representations for qualitative vector addition, and a scaffolding system consisting of multiple representations. These designs are intended to tweak the previously identified registrations to more accurately represent velocity and acceleration and to subtly encourage the player to notice relationships between the two quantities.

FormulaT Racing puts the player in the shoes of a new driver as they train to join the FormulaT Racing Circuit. Early "levels" are structured as driving skill tests and take place on a straight continuous track. Examples of skill tests include driving at a constant velocity, driving at constant acceleration, and learning to manipulate a motion sensitive controller to achieve these desired states. In our observations we noticed that players typically "mashed" the buttons often leading them to miss the acceleration phase—for them the car was either going slow, or fast. In FormulaT Racing players utilize a Nintendo Wiimote controller that is motion sensitive to manipulate their car. Actions were carefully mapped to highlight the vector nature of quantities and to be body-syntonic and cognitively coherent. For example, acceleration is achieved by rolling the controller forward (positive) or backwards (negative). Many challenges force the players to dynamically adjust the roll applied causing them to reflect on acceleration as a changing quantity that directly impacts velocity.

Before racing, players are given their objective from a pit boss. While racing the pit boss occasionally gives tips and corrections using audio cues to help the player achieve level objectives. Key to the pit boss design is the use of formal physics terminology and "just-in-time +1" feedback. Because the informal nature of the typical language utilized in video game helps to draw the player into the game, it is important for our prototype to carefully consider the use of formal physics terminology. Our solution was to keep the "attitude" of the language, such as having the pit boss speak in a southern accent, but to use formal terminology, such as "velocity" rather than "speed." When giving corrective advice we decided feedback would be more valuable if it were given just after it was needed. This "just-in-time + 1" feedback allows the player to reflect on the outcome of his errant technique so that he can better understand why a certain technique works in a given situation.

Data from ethnographic observations suggested players typically determined their own vehicles velocity and acceleration by looking at the spatial relationships between the player car and the competition cars. To utilize this registration, in each of the early levels the player sees his own car, a street complete with lane markers spaced a regular intervals, and a competition car. Because FormulaT Racing does not provide a speedometer, players must utilize the other car on the track to determine if they are succeeding in the task. For example, in the constant velocity challenge the player must catch up to another car on the track and match the other vehicle's speed (the other car moves at a constant velocity). We have also incorporated a velocity vector addition feature in the disguise of a "reverse time" special ability. Once players obtain this ability they can press a button that moves their car back a few time steps and reveals an animated vector arrow showing their current velocity vector. Players can then dynamically draw a new vector that will be added behind the scenes. Through repeated use players can gain a qualitative sense of vector addition.

Taking a constructionist design approach (Papert & Harel, 1991) FormulaT Racing also incorporates a set of tools that encourage reflection by changing the nature of representation. In later levels, rather than drive the car using a gas and brake button, the player "paints" the racetrack different colors, each color corresponding to a different speed (acceleration can be painted as well). Another level forces the player to construct a velocity vs. position graph that the car then matches as it drives around the racetrack. In these levels the player must demonstrate a deep understanding of the relationship between velocity and acceleration to be successful.

Conclusion

We've presented FormulaT Racing, a prototype video game designed from pilot data of kids playing racing video games. The intention of FormulaT Racing is to create a game that accomplishes the twin goals of being consistent with kids' video game culture and making salient core kinematic concepts. FormulaT Racing will next be implemented in an after-school program. The new game designs will be evaluated by observational data and with an adapted post-test method. Data from this experiment will be presented with the poster.

References

diSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and instruction*, *10*(2 & 3), 105-225.

Edwards, L. D. (1995). Microworlds as representations. *Proceedings of the 2nd International NATO Symposium on Advanced Technology and Education*

Gee, J. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Kafai, Y. B. (1996). Learning design by making games: Children's development of design strategies in the creation of a complex computational artifact. In Y. B. Kafai & M. Resnick (Eds.), *Constructionism in practice: Designing, thinking, and learning in a digital world*. Mahwah, NJ: Lawrence Erlbaum.

Lenhart, A., Kahne, J., Middaugh, E., Macgill, A. R., Evans, C., & Vitak, J. (2008). *Teens, Video Games, and Civics.*

Papert, S., & Harel, I. (1991). *Constructionism*. New York: Ablex Publishing.

Roschelle, J. (1991). *Microanalysis of qualitative physics: Opening the black box.* Chicago, IL.

Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University. Evanston, IL.

I Don't Do Science: Urban Minority Girls' Science Identity Development in an Informal Authentic Science Context

Abstract: Urban middle school girls participated in a 10-week voluntary, after-school science club, Science STARS, designed to foster positive science identity development through collaborative, authentic science experiences, culminating in recognition of this work among peers and community members. This study explores the specific roles and paths five participating girls took through STARS as they developed a more positive scientific identity and the role of the facilitators in that development.

Introduction

Urban middle school girls (N=60) at three sites participated in a 10-week after school science club, Science STARS (Students Tackling Authentic & Relevant Science), designed to foster positive science identity development as well as developing expertise in understandings of both science content and process. However, there is very little research about what experiences, tools, and other conditions within informal science environments enable this kind of identity development (NAS, 2009), especially within the under-represented population of urban female youth. During Science STARS, participants met weekly to develop and conduct a student-chosen investigation relating to the overarching theme "Shrinking our Ecological Footprints". As urban middle school girls successfully engaged in scientific discourse that had a perceptible positive impact on their world, they developed a meta-awareness of their possible roles in science, and they were able to see themselves as more interested in the kinds of work being done, the usefulness of the results of science, and their competence as contributors to this work. This study explores the specific roles and paths five participating girls took through STARS as they developed a more positive scientific identity. Each small group is facilitated by pre-service science teachers enrolled in a graduate program that emphasizes reform-based teaching practices in the context of social justice. This study also explores the impact of these facilitators on participants' identity development.

Literature Review & Theoretical Framework

Recent research suggests that identity development plays a pivotal role in how girls come to see themselves as science learners and contributors (Brickhouse & Potter, 2001). This is particularly problematic for urban middle school girls who often belong to low socio-economic classes and race/ethnicities that have been traditionally under-represented in science (Brown, 2004). There is evidence that girls' attitudes towards and achievements in science begin to drop during middle school (Atwater, Wiggins, & Gardner, 1995), a particularly important time for developing high school trajectories and beyond (AAUW, 1996). Multiple reasons for this phenomenon have been identified including: girls do not find school science interesting because they do not see its relevance to their lives or communities and perceive scientific work as isolated and non-collaborative (Miller, Blessing, & Schwartz, 2006); girls are marginalized in school science in subtle yet pervasive ways, including differential treatment from teachers, who have narrow expectations about what boys and girls achieve, and from counselors, who make different recommendations about science course selections for girls (Sadker & Sadker, 1994); and social and parental expectations often convey discriminatory messages that preference males and white peoples' participation in science (Dentith, 2008). The paradoxical reality is that the very discourse that prescribes and thus restricts one's identity can serve as the context where a person renegotiates a new identity (Holland, Lachicotte, Skinner, & Cain, 1998).

Research Design

An exploratory case-study approach was used to address two questions: In what ways did STARS impact individual participant's development of a science identity? What features of the learning environment emerged as central for framing girls' development? Data sources, spanning both emic and etic, included: pre-STARS surveys focused on characterizing participants' science identity, mid- and post-interviews, weekly participant journals, researcher field notes, and audio transcriptions of STARS sessions. At the conclusion of Science STARS, each participant was showcased in a mini-documentary about the science they studied and their role as scientists. Data analysis was conducted by four science educators considering lenses of identity development (Wenger, 1998; Barton, Tan, & Rivet, 2008), ecological features of given environments that contribute to learning (Newstetter, 2009) as well as through open-coding of emergent themes (Strauss & Corbin, 1990). Major codes focused on girls' forms of participation, roles of facilitators and environmental features. Codes and categories were triangulated among the four researchers.

Results

Five participants were selected as case studies because they expressed on their surveys views of self as not a science person, not good in science, and/or having no expectations to use science in their future at the start of STARS. They represented the target audience for Science STARS. In the poster presentation we will present detailed data on all five case. Here we briefly detail two cases, Brittany and India. Both Brittany and India experienced significant shifts during STARS as evidenced by the increased depth of their science interactions. Often these interactions involved shifting from private participation (with a peer or a facilitator) to voluntary public participation. They both also evidenced shifts in identity towards seeing self as scientist, moving from an outsider perspective to an inbound perspective (Wenger, 1998). Specific ecological features (Newstetter, 2009) of STARS' work that contributed positively and in identifiable ways to their development involved the impact of wrestling with uncertainty (key for India), the role of embodied learning (key for Brittany), experiencing agency (key for both), and making room for diverse participation (key for both). In Brittany's and India's groups, the facilitators made room for diverse participation by creating space, advocating for each girl individually, and at times scaffolding participation until the girl in question began to volunteer her involvement. The facilitators also routinely physically engaged the girls with science artifacts, and respected student voices by letting the individual girls' ideas guide the direction of the next session. Lastly, the facilitators' attention (or lack of) to uncertainty in science was significant in the learning environment.

Discussion & Implications

Implications of this work are two pronged. First, the results of this study suggest that future design and implementation of science programs should seek to foster participation among marginalized youth, whose voices are often missing from the scientific enterprise, through 1) authentic science experiences, 2) continued utilization of informal contexts which can replace the high pressure of seemingly irrelevant high stakes testing with a perceptibly more authentic and meaningful high stakes assessment, such as the public documentary, and by 3) capitalizing on the brief window offered by the middle school years as a critical time to nurture a positive view of self as scientist. Second, this research contributes to our understanding of the role of the facilitator to create space for engagement/participation and to instigate/initiate identity transformation. Questions are raised as to how best to support the facilitators to capitalize on the opportunities they have to impact science identity development.

References

American Association of University Women Educational Foundation. (1996). *Girls in the Middle*. Washington, DC: American Association of University Women.

Atwater, M., Wiggins, J., & Gardner, C. (1995). A study of urban middle school students with high and low attitudes toward science. *Journal of Research in Science Teaching, 32*, 665-677.

Barton, A., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *American Educational Research Journal, 45*(1), 68-103.

Brickhouse, N. & Potter, J. (2001). Young women's scientific identity formation in an urban context. *Journal of Research in Science Teaching, 38*(8), 965-980.

Brown, B. (2004). Discursive identity: Assimilation into the culture of science and its implications for minority students. *Journal of Research in Science Teaching, 41*(8), 810-834.

Dentith, A. (2008). Smart girls, hard-working girls but not yet self-assured girls: The limits of gender equity politics. *Canadian Journal of Education, 31*(1), 145-166.

Holland, D., Lachicotte Jr., W., Skinner, D., & Cain, C. (1998). *Identity and Agency in Cultural Worlds.* Cambridge, MA: Harvard University Press.

Miller, P., Blessing, J., and Schwartz, S. (2006). Gender differences in high-school students' views about science. *International Journal of Science Education, 28*(4), 363-381.

National Academies Press. (2009) *Learning Science in Informal Environments*. Washington, D.C.: National Academies Press.

Newstetter, Wendy. (2009) Learners in complex settings: Agentive Learning in University Research Laboratories. Paper presented at the *National Association for Research in Science Teaching*. Garden Grove, CA.

Sadker, M., & Sadker, D. (1994). *Failing at fairness: How our schools cheat girls.* New York: Simon & Schuster.

Strauss, A. L. and J. Corbin (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, Calif., Sage Publications.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity.* Cambridge, Great Britain: Cambridge University Press.

Expertise in Engineering Learning: Examining Engineering Students' Collaborative Inquiry of Computer Systems

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Abstract: This work studies how expertlike engineering undergraduates learned about computer systems modeling and simulation through collaborative inquiry. From a close examination of the student artifacts, noticeable differences between expertlike engineering learners and their non-expertlike counterparts were found. Such differences were consistent to literature. Although inquiry-based learning and collaborative learning have long been recommended as pedagogy to enhance student learning and knowledge construction, experts and novices still demonstrate various differences in their collaboration and inquiry process.

Introduction

Engineering is one of the difficult knowledge domains. Engineers not only need to understand how computer systems work, they also need to know how to develop such systems and to optimize their performance. Traditional computer systems often involve only one client (the entity that requests) and one server (the entity that responses with requested service). However, as technologies advances, nowadays computer systems such as those for handling stock exchange and supply chain management often adopt a multi-tier architecture. A number of recent studies take in the perspective of learning sciences to look into engineering student learning (such as Chan, 2007; Chan, Hui & Dickinson *et al.*, 2009).

There are a few works that distinguish between expert and novice learners in the engineering subject domain. For example, Basili, Selby and Hutchens (1986) studied how experts and novices developed software with specific requirements, and found that experts could analyze the documents using their "own" way and work effectively, but novices needed training and required a procedural approach. Schenk, Vitalari and Davis (1998) investigated how expert and novice system analysts approached the information systems differently and accomplished the tasks differently. They identified the differences in their problem-solving approach in which experts analysis were more creative. Soloway and Ehrlich (1984) explicitly designed an experiment to study between expert and novice programs and notice that expert programmers possessed and used programming plans and rules of programming discourse when writing programs, while novice programmers did not.

Contributions of the Current Work

I am interested to find out the characteristics demonstrated by expertlike engineering learners who are engaged in a collaborative inquiry learning environment. I distinguish and illustrate the differences between expert and novice engineering learners with the subject contents of computer systems modeling and simulations. In particular, I attempt to characterize expertlike engineering students in terms of the followings:

1. How they approach to the problem? Do they approach it with a specific goal?
2. How are their problem-solving behaviors different from their peers? How they make use of given information and available resources to solve the problem?
3. How they organize and represent the subject knowledge?
4. How they collaborate within the group to undergo inquiry-based learning?

I answer the above questions by exploring the student artifacts produced from a collaborative inquiry-based learning conducted in a class of engineering undergraduates. My work may contribute disciplinary-specific examples and provide reference cases for the learning scientists.

Methods and Data Sources

The participants were 124 engineering undergraduates (104 males, 20 females) at the second to the third year (70 second year students, 54 third year students). They took a course for computer simulations and system modeling. These participants formed into groups of 3 to 5, and were engaged a collaborative-inquiry project about capacity sizing for an imaginary trading system. The students formed into 32 groups according to their own preference. Groups with more than half of the members having achieved G.P.A. of 3.5 or above are identified as expert groups. Based on this criterion, 6 out of the 32 groups were identified as expert groups; these groups involved 24 students (19% of all participants, 21 boys and 3 girl). The author admits that such selection criterion is not scientific enough. As a remedy, the two groups were further compared in terms of final examination scores in the course. The final examination was an individual assessment of students' overall learning and its assessment was independent of the project. Students in the expert groups ($M = 83.00$, $SD = 1.93$) different from their counterparts ($M = 64.47$, $SD = 11.11$) significantly ($p < .05$) in terms of final examination performance. Rather then naming the rest of the class as novice group, I refer them as the non-expert groups in the rest of this paper. The participants were required to submit project deliverables that document all planning, findings, and reflections along the project learning process as detailed as possible. Such deliverables reflected how students collaboratively tackled and understood the design problems.

Results

I compared the artifacts of the expert groups with that from the rest of the class. In accordance to the perspectives reviewed in (Bereiter and Scardamalia, 1993; Bruer, 1993; Chi *et al.*, 1981; Chi, Glaser & Rees, 1982), the following characteristics about how experts learn through collaboration and inquiry are identified.

1. Expert groups practiced progressive problem solving while most of their non-expert counterparts adopted the best-fit strategy.
2. Expert groups held knowledge-building goals and demonstrated extensive efforts in seeking external but related information.
3. Expert groups approached the problem with underlying principles and do not take in given information as is.
4. Expert groups demonstrated more sophisticated representation and organization of knowledge and concepts.
5. Expert groups adopted contemporary project management principles as strategies for collaboration and inquiry.

Based on the findings from this study, the followings are suggested for possible follow up in the future:

- Although inquiry-based learning and collaborative learning have been recommended as a pedagogy to enhance student learning and knowledge construction, expertlike learners still demonstrate various differences in their collaboration and inquiry process. Aligning to the previous literatures, they behave differently in a number of aspects such as the problem solving behaviors and the organization of knowledge. The findings discussed in the previous section may provide additional information to learning scientists for improving learning with similar settings.
- The current study provides important information about engineering learning and instruction, However, it is remarked that engineering educators should be aware about the prior knowledge that the students possess, and avoid exposing novices to expert models (Bransford, Brown & Cocking, 2000: p.50).
- Findings from the current studies do provide some useful hints on better implementation of constructivist pedagogies in the engineering discipline, as well as other disciplines in general. For example, contemporary project management skills such as better planning, testing, and documentation of the inquiry process, can be introduced to the students. One can also help the students defining project goal and objectives at the beginning of the projects. In particular, my findings also provide information on how expertlike learners work with system design and computer programming, which are the core competencies for engineering students.

References

Basili, V. R., Selby, R. W, and Hutchens, D. H., (1986) Experimentation in software engineering, *IEEE Transaction on Software Engineering, 12(7)*, 733 - 743.

Berieter, C., Scardamalia, M. (1993), *Surpassing Ourselves: An Inquiry into the Nature and Implications of Expertise*, Chicago, IL: Open Court.

Bransford, J. D., Brown, A. L., and Cocking, R.R. (2000), *How People Learn: Brain, Mind, Experience, and School*, Washington, D.C.: National Academy Press, 2000.

Bruer, J. (1993) *Schools for thought: A Science of Learning in the Classroom.* Cambridge, MA: The MIT Press.

Chan, Y.-Y. (2007). Teaching Queueing Theory with an Inquiry-Based Learning Approach: A Case for Applying WebQuest in a Course in Simulation and Statistical Analysis. In Proceedings of the 37th IEEE/ASEE Frontiers in Education conference, (F3C-1-6), Wisconsin, US.

Chan, Y.-Y., Hui, D., & Dickinson, A., R. et al. (2010). Engineering outreach: A successful initiative with gifted students in science and technology in Hong Kong. *IEEE Trans. on Edu., 53(1)*, 158 - 171.

Chi, M. T. H., Feltovich, P. J. and Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5(2)*, 121 – 152.

Chi, M. T. H., Glaser, R., and Rees, E. (1982). Expertise in problem solving. In R. Sternberg (ed), *Advances in the Psychology of Human Intelligence*, volume 1, Erlbaum.

Schenk, K. D., Vitalari, N. P. and Davis, K. S. (1998) Differences between novice and expert systems analysts: what do we know and what do we do? *Journal of Management Information System, 15(1)*, 9 – 50.

Soloway, E. and Ehrlich, K. (1984). Empirical studies of programming knowledge. *IEEE Transaction on Software Engineering, 10(5)*, 595 – 609.

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Multi-Touch Tabletop Computing for Early Childhood Mathematics: 3D Interaction with Tangible User Interfaces

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Abstract: Research is motivated by advances in early childhood mathematics, the design of virtual manipulatives, and the development of multi-touch, tabletop computing combined with tangible user interfaces. Requirements include: 1) horizontal tabletop design affords physical support for material objects, keeping same interaction structure as users move between physical, virtual, and tangible interactions; 2) tabletop configurations have shown to facilitate greater collaborative activity where students interact with artifacts on surface simultaneously.

Issues Addressed

Multi-touch user interfaces are a growing area of interest, particularly in the field of education. Direct interaction with virtual manipulatives has significant potential for the process of learning (Iishi, 2008; Stanton, et al., 2001). We are developing a multi-touch tabletop system targeted at teaching mathematical and geometric concepts to young students. Most research in multi-touch user interfaces is focused on user interactions in two dimensions. Our system is fundamentally different in that we employ side-mounted cameras to track user interaction, thus enabling the perception of depth from participants' hands to the tabletop's surface. We consider the implications and potential of interaction in three dimensions.

Potential Significance

Our system is distinguished by its ability to observe user interactions in all three dimensions. By employing side-mounted cameras instead of a single bottom-mounted camera or sensor technology, the system is able to observe the distance from the user's hand to the tabletop's surface, thus enabling depth perception (see Figure 1).

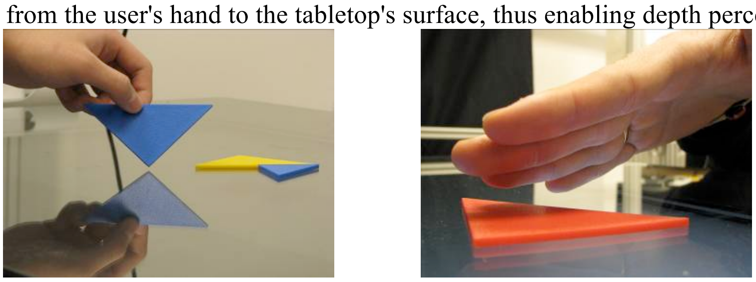

Figure 1: Perceiving depth from the user's hand to the table's surface.

Interaction in all three dimensions has significant potential for the process of learning. We hypothesize that a three-dimensional model more closely resembles the "real world" model that children naturally develop to interpret their physical surroundings than a traditional, two-dimensional user interface. This model has the potential to more effectively develop spatial cognition and geometric concepts by utilizing all three dimensions of interaction. Depth perception enables hand gestures that can provide an immersive, interactive computing environment. Imagine pinching and lifting a virtual block over another or flipping tangram pieces with the flip of a wrist. Three-dimensional gestures can also be integrated with traditional, two-dimensional user interfaces; consider pinching and lifting a virtual document and flinging it off screen to throw it away. One could also zoom into or out of a document by moving the hand into or out from the screen. The potential of depth perception in developing immersive, three-dimensional applications is limited only by software. Consider that a tangram application can support three-dimensional interaction by allowing pieces to be flipped by flipping the wrist rather than clicking a counter-intuitive, two-dimensional button that represents a three-dimensional action. Imagine a drawing application that enables students to draw "off the canvas," or a block stacking application that explores stacking virtual blocks in three-dimensional space with a two-dimensional representation mirrored on the screen.

Technical Solution Based on Tangible User Interactions

The horizontal touch surface is a 30" liquid crystal display covered with a sheet of glass for a smooth, protective surface. Two side-cameras are mounted at adjacent corners of the surface and point toward one central point on the display. Video streams from the cameras are processed on a Mac desktop system. Since no specialized hardware is used, the cost of the system is relatively low compared to projector-based multi-touch tables such as the Microsoft Surface or SMART Technologies SMART Table.

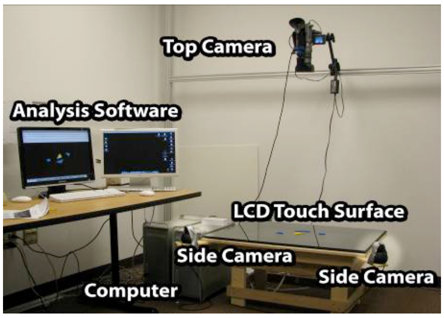

Figure 2: General apparatus and perspective of system.

Given that no specialized hardware is used, the system is mostly software-oriented. Prior to interacting with the system, the software first goes through a learning phase to compose a library of recognized shapes. These shapes are based on physical pieces that are placed on the touch surface. After the learning phase, the user may either interact with the physical pieces or directly manipulate virtual representations of the pieces. To track user interactions, the two video streams are combined to form one coherent, three-dimensional model of the touch plane. The system employs edge detection algorithms to track user fingertips and resolve occlusion when only a portion of a piece is visible.

Preliminary Findings, Conclusions, Implications

One of the greatest technical challenges of using side-mounted cameras to perceive depth is occlusion resolution. Occlusion occurs when a user's hand obstructs a camera's line of sight to a piece. The system must continue to observe the piece's translation and rotation when only a fraction of the piece is visible. Occlusion is resolved by mapping visible points of interest (e.g. corners and edges) to its corresponding library entry. Once this entry is identified, the blocked portion of the shape may be extrapolated. As a result, only a fraction of the shape must be visible to accurately observe the movement of the entire piece.

In addition to the benefits of depth perception, this approach inherits the benefits of traditional multi-touch systems. Research suggests that direct interaction with physical or virtual manipulatives more effectively develops geometric concepts than traditional, two-dimensional, graphical user interfaces (Clements, Sarama & DiBiase, 2003). Multi-touch surfaces are also shown to keep children's' attention longer and horizontal surfaces increase the creative process more so than vertical surfaces (Moulin, Lenne, Abel & Gidel, 2009). Virtualizing user interactions enables the system to monitor the collaborative process in real-time. This can potentially be used to streamline the analysis of user interactions and provide feedback to participants in real-time (Noss & Hoyles, 2006). This feedback has been shown to influence the participation of users; those that dominate the collaborative process tend to decrease their contributions, while those that have participated less increase their contributions (Bachour, Kaplan & Dillenbourg, 2009). Unlike with physical manipulatives, user interactions with virtual manipulatives may be moderated to influence the collaborative process. For example, child A may control only red pieces while child B may control only blue pieces. Moderating control over the collaborative process has also been shown to increase collaboration (Stanton et al., 2001).

References

Clements, D.H., Sarama, J., & DiBiase, A-M. (2003). *Engaging Young Children in Mathematics: Standards for Early Childhood Mathematics Education.* Mahwah, NJ: Lawrence Erlbaum.

Iishi, H. (2008). The tangible user interface and its evolution. *Communications of the ACM, 51*(6), 32-36.

Noss, R., & Hoyles, C. (2006). *Exploring mathematics through construction and collaboration.* In K. Sawyer (ed.). The Cambridge Handbook of the Learning Sciences, (pp. 389-405). New Your: Cambridge University Press.

Stanton, D., Bayon, V., Neale H., Ghali A., Benford, S., Cobb, S., et al. (2001). Classroom collaboration in the design of tangible interfaces for storytelling. Proceedings from SIGCHI conference: *Human factors in computing systems*. Seattle, Washington: ACM.

Bachour, K., Kaplan, F., & Dillenbourg, P. (2009). *An Interactive Table for Supporting Participation Balance in Face-to-Face Collaboration*. Retrieved from http://ses.telecom-paristech.fr/baker/bachour-dillenbourg.pdf

Moulin, C., Lenne, D., Abel, M., & Gidel, T. (2009, December). *Interactive Table for Collaborative Project Training*. Workshop presented at the second event of 2009 Alpine Rendez-Vous held by STELLAR, Garmisch-Partenkirchen, Germany.

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Students' Plausibility Perceptions of Human-Induced Climate Change

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Abstract: Overcoming students' misconceptions may be a challenge when teaching about global climate change because students tend to confuse short-term weather effects with long-term climate transformations, which may stem from misunderstandings about deep time. Furthermore, student plausibility perceptions about human-induced climate change may influence understanding of scientific principles underlying the phenomenon. This study showed significant relationships between understandings of weather and climate distinctions, deep time, and plausibility perceptions of human-induced climate change after instruction.

Purpose of the Study

As students encounter global climate change in school and the media, they often approach the phenomenon with misconceptions. Research studies have revealed several of these misconceptions, including confusion about the distinctions between weather and climate (see for example, Papadimitriou, 2004). The purpose of this study was to examine how knowledge of these distinctions is associated with two additional and potentially related variables: plausibility and understanding of deep time. Plausibility is a critical construct in conceptual change (Dole & Sinatra, 1998). Change is more likely when students find the new conception to be highly credible. Appreciating deep time (or extremely long time periods), is essential to understanding several topics covered in science courses, including biological evolution, stellar life cycles, and global climate change. However, understanding deep time is difficult for students (see for example, Trend, 2001).

Theoretical Framework

Weather involves short duration atmospheric events at a particular location; whereas, climate is weather conditions averaged over long-term periods (at least a few decades) and wide areas (National Climatic Data Center, 2008). Weather and climate distinctions are not clear-cut, however. For example, one can discuss a severe weather outbreak over a wide region. Such ambiguities create challenges for students in understanding weather and climate distinctions, which have been the focus of a wide variety of research efforts (see for example, Papadimitriou, 2004).

Although the research community has thoroughly documented misconceptions about weather and climate distinctions, there has been much less research into how students can overcome these misconceptions. Students may experience cognitive conflict when exposed to scientific theories that are anomalous to their existing conceptions (Chinn & Brewer, 1993). For strong conceptual change, the new conception must be plausible (Dole & Sinatra, 1998). In the case of climate change, confusions about the distinction between weather and climate may contribute to views of human-induced climate change as implausible (Connell & Keane, 2006). Students' knowledge of how geophysical processes change over time may also affect their understanding of weather and climate distinctions; however, understanding deep time has proven difficult for students (see for example, Dodick & Orion, 2003).

Therefore, our purpose in conducting this study was to examine the variance in understanding of weather and climate distinctions explained by knowledge of deep time and perceptions of plausibility that humans are exacerbating changes to Earth's climate. We hypothesized that (1) knowledge of deep time would explain a significant amount of variance in student understanding of weather and climate distinctions above the variance accounted for by prior knowledge. We also hypothesized that (2) plausibility perceptions would provide explanatory power over and above that attributable to prior knowledge about these distinctions and knowledge of deep time.

Methods

Eighty-three undergraduate students from a university in the southwestern United States participated in the study. These participants were predominantly female (64%) and White (62%). Participants ranged in age from 18 to 66, and represented all undergraduate levels with 25% being Freshmen, 31% Sophomores, 29% Juniors, and 15% Seniors. We recruited participants from science courses in the university's geosciences department.

We used three questionnaires to examine: (1) knowledge of distinctions between weather and climate, (2) plausibility perceptions of human-induced climate change, and (3) understanding of deep time. Based on misconceptions research (see for example, Papadimitriou, 2004), we created a knowledge of weather and climate distinctions questionnaire (DWCM), where students classified 13 statements as related to either "weather" or "climate." We measured student understanding of deep time using the GeoTAT instrument, developed by Dodick and Orion (2003). The GeoTAT consists of six open-ended questions measuring "understanding of the temporal relationships among geological strata and their fossil contents" (p. 420). We also developed the plausibility perceptions measure (PPM), where students rated plausibility of eight statements about human-induced climate change culled from the latest report made by the United Nations' expert panel on global climate (Intergovernmental Panel on Climate Change, 2008). Participants completed the three questionnaires online through the university's course management system, and through this system, we made the questionnaires available to the students at the beginning and near the end of a semester's instruction. The participants first completed the DWCM, then the PPM, and finally the GeoTAT during both the pre and post instruction measurement periods.

Results and Discussion

To examine how well student understanding of deep time and plausibility perceptions of human-induced climate change explained understanding of distinctions between weather and time after instruction (DWCM post), we conducted a hierarchical multiple regression analysis. To account for background knowledge, we first entered DWCM pre, followed by GeoTAT post, and then PPM pre. Table 1 summarizes the results of our analysis, including means and standard deviations. For the full model, R^2 was significant, $F(3,79) = 10.90$, $p < .01$, indicating that about 29% of the variance in DWCM post was explained by the three independent variables. DWCM pre accounted for about 18% of the variance, with GeoTAT post accounting for an additional 6% of the variance above DWCM pre, and PPM pre accounting for an additional 5% above GeoTAT post. The results from the multiple regression analysis support both of our hypotheses that (1) understanding of deep time explains student knowledge of weather and climate distinctions after instruction above and beyond their prior knowledge about these distinctions and (2) plausibility perceptions of human-induced climate change add significant explanation above and beyond deep time understanding.

Table 1: Hierarchical regression predicting student understanding of weather and climate distinctions after instruction (DWCM post, $M = 9.30$, $SD = 1.94$).

	R^2	ΔR^2	ΔF	p	M	SD
Step 1: DWCM (Pre)	.183	.183	18.10	< .01	7.89	2.26
Step 2: GeoTAT (Post)	.242	.059	6.26	.014	12.75	4.33
Step 3: PPM (Pre)	.293	.051	5.69	.019	7.53	1.42

Note. The possible score range was 0 to 13 for the DWCM, 1 to 10 for the PPM, and 0 to 32 for the GeoTAT.

Conclusions

The results of this study reveal that greater knowledge of deep time and increased plausibility perceptions about human-induced climate change explain an increased of weather and climate distinctions, a common source of misconceptions related to global warming. To our knowledge, this is the first empirical study showing a significant relationship between plausibility and changes in knowledge, which in turn provides support to conceptual change theories where message plausibility is implicated as a key factor (Dole and Sinatra, 1998). Furthermore, this study shows that explicit instruction about climate change can ameliorate misconceptions about weather and climate distinctions. These significant relationships are a nascent research program's initial step toward deepening student understanding of climate change.

References

Chinn, C., & Brewer, W. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science education. *Review of Educational Research, 63*, 1-49.

Connell, L., & Keane, M. T. (2004). What plausibly affects plausibility? Concept coherence and distributional word coherence as factors influencing plausibility judgments. *Memory & Cognition, 32*, 185-197.

Dodick, J., & Orion, N. (2003). Cognitive factors affecting student understanding of geologic time. *Journal of Research in Science Teaching, 40*, 415-442.

Dole, J., & Sinatra, G. (1998). Reconceptualizing change in the cognitive construction of knowledge. *Educational Psychologist, 33*, 109-128.

Intergovernmental Panel on Climate Change (2008). *Climate change 2007: Synthesis report.* Geneva, Switzerland: World Meteorological Organization.

National Climatic Data Center (2008). *Weather/climate events.* Retrieved April 21, 2008, from http://www.ncdc.noaa.gov/oa/climateresearch.html.

Papadimitriou, V. (2004). Prospective primary teachers' understanding of climate change, greenhouse effect, and ozone layer depletion. *Journal of Science Education and Technology, 13*, 299-307.

Finding the "Learning" in Biology Students' Use of Learning Management Systems

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Abstract: This study investigated how students used Learning Management Systems (LMS) to interact with each other, collaborate, and co-construct knowledge without mediation by the instructor. Results indicate that students successfully used the LMS to interact and, to a significant extent, collaborate with each other, but there was very little evidence of knowledge co-construction within the LMS. The results suggested that the ease and availability of face-to-face meetings as well as limitations with the technology were influencing factors.

Introduction

Contemporary conceptions of learning emphasize social, distributed, and collective forms of interaction between students (e.g., Brown, Collins, & Duguid, 1989). Computer-supported collaborative learning (CSCL) researchers have demonstrated the value of peer interactions via online environments and elaborated many of the conditions under which students can use technology to profit from working together (e.g., Dillenbourg, 1999). Thus it becomes increasingly important for educators to build opportunities for student peer interaction into their curriculum *and* to provide students with the tools for social interaction that have the potential to lead to collaborative and constructive learning outcomes. Web-based Learning Management Systems (LMS) are nearly ubiquitous in higher education today. Although most LMS are used for the distribution, management, and retrieval of course materials, these systems can also incorporate functionality that supports interaction between students and instructors and among students (West, Waddoups, & Graham, 2007). While there has been a significant amount of research on the kinds of communication tools found within LMS (see De Wever, Schellens, Valcke, & Van Keer, 2006), there has been little research on how students use the collection of LMS tools to socially interact with each other and arrive at common goals with their peers.

The research study described in this paper was primarily focused on how LMS support peer learning. The context for this study was an undergraduate biology course that had a required group project. In focusing on the group assignment, three research questions were investigated: (a) what types of peer interactions between students take place within LMS, (b) what factors influence the types of peer interactions between students within LMS, and (c) how LMS can be improved in order to better support student learning.

Defining Student's Online Social Processes

In this study, students' online communication within LMS was characterized as one of three forms of interaction: basic interaction, collaboration, or knowledge co-construction. Basic interaction can be defined as "sustained, two-way communication among two or more persons" (Garrison, 1993, p. 16). For this study, basic interaction was defined as **any kind of communication that took place online within LMS tools.** Collaboration is often defined as "a coordinated … activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" (Roschelle & Teasley, 1995, p. 70) in which the group members collectively negotiate the final outcome or deliverable product (Dillenbourg, 1999). Thus, in this study, basic interaction was further distinguished as collaboration when **students used LMS tools to engage in interaction that served to develop and/or sustain shared ideas about a collective problem.** Knowledge co-construction refers to the types of Vygotskian social interactions with other people that allow individuals to build their understanding about the world. Just as not all peer interaction is collaborative, not all collaborations automatically lead to knowledge creation; collaborators must engage in conversation in which participants' viewpoints are articulated, accommodated, and challenged by group members in order to construct new meanings that are retained and elicited at a later point in time (Murphy, 2004). In this study, knowledge co-construction was thus defined as **collaboration between students within LMS tools when either new information was conveyed from one student to another and retained by the receiving student or a new understanding was elicited by students through their collaborative interactions.** Within this study, collaboration and knowledge co-construction were defined as specific forms of social discourse of the more general construct of peer interaction and were limited to the content of students' online messages.

Setting, Participants, and Methodology

This study was conducted during one semester at a public American Midwestern four-year university. Students from one upper-division undergraduate laboratory course in Biology were asked to participate. As part of this course, students completed a group project of writing a mock grant proposal to the National Institutes of Health (NIH) on any unpublished biological topic of their choosing. Students worked independently or in self-selected groups of 2-6 students. Overall, there were 32 groups formed for the group project, twenty-one of which voluntarily decided to use the LMS to create their own site (82 students, average group size: 4 students).

The content of all communication between site participants within LMS was collected. An online survey (n=56, 44% response rate) was also administered after students turned in their group project. In order to analyze students' peer-to-peer communication, online messages were combined or separated into individual "units of meaning" based on the natural breaks in students' conversations and messages to each other (Henri, 1992), resulting in a total of 397 peer-to-peer message units. Next, each message unit was coded in order to classify the type of peer interaction that took place. Finally, a second type of coding examined the content of the message units. There were a total of 627 "topic" codes assigned with each of the 397 message units assigned a maximum of three codes (27 different coding categories).

Results

The majority (60%) of the 397 peer-to-peer message units within LMS were identified as collaboration, followed by basic interaction (37%), and knowledge co-construction (3%). While the median number of message units was 11.5 per student group, there was a wide disparity in the number of message units for each student group ranging from 4 units to 120 units. The majority of topic codes assigned to message units coded as basic interaction discussed face-to-face meetings (35%). Message units coded as collaboration were assigned a wide variety of topic codes, the most popular of which was biology concepts and procedures (17%). Half (50%) of the message units coded as knowledge co-construction also concerned biology concepts and procedures and, in addition, also contained evidence of new learning.

Nearly three quarters (74%) of LMS users reported using their site at least a few times per week. Over three quarters (82%) of students also reported that they met face-to-face at least once every week suggesting that LMS use was not a substitute for meeting. When asked what students discussed at face-to-face meetings (52 total comments), most of the students (n=47) replied that they divided work or went over certain portions of the grant proposal and that they did so because it was easier than meeting online.

Discussion and Conclusion

The results show that every group that used the interactive LMS tools had at least one collaborative exchange on their site, and about half of those groups had more collaborative messages than interactive messages. There was an abundance of basic interaction and collaborative messages found within students' online messages, providing support for potential student learning within this technology. However, there was very little evidence of knowledge co-construction in students' online communications. That is not to say that students did not learn from each other or from this course assignment, only that evidence of such learning was not found in the majority of messages within LMS. There were several possible factors that may have influenced whether students engaged in collaboration or knowledge co-construction within LMS including the high rate of face-to-face meetings and problems and limits of the LMS technology.

While LMS do have many of the basic tools to support students' knowledge co-construction, those tools lack the necessary features to guide, facilitate, and scaffold students successfully. LMS should therefore incorporate some basic scaffolds to facilitate student collaboration and knowledge co-construction for projects like the one investigated in this study. LMS are complex, multifaceted systems that require continued design improvements as well as attention from instructors, instructional designers, and researchers in order to achieve their potential as a technological facilitator for student learning.

References

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

De Wever, B., Schellens, T., Valcke, M., & Van Keer, H. (2006). Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review. *Computers & Education, 46*(1), 6-28.

Dillenbourg, P. (1999). Introduction: What do you mean by 'collaborative learning'? In P. Dillenbourg (Ed.), *Collaborative learning: Cognitive and computational approaches* (pp. 1-19). Oxford, UK: Elsevier.

Garrison, D. R. (1993). Quality and theory in distance education: Theoretical considerations. In D. Keegan (Ed.), *Theoretical principles of distance education*. New York: Routledge.

Henri, F. (1992). Computer conferencing and content analysis. In A. R. Kaye (Ed.), *Collaborative learning through computer conferencing: The Najadan papers* (pp. 117-136). London: Springer-Verlag.

Murphy, E. (2004). Recognising and promoting collaboration in an online asynchronous discussion. *British Journal of Educational Technology, 35*(4), 421-431.

Roschelle, J., & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (Ed.), *Computer supported collaborative learning* (pp. 69-97). Berlin: Springer-Verlag.

West, R. E., Waddoups, G., & Graham, C. R. (2007). Understanding the experiences of instructors as they adopt a course management system. *Educational Technology Research & Development, 55*(1), 1-26.

Analyzing People's Views of Science Though Their Categorization of Television Science Programs

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Abstract: In this study, participants view representations of science from television programs and categorize the show's characters as "scientists" or not. Follow-up interviews reveal that when thinking about the science and knowledge claims in the television shows, participants adopt one of two views about scientists: either "process-dominant" (scientists as people who investigate claims using some process) or "persona-dominant" (scientists as people who have a specific look, demeanor and credentials).

Introduction

The argument is often made that, in a democracy, an understanding of the nature of science is necessary for people to participate fully as informed citizens (Driver, Leach, Millar & Scott, 1996; Sandoval, 2005). In concert with this argument, I suggest that if we want to uncover the views people hold about the nature of science we should do so in contexts where they actually interact with public claims of scientific knowledge. The NSF finds that about 40% of US adults primarily get their information about science and technology from television (National Science Board, 2008); therefore it seems reasonable to use science-based television shows as a context in which to explore people's views on the nature of science. In this study, I have chosen two popular shows, *Mythbusters* and *Ghost Hunters*, which make arguments and claims that are presented as scientific. How might a viewer interpret the differing methods, attitudes, and unusual versions of science presented by *Mythbusters* and *Ghost Hunters*? And what might these interpretations reveal about the viewer's views on the nature of science?

Theoretical Background

For several decades, researchers have attempted to understand exactly what views people have about the nature of science, both as a practice and as a source of knowledge. A great deal of research is done through questionnaires that overtly ask participants what they think science is, and how it works (e.g., Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) This research often argues that people hold relatively concrete ideas about the nature of science, often seen to run from *naïve* (e.g., scientific knowledge as absolute) to *informed* (e.g., scientific knowledge as tentative). While this prior research has identified some broad trends in how people view science in school, the various methodologies used to probe those views rely on tacit assumptions that may not be accurate or useful for understanding how people make sense of science outside of school. Some researchers (Leach, Millar, Ryder, & Séré, 2000; Elby & Hammer, 2001; Hammer & Elby, 2002) have argued that much of this research incorrectly assumes that views of science are articulable and consistent across contexts. According to Leach, et al., (2000) there is no evidence that a person's responses to *generalized* questions about the nature of science can be used to predict the knowledge drawn upon by the person in a *specific context*. I go further in arguing that studies that do attempt to localize questions in a context (e.g., Leach, et al., 2000) do not go far enough. These marginally contextualize studies often do not: 1) Have a real world familiarity or significance. 2) Supply participants with the underlying arguments of real world scientific claims. 3) Portray a diversity of scientific methodologies (Sandoval, 2005). Therefore, I have chosen to use two television shows as the contextual basis of my study. These shows (*Mythbusters* and *Ghost Hunters*) reflect authentic popular representations of "science," are consequential to the viewer in that the topics are familiar, and construct an argument (each using a different method) and a resultant claim of knowledge.

Method

There were eight participants for this study: four adults (3 females, 1 male; aged 41-47) and four children (2 females, 2 males; aged 11-14.) Each participant viewed a 20-minute clip from both *Mythbusters* – experiments about whether a penny dropped from a skyscraper can kill a person – and *Ghost Hunters* – collection of video and audio recordings in an allegedly haunted tavern. Clips were counterbalanced to control order effects. After each clip, the participant was interviewed about the specific show they had just seen. The interview protocol used was divided into three sections: 1. An introductory set of questions. 2. A set of questions intended to draw out some of the participants' opinions about how the shows' methods and evidence. 3. A set of questions designed to elicit the participants' views of scientists.

Analysis & Results

Interviews were transcribed and labeled on a spectrum from naïve to informed understanding of science. While I was able to find many cases where the participants' responses seemed to fit these categories, there seemed little consistency within interviews, demonstrating that individual pieces of evidence activate different ideas about science. Furthermore, this top-down approach left an unacceptable number of responses unable to be categorized. Therefore, I took a more bottom-up approach and analyzed the nature of single responses and what larger patterns emerged from them.

Based on this analysis, it seems the participants held one of two very different views of science. One group claimed neither the Mythbusters nor the Ghost Hunters were scientists while the other concluded both were scientists. Participants were evenly split (4 each) into the two groups. These two groups have been labeled *Persona-dominant* or *Process-dominant* based on the very different benchmarks each group used to categorize the shows. The members of the Process-dominant group, which felt both shows were science, seem to place a premium on the process and actions a scientist goes through. This group viewed scientists as anyone who used the scientific method (or a caricature thereof). For example, one participant stated plainly when asked whether or not the Mythbusters were scientists: "They start out with a question if a myth is right or wrong and then they go test it which is kinda like what the scientific method is. You have a question and you try to answer it." Likewise, the plausibility of the existence of ghosts did not matter to this group; they all concluded the Ghost Hunters were scientists because of the *process* they claimed to employ, not due to the plausibility of the target studied.

The Persona-dominant group, however, were more interested in what a scientist looks like and where the scientist works. Members of this group were particularly dubious of the fact that neither the Mythbusters nor the Ghost Hunters display any credentials: One claiming, "I would have felt better if they'd said, 'So-and-so is from MIT and so-and-so is from Harvard.'" The Persona-dominant group view scientists as professionals, working in a sterile lab and doing their job in a very serious way, as evidenced by one member of this group asserting, about the Mythbusters, "I think they're guys who are, um, probably pretty crafty about figuring out ways to do different things… I was going along with them up till the part they started goofing around."

What is striking about the fact that each participant fell into one of two categories is that not one of them made any real distinction between the two shows. For these participants, at least, determining if something is science or not is a relatively surface level task. The Persona-dominant group saw people that violated their prototypical image of a scientist and thus decided they could not be scientists. While the Process-dominant group made similar surface level determination by deciding anyone seeming (or claiming) to employ a method must be a scientist, and no one is this group dug deeper to determine the specifics of the given method and critically evaluate its validity.

Conclusion

This small study raises interesting questions about how people view science, and how researchers attempt to uncover those views. Through the categorization of television scientists it became clear that for some participants the process a scientist goes through was more important than what the he or she looked like or was testing. On the other hand, other participants were much more interested in the persona of the character presented as a scientist. These views seem much different, and much more pliable, than views uncovered in previous (decontextualized or marginally contextualized) research. However, this study says little about how these views actually impact how people evaluate claims to scientific knowledge. In future research, I hope to explore this question more fully.

References

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's image of science.* Buckingham: Open University Press.

Elby, A. & Hammer, D. (2001) On the substance of a sophisticated epistemology. *Science Education*, *85*(5), 554-567.

Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B.K. Hofer & P.R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 169-190). Mahwah, NJ: Erlbaum.

Leach, J., Millar, R., Ryder, J., & Séré, M-G. (2000). Epistemological understanding in science learning: the consistency of representations across contexts. *Learning and Instruction, 10*, 497-527

Lederman, N.G., Abd-El-Khalick, F., Bell, R.L., & Schwartz, R. (2002). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497-521.

National Science Board. (2008). *Science and Engineering Indicators 2008*. Arlington,VA: National Science Foundation.

Sandoval, W.A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*. *89*(4), 634-656

An Analysis of the Interactional Patterns in One-to-One and One - to- Many Collaborative Concept Mapping Activities

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Abstract: This paper reports on a study to investigate the effects of collaborative concept mapping in a one-device-per-student (1:1) digital learning environment, as compared with one-device-to-many-students (1:m), in terms of students' overall learning gains, knowledge retention, quality of the concept maps, interactional patterns, and learning perceptions. Guided by the methodology of quasi-experimental research, we adopted Group Scribbles (GS) 1.0 in our empirical study where students carried out collaborative concept mapping activities in two different settings: (a) students working in pairs with one Tablet PC assigned to each of them; (b) multiple students sharing a Tablet PC. In particular, we investigated the students' learning process, identified and compared various interactional patterns exhibited by the student groups who were engaged in both settings, and discussed how such group dynamics might have affected the quality of the student artifacts produced by individual groups.

Introduction

Social study is an integrative theme that applies multiple disciplines of learning concepts and principles to social life. In most of the routine social study lessons in schools, teachers are in general still practicing didactic instructions, drill and practice, and continuous assessments. They are learning outcome-oriented but not keen on ensuring students' thorough understanding of what they learned, which results in the fact that students only focus on memorizing fragmented knowledge without synthesizing it. This paper reports on a study that aimed to investigate the process and the effects of collaborative concept mapping in a 1:1 digital learning environment, as compared with 1:many mode. In particular, we are keen on exploring the students' learning process and identifying various interactional patterns exhibited by the student groups who were engaged in the two collaborative modes through our analysis of student interview transcripts and video recordings during the activities. Eventually, we triangulated all the data and formulated our findings in the nature of 1:1 and 1:4 computer-supported collaborative concept mapping activities.

Literature Review

One-to-one technology enhanced learning is the way that a student uses at least one computing device with a networking environment for learning (Chan *et al*, 2006). The devices used for such a learning mode usually incorporate the affordances such as: personalization, connectivity and supporting social interactivity (ibid). With the advancement of the information technology, the concept mapping software that provides the affordances of selecting, deleting, classifying, sequencing, modifying, connecting and listing of concept maps has been developed. Plotnick (2001) also points out that as computer-supported concept mapping offers the ease of editing, dynamic linking, format conversion, ease of transfer and storing, which are very conducive for learners to create concept maps. Otherwise, various researchers have been seeking for ways to categorize interactional patterns in small learning groups, with or without computer supports, through their ethnographic studies on such learning activities. In Table 1, we compare three relevant studies and a recent effort to synthesize them.

Table 1: Consolidation of interactional patterns in small groups

	Milson (1973)	Roth (1995)	Huang (2001)
Ideal	Ideal	Symmetric interaction	Turn taking
Leader	Dominant leader	Asymmetic interaction	Leader
		Shifting symmetric interaction	Focus
Tete-a-tete	Tete-a-tete	Parallel occasional interaction	
Fragmented	Fragmented, cliquish	Asymmetric interaction	Fragmented
	Stilted		
No participation	Unresponsive	No participation	
	Unsocial		

Methodology

Sixty four students from two Grade 6 classes in a primary school were involved in the study. They were taught in the second unit of the Social Study lesson, *"Investment, Financial Management and Economic Activities"*, as well as taking a competency pre-test on the subject, prior to the study. Students were split into eight "1:1 groups" and eight "1:4 groups". By using the Group Scribbles (GS 1.0) software, each of the members of the 1:1 group was assigned a Tablet PC to perform collaborative concept mapping, in the 1:4 group 4 students sharing one Tablet PC. The quantitative data consisted of the results of pre-, post- and postponed-tests, with the "N-G score" proposed by Novak & Gowin (1984) about the scoring rubric of the students' concept maps. A questionnaire was administered to investigate student attitudes in collaborative learning, the usability of the software, and learning by concept mapping. Eventually, we triangulated all the data and formulated our findings of the nature of 1:1 computer-supported collaborative concept mapping activities.

Figure 1: collaborative concept mapping activities

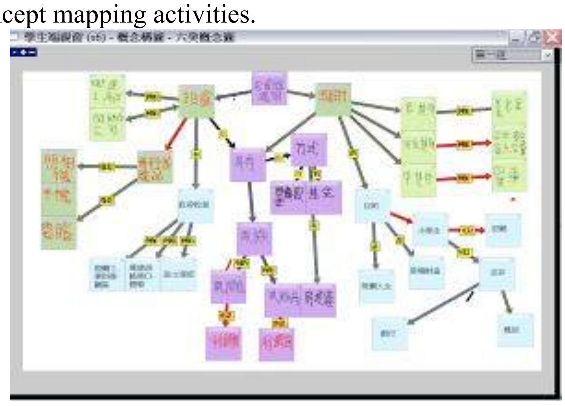

Figure 2: Students' concept map

Conclusions

Social Studies emphasizes the skills of synthesis and application. The key to the mastery of the subject is to move away from the conventional "rote learning" and take place with actively engagements in meaningful learning and knowledge building. In this study, we investigated collaborative concept mapping as a solution to this issue. Both 1:1 and 1:4 settings were implemented and compared, with the following findings being drawn,

- Learning outcomes: Our analysis of student performances show that both 1:1 and 1:4 settings had indeed been able to improve the students' results and demonstrated good retention. Furthermore, both settings did not result in significant differences in the improvement in these two aspects.
- Results of concept mapping: Although little difference in the concept map scores between students engaged in the two settings, the standard deviations of the 1:1 groups had been greater than those of the 1:4 groups. According to our analysis, the underlying reason of the greater differences in the performances among the individual 1:1 group members would be that the levels of group bonding had a greater influence on the effectiveness of their collaborations.
- Interactional patterns: We analyzed all the student groups' interactions and discovered that the 1:1 groups had practiced four interactional patterns respectively, namely, "ideal" (the most popular mode), "leader", "tete-a-tete" and "fragmented". The 1:4 groups, on the other hand, assumed the "leader" and "fragmented" (the most popular) patterns but not the other two. We argue that the 1:1 group had demonstrated interactions of better quality as compared with the 14 groups as the former setting had facilitated greater autonomy to individual students, thus enhancing their level of participations in collaborative learning. On the other hand, there had been isolated students occurred in some of the 1:4 group, resulting in far-from-ideal group interactions.

References

Chan, T.-W., *et al.* (2006). One-to-one Technology Enhanced Learning: An Opportunity for Global Research Collaboration. *Research and Practice in Technology Enhanced Learning, 1*(1), 3-29.

Milson, F. (1973). *A Introduction to Group Workskill*. London: Routledge and Kegan Paul.

Novak, J. D. (1998). *Learning Creating and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations*. New Jersey: Lawrence Erlbaum Associates.

Plotnick, E. (2001). Concept mapping: a graphical system for understanding the relationship between concepts. *Teacher librarian, 28*(4), 42-44.

Roth, W. M. (1995). Authentic school science knowing and learning in open-inquiry science laboratories. Dordrecht: Kluwer.

Huang, H.-H. (2001). A study on the interactive process of online learners: A case study on text-based communication. Master Dissertation, Chia-Yi, Taiwan: National Chung Cheng University. (In Chinese)

Teachers' concepts of spatial scale. An intercultural comparison between Austrian, Taiwanese, and US-American teachers.

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Abstract: In the science curricula of various countries, scale receives an important place in middle as well as in high school science education. This study explored scale concepts of inservice and preservice teachers from three countries, Austria, Taiwan, and the USA. Accuracy of scale concepts differed in the samples of the three countries. The Austrian and Taiwanese samples held more accurate concepts of scale than the U.S. sample. Inservice teachers had more accurate concepts than preservice teachers.

Introduction

There are powerful ideas that stretch across all the science domains. One of these prevailing ideas is scale. Scale encompasses not only variables such as size and distance but also includes other variables such as time, weight, and temperature. Scale is very important in science because the properties of materials change as the magnitude of scale increases or decreases. As the American Association for the Advancement of Science has pointed out, it is crucial for students to develop an understanding of the "immense size of the cosmos, the minute size of molecules, and the enormous age of the earth (and the life on it)" (AAAS, 1993, p. 276).

This study examined teachers from three different countries (Austria, Taiwan, and the USA). In the curricula of all three countries, scale receives an important place in middle school and high school science education (Austrian Federal Ministry of Education, Arts, and Culture, 2009; Ministry of Education, 2009; State Board of Education, 2009). With regard to middle school students' knowledge of scale, the three countries differed strongly from each other in the PISA studies. Concepts of scale were mainly measured in the mathematics part of the PISA studies and are regarded as basic concepts of mathematical education. In the 2006 PISA studies, students in Taiwan received the best rank of 57 countries when mathematical knowledge was measured. Austria was 18th, the USA 35th (OECD, 2006). In this study, the accuracy of scale concepts of teachers from the three countries was investigated. Students in preservice teacher programs (novice teachers) and inservice teachers (experienced teachers) participated. In the study, differences between the three countries as well as differences between novice and experienced teachers were explored.

Methodology

Participants in this research study included secondary science teachers drawn from two different countries that use metric in everyday contexts: Austria (n = 101), and Taiwan (n = 59) who volunteered to be part of the study. The concepts and experiences of these teachers were compared to teachers from the United States (n = 66) from a previous study of teachers' concepts of size and scale (Jones, Tretter, Taylor, & Oppewal, 2008) for a total of 226 teachers (131 females, 95 males). Participants were recruited from undergraduate and graduate teacher education programs and area schools.

All participants of the study completed two assessments designed to examine conceptual categories of size and scale accuracy. These assessments included the Scale Anchoring Objects (SAO) and the Scale of Objects Questionnaire (SOQ). The SAO assesses representative objects that participants use for conceptual understanding at a variety of scales from a nanometer to a billion meters. The instrument asks participants to generate objects representative of different size scales (nm, µm, mm, cm, etc.). The SAO reflects a number line of sizes that participants mentally hold (Jones, Tretter, Taylor, & Oppewal, 2008). The accuracy of a participant's understanding of scale was measured by the number of correct answers in four ranges, the nanometer to millimeter range (nm – mm), the centimeter to meter range (cm – m), the 10 meter to 1000 meter range (10m – 1000m), and the million to billion meters range (million – billion m). The SOQ assesses perceived sizes of a variety of objects. From a list of options spanning less than a nanometer to over one billion meters, participants indicate which scale range each object falls within. The instruments indicates which scale sizes are well distinguished from each other and where in the size continuum individuals conceptualize distinctly different categories of scale (Jones et al., 2008). The accuracy of a participant's understanding was measured by the number of correct answers in four ranges, nm – mm, 1mm – m, 1m – 1000m, million m – billion m.

Results

Scale Anchoring Objects

A multivariate analysis of variance with the factors nationality (Austria, Taiwan, USA) and experience (novice versus experienced teachers) was carried out. Dependent variables were the number of correct answers in the four ranges of scale. The analysis yielded a highly significant difference between the three nationalities ($F_{20, 406} = 8.355$; $p < .01$). According to post-hoc Tamhane tests, Austrian and Taiwanese participants gave significantly more correct answers than US-american participants in three ranges: nm – mm, 10m – 1000m, million – billion m. The Taiwanese sample scored significantly better than the Austrian sample in the nm – mm range, the Austrian sample scored significantly better than the Taiwanese sample in the 10m – 1000m range. There were no differences in the number of correct answers in the cm to m range. The MANOVA showed neither a main effect for the factor experience ($F_{20,202} = .999$; $p > .5$) nor an interaction effect ($F_{20,406} = .142$; $p > .5$).

Scale of Objects Questionnaire (SOQ)

A multivariate analysis of variance with the factors nationality and experience was carried out. Dependent variables were the number of correct answers in the four ranges of scale. The analysis yielded a highly significant difference between the three nationalities ($F_{10, 430} = 5.413$; $p < .01$). In all four ranges the Austrian sample scored significantly higher than the US sample as post-hoc Tamhane tests showed. Taiwanese teachers gave more correct answers than the American teachers in all ranges except the >1m – 1000m range. The Austrian sample gave significantly more correct answers than the Taiwanese sample in the >1m – 1000m range. The multivariate analysis of variance also showed a significant main effect for the factor experience ($F_{10, 430} = 2.210$; $p < .5$). In-service teachers gave more correct answers in the >1m – 1000m and >million – billion m range than preservice teachers. There was no interaction between nationality and experience ($F_{15, 648} = 1.014$; $p > .5$).

Table 1 and 2: Mean values for SAO and SOQ for three nationalities

	SAO		
	Austria	Taiwan	USA
nm to mm	66.1	76.9	34.0
cm to m	99.4	100.0	94.2
10m to 1000m	98.0	91.3	92.6
mil to bil m	67.3	66.0	35.7

Note. Values are mean percentages of correct answers

	SOQ		
	Austria	Taiwan	USA
nm to mm	66.1	63.3	52.2
>1mm – m	84.3	77.9	601.
>1m – 1000m	88.9	73.9	69.1
>mil – bil m	64.0	60.4	46.2

Discussion

The results of the SAO analyses showed there were significant differences between the three countries in all ranges except the cm to m range. This range reflects sizes and objects which are usually encountered in daily life and which can be experienced directly by seeing and/or touching. In contrast, the nm – mm and the million – billion m range reflect objects and sizes which are encountered in academic contexts. In these ranges, the differences in concept accuracy reflect the results of the PISA study: The Austrian and Taiwanese samples consistently received higher scores than the U.S. sample. It seems that differences in accuracy of concepts are established in school and remain stable even in experienced teachers. Furthermore, in all countries, inservice teachers had more accurate concepts for large sizes. It seems that preservice teachers have more difficulty in conceptualizing scales beyond the human realm and that accuracy of concepts is further developed by professional teaching experiences.

References

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy*. New York: Oxford University Press, Inc.

Austrian Federal Ministry of Education, Arts, and Culture (bm:ukk). (2009). *Lehrpläne der Oberstufe der Allgemein Bildenden Höheren Schulen*. Retrieved October 27, 2009, from http://www.bmukk.gv.at/schulen/unterricht/lp/lp_ahs_oberstufe.xml

Jones, M.G., Tretter, T., Taylor, A.R., & Oppewal, T. (2008). Experienced and Novice Teachers' Concepts of Spatial Scale. *International Journal of Science Education, 30(3)*, 409-429.

Ministry of Education. (2009). *Educational system*. Retrieved October 27, 2009, from http://english.moe.gov.tw

OECD (2006). *PISA 2006. Science Competencies for Tomorrow's World. Volume 1 – Analysis*. Retrieved March 1, 2010, from http://www.oecd.org/dataoecd/30/17/39703267.pdf

State Board of Education. (2009). *NC standard course of study, K-12*. Retrieved October 27, 2009, from http://www.dpi.state.nc.us/curriculum

Sources of Evidence for Embedded Assessment in Immersive Games

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Abstract: In this poster, we offer a designer's look at how the activities and data of learning and assessment can be structured in immersive virtual game environments called Massively Multi-Player Online Games (MMOG). In doing so, we examine the sources of evidence from which learning and assessment activities are derived in MMOGs, offering examples of how multiple evidence channels in operation through game-based activities can be utilized to construct rich data trails for assessment.

Sources of evidence in MMOGs

A growing body of literature points to the value of a sub-type of virtual worlds-based game called the Massively Multi-Player Online Game (MMOG) for engagement and learning. Researchers investigating educational MMOGs have explored the design, functionality, and learning impact of such environments, focusing primarily on analysis and evaluation of the curricula embedded in them (e.g. Nelson & Ketelhut, 2007; Nelson, 2007). In this poster, we approach the issue from a different analytical framework, examining the kinds of activities supported by virtual worlds, with a particular focus on how such activities may provide meaningful data for assessment.

In spite of the sensory and situational complexity of MMOGs, there are relatively small numbers of possible recordable interactions supported by the environments from which researchers can gather data relevant to assessment. These interactions provide data via what we define as Global Evidence Channels. These evidence channels track learner activities in three main categories: Location/Movement, Object Interaction, and Communication Activities (Table 1).

Table 1: Global Evidence Channels

Location/Movement	Object Interaction	Communication Activities
Location tracking • X location visited • Time spent at X • Coordinates Movement tracking • Direction • Speed • Acceleration/deceleration • Teleporting Movement patterns • Order of movement • Movement as response • Movement strings over time	Objects: • View • Select • Click • Manipulate • Pickup • Release Object Types: • Artifacts and inventory • Tools • NPCs • Humans • "intangibles"	• Type • Speak (VoIP) • Response selection • Emote • In and out of character • Human and NPC • Goal-oriented vs. social

Location/Movement

The exploration of virtual worlds by learners offers a rich source of direct and indirect evidentiary data that can be mined by researchers, educators, and evaluators. By tracking locations visited and the patterns of movements of learners through a virtual world over time, researchers can assemble a historical trail which provides information about the moment to moment learning of those students.

In creating MMOG-based assessments, designers can plot out assessment hotspot locations in the virtual worlds. Each hotspot can contain opportunities for interactions that help indicate the learning state of a player at that point in space and time. The sequence of location visits within a carefully designed world can also provide evidence about the state of knowledge construction in a given domain among groups of learners. Related to the location evidence collection supported by MMOGs is movement-based evidence. Examining the direction, speed, and duration of travel within a virtual world designed to elicit evidentiary activity can provide data on student learning over time.

Object Interaction
A second channel of evidence supported by MMOGs is Object Interaction. Object interaction occurs in two main ways in MMOGs: simple viewing of objects in 3-D space and direct interaction with objects, i.e. selecting, clicking on, rotating, picking up, moving, or dropping objects in the MMOG world. Within these two categories, players' actions can be divided into two types: "browsing" and "purposeful". In MMOGs, players often interact with objects without clear purpose. In this mode, they click on all visible objects simply to see what happens (e.g. signs, buildings, landscape, and NPCs). In contrast, *purposeful* object interaction is when players seek out, view, select, and interact with objects in a clear and strategic manner to accomplish some goal. They click on specific objects in a virtual world that need to be collected to advance the game or that are awarded as reinforcement for a successful quest completion.

In addition to examining the kinds of interactions a player has with given, data for assessment can be gleaned by examining the types of objects with which the player interacts in completing an assessment quest. There are several object types, each of which provides a different type of data to be analyzed: realistic, enhanced, and media objects. In addition to the different object types, there are a number of in-world object classes with which players can interact, and through which assessment data of varying kinds can be gathered. In examining player use of these different object classes, researchers can investigate the manner in which players interact with the objects, the choice of objects used for specific tasks, the selection and assembly of objects into a limited inventory of useable tools, and the de-selection or discarding choices of objects.

Communication Activity
A third evidence channel supported by MMOGs is Communication Activity. MMOGs generally support three classes of communication: text-based instant messaging, voice-based communication, and non-verbal signaling (also called "emoting"). Across all classes of communication, players can interact with other players (and with NPCs) for social and/or quest-related purposes. Quest-related communication consists primarily of pre-quest planning strategies for upcoming quests, mid-quest communication used to share information about the quest and conduct ongoing evaluation of the current status/effectiveness of team members---a kind of formative peer-based evaluation system---, and post-quest summative peer evaluations. In post-quest communication, players review successful or failed quest strategies and plan changes for future quests to increase the odds of group success.

Dyadic and Triadic Channel Combinations
When players explore MMOGs, their activities and interactions are virtually never completed in the neatly delineated fashion we outline above. Rather, players perform actions that produce evidence in dyadic and triadic combinations from which useful assessment data can be derived.

Conclusion
With careful design, MMOGs can support activities that provide data useful for real-time and post-hoc assessment of individual and group learning over time. These data have no inherent value for assessment by themselves. It is only through careful design of the virtual worlds, in-world objects, tasks, and quests that the data take on meaning for assessment. As we progress in our own research, we are working to refine the initial ideas presented here, and seek to answer the many questions raised by this discussion.

References
Nelson, B. (2007). Exploring the use of individualized, reflective guidance in an educational multi-user virtual environment. *The Journal of Science Education and Technology 16(1):* 83-97.

Nelson, B. & Ketelhut, K. (2007). Scientific Inquiry in Educational Multi-User Virtual Environments. *Educational Psychology Review 19(3):* 265-283.

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Do social skills play a role in collaborative project-based learning? Impact of the distribution of perceived social skills within learning groups in a Computer Supported Collaborative Learning- setting: An empirical pilot study

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Abstract: The pilot study looks for empirical answers to the following question: What distribution of perceived social skills within learning groups is predictive for group member's degree of satisfaction with group performance and quality of collaboration? Data collection took place with two questionnaires at the beginning and the end of semester. The analysis of 20 learning groups (*N* = 59 teacher training students) revealed the following trends: High exchange orientation (i.e. being able to cooperate, compromise, resolve conflicts etc.) and high assertiveness within groups are associated with more satisfaction concerning collaboration quality and group performance. Heterogeneous groups with low group-means of the social skill exchange orientation were less satisfied with their work and stated to be less efficient in collaboration than other groups.

Research design

The present study was conducted with 59 students of the University of Teacher Education Pädagogische Hochschule Bern. The students participated in a media education course and had to work on a media project in groups of two or three during three months. Our research questions were:

1. Which individual social skills are predictive concerning satisfaction and quality of cooperation, in a collaborative project-based learning setting?

And on a group level:

2. Which configuration of social skills within the learning group is perceived by the group members to be effective for successful project-based collaborative learning?

At the beginning of the course all students completed a self-assessment questionnaire (pre-questionnaire) about their social skills. At the end of the project, students filled in a questionnaire covering their satisfaction with the project and their perceived quality of collaboration. 59 students (20 project-groups) completed pre- and post-questionnaire.

Self-assessment of individual social skills (pre-questionnaire)

The questionnaire contained 16 self-referential statements for which students had to choose between four responses (totally agree – totally disagree).

Indicators of satisfaction and quality of cooperation towards the end of the project work (post-questionnaire)

To measure satisfaction with the achieved project work and the quality of collaboration we used the following six questions with four possible responses (totally agree: 4 – totally disagree: 1):

1. I am satisfied with the achieved level of team work (satisfaction)
2. The group worked together in an efficient way (efficiency)
3. The responsibilities were clearly distributed within the group (division)
4. There was a group leader (centralized management)
5. We got along well within the group (harmony)
6. We supported each other and / or complemented one another well within the group (support).

Results

Self-assessment of perceived individual social skills

In order to reduce complexity we tried to find similar answering behavior within the 16 asked questions.

The items of the questionnaire were reduced to higher-level factors using principal component analysis (pca). The extracted five factors explained 67% of the variance. All factor scales had satisfactory internal consistency between (Cronbach's alpha: $0.698 \leq \alpha \leq 0{,}817$). We labeled the five factors: exchange orientation, empathy, initiative, leadership and assertiveness.

Correlation between social skills factors (of pca, first questionnaire) (pre questionnaire), indicators of work satisfaction and perceived quality of cooperation (post questionnaire) and within items of the post questionnaire

The social skills correlated to various items concerning satisfaction and perceived quality of collaboration. Highly significances ($p<0.01$) were found between 'satisfaction in work' and 'collaboration efficiency' $r(59) = .43$; satisfaction in work and 'distribution of work' $r(59) = .36$; 'collaboration efficiency' and 'distribution of responsibilities' $r(59) = .49$; collaboration efficiency' and 'group leader $r(59) = .53$; collaboration efficiency', and 'mutual support $r(59) = .63$; 'group harmony' and 'mutual support' $r(59) = .56$; distribution of responsibilities and mutual support $r(59) = .43$. Significant correlations ($p<0.05$) could be found between 'distribution of responsibilities' and 'group leader' $r(59) = .43$; 'empathy' and 'satisfaction with work' $r(59 = -.30$; 'empathy' and 'collaboration efficiency' $r(59) = -.28$ and 'empathy' and 'mutual support' $r(59) = -.27$.

Proposal of a possible way to combine the results of the analysis of individual social skills and the interindividual (group related) specificity of different social skills

The quality of collaboration within groups is not singularly based on the individual group member - level of a particular social skill (e.g. exchange orientation). Rather a systemic view might be appropriate, were a group consisting of persons with both high and low individual levels of a particular social skill will likely perform differently than groups were the members perceive the same or a more comparable level of the concerned social skill. We call this pattern of individual social skills within a group the skill - configuration.
In order to analyze how satisfaction and quality of collaboration within groups was dependent on the skills configuration, we split the sample for each of the five skills (see pca) into homogeneous and heterogeneous groups (based on the average range between group members with the highest and with the lowest skills level) and in groups that showed a high or a low average group level of the skill. Thus, for each social skill, four group types could be differentiated: HOLO: homogeneous group with low means in a specific social skill; HELO: heterogeneous group with low means of the focus social skill; HOHI: homogeneous group with high means of the focus social skill, and HEHI: heterogeneous groups with high means of the focus social skill. Using group typologies based on homogeneity/heterogeneity and average skills level showed various promising effects in our pilot study even considering that the range of heterogeneity within the heterogeneous groups was quite small:

Performing several analyses of variances (ANOVA) we could find the following results:

- Exchange orientation: (HELO groups were less satisfied with their work, $F(1,18) = 5.589$; $p < .001$, and less efficient in collaboration, $F (1,18) = 12.447$; $p < .001$) than the three other group types. Thus, a low exchange orientation is a threat to work satisfaction and collaboration quality only, when group members show different levels in this skill. Presumably, it is the high exchange oriented group members that suffer the most in this kind of skills configuration. Initiative: HOLO groups were less supportive and complementary than the other three group types, $F(1, 19) = 3.455$, $p < .10$. For HELO groups such an effect was not found. To have no group members that act socially initiative is therefore especially disfavorable to mutual support giving.
- Leadership: HOHI groups had a more efficient collaboration than groups of types HEHI and HELO,$F(1, 19) = 2.906$; $p < 0.10$). Many high leadership oriented people make for efficient collaboration within a group. However, groups that show a homogeneous skills configuration with respect to leadership (HOHI and HOHE) have less often a centralized leadership than heterogeneous groups (especially HEHO), $F(1, 19) = 4.376$, $p < .05$.
- Assertiveness: Members of HOLO and HELO groups reported to have lower mutual support than members of HOHI groups. $F(1, 19) = 2.705$, $p < .10$.

Multilevel analysis might also be valuable for our data but for our pilot study with a small amount of participants and groups we did not consider the multi-level approach. In our ongoing study with a lager amount of groups and participants multi-level analysis approach will be compared to the described method in the pilot. The major problems we encountered in our pilot concerned the reduction of complexity and the interactions between the parameters on individual level and on group level.

References

Heuermann, A. & Krützkamp, M. (2003). Selbst-, Methoden-, und Sozialkompetenz. Bausteine für die Sekundarstufe II. Berlin: Cornelsen.

The Use of Animations and Online Communication Tools to Support Mathematics Teachers in the Practice of Teaching

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Abstract: This paper reports on a pilot study on the effect of animated classroom stories, as a reference point, directly embedded in the space of online communication tools to help mathematics teachers collectively learn to notice critical events of teaching practice. The main results include: more than 70% of the teachers' comments focused on instructional practice, chat and forum could be complementary to help experienced teachers, and only forum could be suitable for novice teachers.

Introduction

The practice of teaching is important but very complex and difficult (Leinhardt & Ohlsson, 1990): the teacher must be able to continuously structure or restructure his or her knowledge in different ways in order to adaptively respond to changing practical demands from moment to moment, adapting different semiotic resources from student to student, and from class to class. We aim at using interactive rich-media representations of teaching and online communication tools for the design of virtual settings to support mathematics teachers in learning to do the practice of teaching. We used animated classroom stories[1] as reference artifacts to prompt discussion among teachers, engaging them in talking about the rationality they invest in action (Herbst & Chazan, 2003). Although animations may reduce some degrees of complexity of classroom interaction, they were designed in such way that eliminated noisy elements (often present in video records of practice) helped teachers attend to important events of classroom interaction. We also embedded the animations as reference points directly into the online discussion space. That original feature can make the discussion among the participants more meaningful and in-depth.

Our first research question is to look at how much of the teachers' discussion is focused on classroom interaction and whether their exchanges are more in-depth when they refer to the embedded animations. The second question is concerned with how the nature of the discussion tool (chat vs. forum) is correlated with teachers' noticing. The third question is to examine the differences in noticing between experienced and novice teachers in those specific settings. Noticing, evaluating, and interpreting noteworthy features of teaching practice are important for teachers to improve their own professional practice (van Es & Sherin, 2008). The study is the first critical step of a design-based research agenda (Collins, 1992) toward building complex virtual settings for teachers to learn to do the practice of teaching.

Method

Nine experienced mathematics teachers were randomly organized into two virtual groups: four in the forum condition and five in the chat condition. A similar pair of sessions was carried out with eight novice mathematics teachers: four in each condition. Those participants had previously seen the animated stories and discussed them either in a study group or in a teacher education class. In both conditions, the participants did the same warm-up activity: viewing a clip from the beginning of a lesson and a clip from the end of the lesson, then responding questions about what might happen in between, and finally viewing the full story. After that the forum participants went to a forum in which three threads with questions about three noteworthy moments were created in advance. The chat participants individually responded to those same questions before joining a chat. A moderator was available in both conditions.

Data included screen records of interaction between the teachers and the online experiences, session logs, and video records of focus groups after the online experiences. Sentences of forum and chat logs were coded to understand what and how teachers noticed during discussion. Our coding system (Chieu, Weiss, & Herbst, 2009) is partly based on the codes used by van Es and Sherin (2008). It consists of five categories: The Topic (what was talked about) codes consisted of five "content topics" (*mathematics*, *students' mathematics*, *teachers' tactics*, *teachers' planning*, and *emotion and climate*), three "context topics" (*media*, *user-interface*, and *interpersonal*), and *other*. The Subject (who was being talked about) codes were *subjectless*, *student*, *teacher*, *self*, and *other*. The Stance (how teaching practice was analyzed) codes were *descriptive*, *evaluative*, *interpretive*, and *other*. The Specificity codes (level of specificity used to discuss teaching practice) were *general* or *specific*. The Temporality codes (how the embedded animation was referred to) were *none or reference to the animation in general* / *scene of the animation* / *action in the animation* / *specific time code*.

[1] Interested readers may request an account at http://grip.umich.edu/themat/ to watch examples of animations.

Results And Discussion

Overall, the participants in all groups concentrated on discussing their professional practice (more than 70% of their comments were about content). More specifically, they narrowed the focus on making references to students' mathematics, teachers' tactics and planning, and students' emotion and classroom climate. The participants predominantly attended to the animated teacher and/or students. They frequently took evaluative and/or interpretive stances. Except for the pre-service teachers in the chat condition, the teachers' comments were specific, and the specificity was often about pedagogy. The experienced teachers often referred to the animation when they made comments. Those figures were comparable with the results of the video club study (van Es & Sherin, 2008).

We found that relationships existed between referring to the animation and making specific comments. For example, in any group the probability that a sentence that did not refer to the animation in general would be specific was just 60% of the probability that a sentence referring to the animation would be specific (95% CI = [.24, .97], $p = 0.001$). The findings mean that teachers' comments were more specific when they referred to the embedded animation than when they did not. The existence of those relationships shows evidence for the effectiveness of the embedded clips. Indeed, if one assumes that making specific comments engages teachers in more meaningful and in-depth discussions, and helps them notice critical events of instructional practice better (which might influence how well they learn how to do the work of teaching better), then it is useful to stimulate them to refer to the specificities of the shared artifacts when they make comments. Embedding animation clips directly in the virtual space of discussion is an effective way to support this specificity.

The study also found that both chat and forum conditions can be complementarily used to engage in-service teachers in meaningful exchanges about their professional practice. The chat condition, however, may not be useful for pre-service teachers to be able to create in-depth and significant exchanges about teaching practice. The forum condition could be much better for pre-service teachers. Indeed, in that condition they can attend to and discuss instructional practice in a manner that is closer to the way experienced teachers do.

Concluding Remarks

In this paper, we report on a study to understand the nature of the discussion of both teachers in online chat and forum conditions in which animated clips of classroom interaction are embedded and used as a reference point to facilitate and stimulate meaningful and in-depth discussion. We especially look at how the participants notice critical events of the embedded classroom story. The study found evidence to support the *original feature* of our online experiences: *embedding animations directly to the online discussion space*. Although the study did not analyze teachers' actual practice of teaching, it did analyze their ability to notice and interpret critical events of the practice, an important part of their professional work (van Es & Sherin, 2008).

The study, as the first step of a design-based research approach, also identified technological problems and provided suggestions for those problems. For example, because of little experience in the use of forum, several teachers in forum mistakenly responded to a "seed" entry though they wanted to respond to a sub-entry of that "seed" entry. This finding may indicate the need to implement a new forum format in which members' entries will be organized in a semantic and tree-structured system rather than in a chronological system that has been very common in many web-based forums. That feature has been implemented in a new forum tool in the second iteration of our development process. Our preliminary observations with the use of the new forum tool by pre-service teachers suggest that the new forum format seems to sort the above confusing issue out and also help the users follow discussion stories more easily.

References

Chieu, V.M., Weiss, M., & Herbst, P.G. (2009, April). *A pilot study toward building web-based interactive rich-media virtual settings for teacher preparation and development*. Paper presented at the Annual Meeting of AERA, San Diego, CA.

Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New directions in educational technology*. Berlin, Germany: Springer-Verlag.

Herbst, P., & Chazan, D. (2003). Exploring the practical rationality of mathematics teaching through conversations about videotaped episodes. *For the Learning of Mathematics*, *23*(1), 2-14.

Leinhardt, G., & Ohlsson, S. (1990). Tutorials on the structure of tutoring from teachers. *Journal of Artificial Intelligence in Education*, *2*, 21-46.

van Es, E.A., & Sherin, M.G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. *Teaching and Teacher Education*, *24*(2), 244-276.

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Pre-Implementation Technology Acceptance Model—In the Case of a University-Based Electronic Portfolio System

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Abstract. To reduce the risk of failure when implementing an innovation, understanding factors that may influence users' intention to use a system should be obtained before the system is implemented. This study proposed and tested a pre-implementation technology acceptance model. This model may help change agents to evaluate the feasibility of the innovation and to identify the key factors that may determine the success of the innovation.

Introduction

Enthusiasm and expectations about the benefits that an eportfolio system could bring for students has run very high recently. However, current practices of developing and implementing eportfolio systems are primarily determined by administrators or faculty; students' voices are substantially neglected from both practices and research (Ayala, 2006). Research shows that it is important to understand whether users view a product as valuable even before they have any real experiences with it, because such perceptions may strongly influence their intention to use the product and the level of satisfaction that they feel with it (Sweeny & Soutar, 2001). While Davis, et al. (1989) called for an investigation on "how far upstream in the development process we can push user acceptance testing (p.1000)," on the basis of the Diffusion of Innovation Theory (Rogers, 2003) and Technology Acceptance Model (Davis, et al.), this study proposed and tested a model to show how users' intentions to use an eportfolio system may be predicted by variables such as prior experiences, key usability concerns, perceived values, organizational championships, and attitudes before users have any chance to interact with the system. Eight hypotheses for the relations between these variables constituted this model.

H1: Perceived values may significantly influence users' intention to use an eportfolio system.

H2: Perceived values may significantly influence the perceived importance of the key usability concerns.

H3: Perceived key usability concerns may significantly influence users' attitude toward using an eportfolio system.

H4: Perceived importance of institutional championship may significantly influence the perceived values of an eportfolio system.

H5: Perceived importance of institutional championship may significantly influence the perceived importance of key usability features

H6: Perceived importance of institutional championship may significantly influence the attitudes toward using an eportfolio system.

H7: Users' attitudes toward using an eportfolio system may significantly influence users' intention to use it.

H8: Users' prior experience may significantly influence the perceived importance of the key usability features.

Method

A web-based questionnaire composed of 6 scales (for the aforementioned 5 predicting variables and 1 dependent variable) with a total of 40 items measured with 5-point Likert scales was developed. Exploratory and confirmatory factor analyses were conducted and identified two to three factors within each scales (Figure 1). Three hundred and sixty four college students who never used an eportfolio system before were invited to participate in this study.

AMOS was used to test the convergent validity. The standardized path loadings were all significant and greater than 0.7. The composite reliability (CR) and the Cronbach's alpha for all constructs exceeded 0.7, and the average variance extracted (AVE) for each construct was greater than 0.6. These results suggested satisfactory convergent validity of this model. The tests on the structural model found that all the fit indices and the parsimonious fit measures meet the recommended criteria (Figure 1). These results suggested that this model appropriately explains the structure of the data and that all hypotheses were supported.

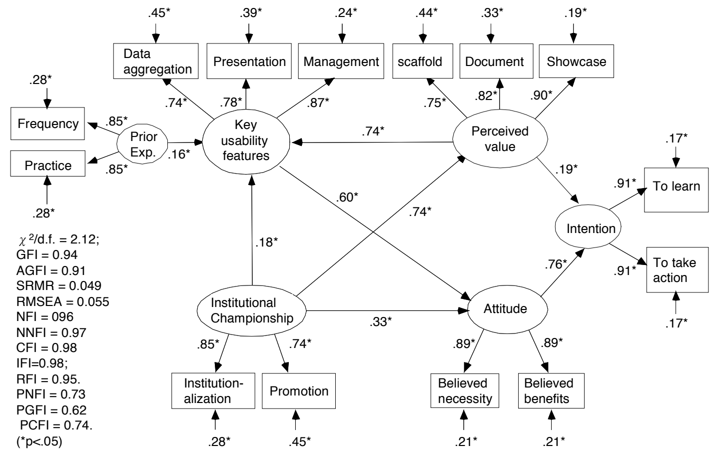

Figure 1. Testing results of the structural model

Conclusion

Implementing an information system, such as eportfolio in schools, is usually a big investment and often susceptible to failure if users' opinions were not well considered. This study provided a framework for understanding factors that influence users' intention to use a system before they have real experience with it. It helps to evaluate the feasibility of implementing an innovation.

References

Ayala, J. I. (2006). Electronic portfolios for whom? Educaus Quarterly, 29, 12-13.

Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. Management Science, 35, 982-1003.

Rogers, E. M. (2003). Diffusion of Innovation. New York: Free Press.

Sweeny, J. C., & Soutar, G. N. (2001). Consumer perceived value: The development of a multiple item scale. Journal of Retailing, 77, 203-220.

Aggregation in the blogosphere

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Introduction

Students can make two kinds of contributions to a blogosphere; these are primary. As a blogger, each student produces an open journal, a monologue about the course content. As a discussant each student participates in a dialogue about the content of one or another post. As a secondary form of participation students can read in the blogosphere.

As a blogger, a student posts her reflections on some part of the course material. A blog post may refer to the text or quote the text, refer to the lecture, an issue that was discussed in class, another blog, or to an outside article, site, or book. Frequently students will include personal experiences or anecdotes as part of their post. The students develop their individual voices. The monologues of the students are published and broadcast, emerging in an open space, giving students exposure to multiple viewpoints and voices. The ratio, the balance, of these voices gives a student a textured view of the course material. In addition to authoring posts, students act as discussants on each other's posts. Much of the commentary is either an agreement or expatiation on another student's point. Other responses are more discursive.

This paper presents part of a case study of students co-blogging throughout the semester. The class blogosphere became a repository of information, opinions, monologues and dialogues about the course content. Over the course of the semester there was an aggregation of information that was "mined" by the students. The focus of analysis is on the impact of the students' co-blogging work on two papers they wrote during the semester. The data shows that each student's individual contributions to the blogosphere prepared the student for writing the papers. The data also shows that students leveraged the contributions of other students when they wrote their papers.

Background literature

A co-blogging community is social and student-owned (Oravec, 2002). Because co-blogging is Web 2.0 technology, the "buy-in" for students is fairly cheap (Glogoff, 2005; Duffy 2008). The informal nature and ease-of-use of co-blogging encourages students to explore and publish their own ideas under less pressure than in formal in-class discussions (Althaus, 1997). Because each student has her own blog, she has full control over the content and can establish personal and intellectual ownership of her work (Fredig & Trammell, 2004). When a student writes a blog post she practices at producing a narrative about the significant elements of the course material (Williams & Jacobs, 2004). Co-blogging creates opportunities to exchange, explore, and present alternate viewpoints (Fredig & Trammell, 2004). It exposes students to alternate ways of "seeing" and "constructing" what is significant and why (Oravec, 2002; Fredig & Trammell, 2004). Discussions on issues related to the course material naturally emerge, enabling students to collaboratively work through the arguments and trade-offs, weighing and comparing different explanations and justifications, which positively impacts learning (Andriessen, 2006).

The Co-blogging Environment

The co-blogging environment has been developed using the design-based research methodology, over a number of years, in several different courses; it is implemented using a wiki-based educational platform, the WDP, that supports a variety of collaborative learning activities (Larusson & Alterman, 2009). In the co-blogging environment, each student has a blog. Each blog post shows a picture of the author, a title, and a tag that relates the post to a lecture given in class. At the bottom of a post, there is a list of people who read the post. Any threaded discussion that emerges is shown below the relevant post. As a student writes her blog, she can read another student's post on the same topic with a click of the mouse. When a student begins to write a blog post she can use one of the tags that are assigned to each lecture. At the "front entrance" to the blogosphere, there is a list of the five most recent posts or comments on posts. Each item in the list displays the name of the author of the post or comment and a short excerpt from the contribution. Students can also access the posts via a word cloud or by doing a keyword search. Students receive daily email newsletters that summarize the online co-blogging activity in the previous 24 hours. The newsletter lists the title, author, and first line of all the newly created blog posts, and a list of similar information for any new comment. Students can use the links on the newsletter to directly navigate to any post or comment on the blog site that is of interest.

Case Study

In an introductory undergraduate course taught in Fall 2008 on *Internet & Society*, 25 students from a variety of disciplines co-blogged throughout the semester. At the beginning of the semester, an in-class tour and exercise introduced the students to the important features of the co-blogging environment. The students were required to blog at the pace of one post per lecture: there were two lectures per week. A typical post was 1 or 2 paragraphs in length. The students were also required to read and comment on other contributions to the blogosphere. The co-blogging work of each student counted for 35% of his or her grade. All of the students' online work was automatically recorded in a transcript, which enabled both quantitative and qualitative analyses. Lecture slides were used as a basis for tagging content in the blogosphere and the paper. For each set of lecture slides, the instructor identified a set of key topics that were covered by the lecture. All the posts and comments in the blogosphere were coded using these topics/tags.

Capitalizing on the aggregation of information while writing papers

The total number of additions to the blogosphere is a rough measure of the amount of information "digested" by the class while doing the co-blogging exercise. Because posts and discussions, once created, persist throughout the semester, the students can "mine" the aggregated information as a resource for another learning activity, when the situation warrants it. Many students sampled other contributions in the blogosphere before posting to their own blogs (roughly 35%). Right before a paper deadline, many students did heavy reading in the blogosphere in order to access and review ideas, arguments, examples that were relevant to the paper they were writing, reproducing, in their own words, the content of relevant posts and discussions they found in the blogosphere.

Figure 2 shows the relation between activity within the blogosphere and students authoring papers during the time the class read two books for which they wrote short papers.

1. The y-axis compares the number of topics/tags on each student's posts and comments (primary participation) to that number for the same student's topics/tags in his or her paper. A positive number means that more of a student's paper was composed of topics they posted and/or commented upon in the blogosphere. A negative number means that a majority of the content in a student's paper did not originate in contributions to the blogosphere.
2. The x-axis computes a similar number for reads (secondary participation). So, a positive number means that more of a student's paper was composed of topics they read about in blogosphere prior to writing her paper. A negative number means that a majority of the content in a student's paper did not originate from reading in the blogosphere.

Consider each of the four quadrants of the graph starting in the upper left-hand quadrant:

Q1: Primary participation provided preparation for writing papers.
Q2: Primary and secondary participation provided preparation for writing papers.
Q3: Secondary participation provided preparation for writing papers.
Q4: Most of these students' papers were derived from work that was not influenced by their activity in the blogosphere.

For 16 of the 25 students, their work in the blogosphere familiarized them with a majority of the concepts that appeared in their two papers (their data is either positive on the x-axis or y-axis). The largest group of students (Q3) benefited most from the reading. The next largest group (Q2) benefited significantly from both primary and secondary participation in the blogosphere.

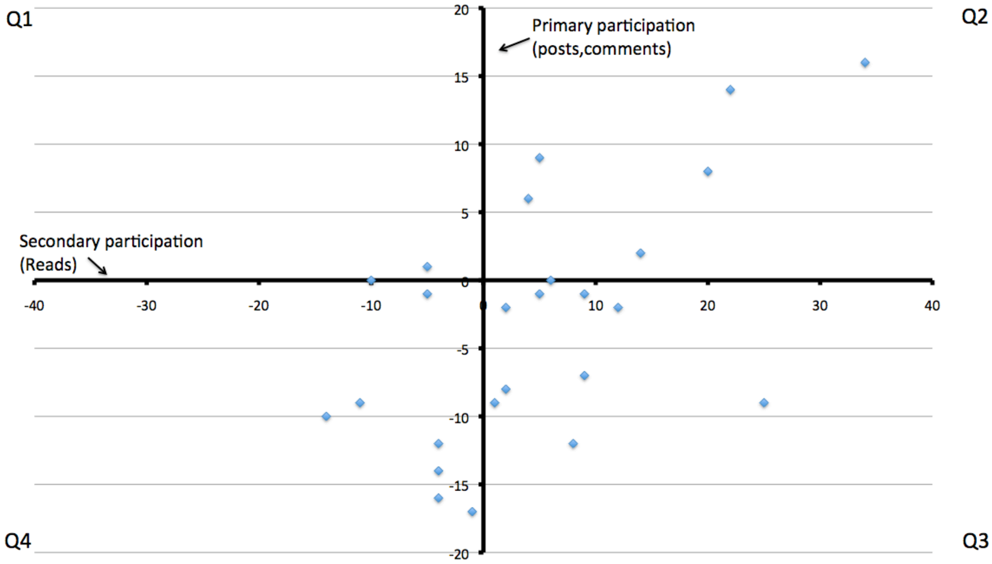

Figure 1: Activity in the blogosphere exposes students to topics they discuss in their papers.

See page 3 of paper for reference list.

DevInfo GameWorks: Supporting inquiry-based game design

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Abstract: We report on a pilot of DevInfo GameWorks, a web-based system that allows users to create and play data-driven educational games. In particular, we focus on the challenges of scaffolding game creation, encouraging meaningful inquiry as the basis for game design, and supporting a community of learners. Preliminary findings point to several areas for continued investigation and development.

The promise and challenge of learning through designing games

Research over the past two decades has pointed to the power of engaging learners in designing their own games. At the same time that the idea of learning through *playing* digital games has gained currency (Gee, 2007; Salen, 2008), educators taking a "constructionist" approach (Bruckman, 1998; Papert, 1991) have pointed to the even greater potential of learning through *creating* games, especially when the goal is to create games with an educational purpose (Carbonaro, et al., 2006; El-Nasr, 2006; Kafai, 1996). Game-creation has the potential to support higher-level thinking and expression using multiple literacies, and to boost motivation and self-esteem for children who don't consider themselves good at traditional literacy practices (Robertson & Good, 2005).

In this work, however, three persistent challenges remain. First, despite the increasing availability of tools designed to support game-programming by novices (e.g., Overmars, 2004), making digital games still generally demands substantial time and technical skills. Second, it is not easy for learners to create games that are satisfying to play, interesting, and genuinely educative. While we believe that games can provide a framework for meaningful inquiry, novice game-designers understandably tend to concentrate on the mechanics of their game rather than educational implications (e.g., Kafai, 1996; Overmars, 2004). Third, while a supportive, interested, and widely-distributed audience for learner-created games can provide crucial motivation and feedback (Resnick, et al., 2009), environments that support this kind of authentic community remain rare.

Background and Methods

We have attempted to address these three challenges through DevInfo GameWorks ("DIGW"), a system that includes game templates that allow easy creation of new game content; tools and resources to help learners focus on inquiry with real data; and tools for feedback, collaboration, and social networking so that there is a community of learners.

The center of DIGW is a website (http://digw.org) that has templates designed to allow easy creation of data-driven games that can be played in three formats: online in real time by multiple players, in solitaire mode, or in printed form offline. (The first game template is based loosely on tic-tac-toe, but with enhanced elements of strategy, knowledge, and chance.) Using databases of indicators related to the United Nations Millennium Development goals and other data sets, as well as user-created media, learners can design and play games that are based on inquiry into rich sets of information, and which focus on meaningful relationships among data. (For example, learners might investigate questions such as, "what is the relationship between GDP and HIV infection rates in Africa?" or, "What are the biggest health problems in my community, and how big are these problems regionally and globally?")

At the same time, social-networking features help generate situations in which intentional learning becomes natural: learners are able to engage with serious content in playful ways; older users can mentor younger ones; and the community as a whole has an overarching goal of increasing the knowledge and engagement of the group.

Many DIGW users are students using the system as part of a class assignment or project, but the system is also available for use by the general public. Teachers who wish to use the system as part of a class have access to curriculum materials and guides, but no attempt has been made to standardize use of the system across all learning contexts.

Because of this variety of uses, and the range of educational aims that inform these contexts, our analysis has not focused on finding some sort of cause-effect relationship between DIGW and a predefined "achievement" measure; rather, we have looked at the extent to which the system supports new ways of engaging in higher-level thinking activities, especially those that involve so-called "21st Century skills" such as collaboration, "network awareness," and critical consumption of information (e.g., Davidson, 2009; Wagner, 2008). To do so, we have examined the quality of engagement and learning, as measured by field observations, evaluation surveys, interviews with facilitators and participants, and a content-analysis of the games themselves.

Finding and implications

When DIGW was first proposed, the immediate goal was to increase awareness of global issues in general and the Millennium Development Goals in particular. An early pilot with urban sixth grade students established that DIGW can be an effective tool for this aim (Robertson, Baglin, & Kupperman, 2009). Since then, however, the system has been used to achieve a wide variety of different content goals: for example, a primary school teacher in South Africa was attracted by the opportunity for learners to practice English language expression in an authentic environment; a college professor used it to help her students learn literacy education concepts; and a high school journalism teacher saw it as a way for her students to do grass-roots journalism.

Across these varied contexts, it has become apparent that two aspects of the system are particularly relevant in terms of supporting high-level intellectual engagement and the 21st Century skills mentioned above. First is a strong sense of the audience – in other words, the potential players – during game design. In the most successful designs, this sense of audience helps shape everything from the game's topic to media choice and text phrasing. Ultimately, a good DIGW design must be interesting and appropriately challenging for players, and it also should convey some important information. Of course, a sense of audience is important in any kind of authoring, from traditional texts to blogs or video, but because a DIGW game is *played* rather than read or viewed, the player's perspective is especially compelling.

The second aspect we have found to be particularly relevant is the importance of a tangible artifact as a product of inquiry, along with opportunities for social sharing and feedback around this artifact. Having a concrete and public outcome seems crucial to fostering a sense of ownership and pride in the inquiry and design work. This second aspect closely echoes the findings of Resnick and colleagues (2009) about users of the programming environment Scratch: young people were able to do remarkably self-motivated and sophisticated work in an environment that supported personally meaningful projects and social sharing. DIGW pushes this idea further to include an additional emphasis on inquiry into real-world data (both from electronic databases and from local communities) and globally relevant issues.

All of that said, more work is needed to address the persistent challenges listed at the beginning of this paper. First, even though DIGW greatly reduces the technical knowledge necessary to create a game, it is still not trivial to make a game that is genuinely and uniquely interesting, educative, and challenging to others. (At the same time, the intellectual work of designing a game is important, and we don't want to shortcut that by making game creation "too easy.") We are continuing to work on ways to scaffold this process. Secondly, we need to better help participants frame interesting questions for inquiry and find rich data representations. Project participants are directed to a range of sophisticated tools that can be used to access, organize, and analyze data, but we know that access to tools by itself is not enough. We are developing a number of strategies to support deeper inquiry, including the creation of a library of "interesting questions" and related resources. Finally, when done in a school setting, even a task like game design can be reduced to schoolwork – an involuntary demonstration of knowledge for the teacher. Ultimately, then, success will depend not just on better technological tools and materials, but on better ways to think about teaching, school, and learning.

References

Bruckman, A. (1998). Community support for constructionist learning. *CSCW, 7*, 47-86.

Carbonaro, M., et al. (2008). Interactive story authoring: A viable form of creative expression for the classroom. *Computers & Education, 51*(2), 687-707.

Davidson, C. N., & Goldberg, D. T. (2009). The future of learning institutions in a digital age. Cambridge, MA: MIT Press.

El-Nasr, M. S. & Smith, B. K. (2006). Learning through game modding. *Computers in Entertainment, 4*(1).

Gee, J. P. (2007). What video games have to teach us about learning and literacy (Rev. and updated ed.). New York: Palgrave Macmillan.

Kafai, Y. B. (1996). Learning design by making games. In Y. Kafai & M. Resnick (Eds.), Constructionism in practice (pp. 71-96). Mahwah, NJ: Lawrence Erlbaum Associates.

Overmars, M. (2004). Teaching computer science through game design. *Computer, 37*(4), 81-83.

Papert, S. (1991). Situating constructionism. In I. Harel & S. Papert (Eds.), Constructionism (pp. 1-11). Norwood, NJ: Ablex Publishing.

Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., et al. (2009). Scratch: Programming for all. *Commuications of the ACM, 52*(11), 60-67.

Robertson, B., Baglin, S, & Kupperman, J. (2009, November). DevFacToe: Changing the world, one game at a time. Presentation at the Michigan Council for the Social Studies, Mount Pleasant, MI.

Robertson, J. and Good, J. (2005). Story creation in virtual game worlds. *Communications of the ACM, 48*, 61-65.

Salen, K. (2008). The ecology of games: Connecting youth, games, and learning.

Wagner, T. (2008). The global achievement gap: Why even our best schools don't teach the new survival skills our children need--and what we can do about it. New York: Basic Books.

"Oh god, please don't let me hurt them!": Assessing Self-Regulated Learning in Medical School Education

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Abstract: With recent trends in residency training moving towards outcomes-based education, changes are needed in the design of undergraduate medical education. This study explores medical students' learning facilitated by an online system, the ENCORE LMS, designed to enhance the standard curriculum by promoting self-regulation and self-reflection. Student survey responses and analysis of their online journals provide evidence of content mastery and development of self-regulated learning. We discuss the effectiveness of this student-centered learning management system.

Introduction

While medical school education has evolved in response to basic and clinical research discoveries and an enhanced understanding of learning methods, undergraduate medical education (UME) retains at its core the time-based curriculum of two pre-clinical years focused on basic science lectures and two clinical clerkship years. This model was established nation-wide a century ago, with its roots dating back to the 1870s (Flexner, 1910). Outcomes-based education has recently taken hold in residency programs and, anticipating that this trend will move upstream, the medical school at a large Midwestern U.S. research university is investigating a competency-based approach for UME. Combined with rigorous assessments, this curriculum reform will ultimately permit a student to move through medical school at his or her own pace while still achieving mastery over the content required by licensing boards.

To support this new curriculum, named ENCORE, the medical school is partnering with faculty at the university's Schools of Information and Dentistry to prototype a new learning management system (LMS), following Dalsgaard's (2006) recommendation to replace the monolithic learning management system in order to "engage students in an active use of the web as a resource for their self-governed, problem-based and collaborative activities." Key features of ENCORE include explicit competency standards that must be met for graduation, assessments that track student mastery of outcomes, and flexible learning paths based on the individual needs and interests of students. ENCORE relies on a self-regulated learning model; a metacognitive process built on the concept of, and positively correlated with, perceived self-efficacy or personal judgment of performance capability (Schunk, 1985; White & Gruppen, 2007). Self-efficacy contributes to motivated learning, which emphasizes acquiring skills and knowledge over task completion. Self-regulation includes strategies for planning, monitoring, and modifying student cognition (Pintrich & De Groot, 1990). The benefits of self-regulated learning have been established through controlled studies that show students with good self-regulation skills performing at a higher academic level than those without such skills (e.g., Zimmerman & Bandura, 1994). Challenges include maintaining motivation and developing the skills to effectively use feedback.

ENCORE's portfolio-oriented LMS features tools for managing learning outcomes, listing and tagging learning resources, recording patient encounters, reflective journals, formative and summative assessments, and faculty feedback. Faculty mentors provide a default set of learning activities while students self-select (and sometimes self-define and acquire) learning activities and learning resources, such as journal articles and anatomy videos. Self-regulated learning in ENCORE occurs both independently and in peer groups. Students decide when they are ready for summative assessments based on their use of formative assessments. The research question for this project is: How do medical students develop and express self-efficacy and identity as self-regulated learners in an environment facilitated by a new learning management system?

Methods and Preliminary Analysis

During the summer of 2009, six first year medical students were recruited to participate in a six week evaluation of the ENCORE curriculum. The pilot curriculum had three major threads: clinical experiences with patients, collaborative learning projects, and independent learning. An online survey instrument was administered six times during the study, prompted at different times of the day, to ask students about the reason for their most recent use of the LMS, their assessment of the value of the LMS, and the relevance of that use to the learning objectives. Students also utilized the system to record journal entries regarding their various learning activities.

Survey data revealed that, at the moment of prompting, 37% of the students were using the ENCORE LMS because they wanted to, while 73% of the time they were completing a compulsory task. Using a 5 point Likert scale (1 = not at all relevant to 5 = very relevant) to measure the fit between the LMS tools and learning activities, 89% of the student responses were that the system tools were somewhat or very relevant to the current learning task. Using a similar scale, 81% of the student responses were that the LMS somewhat or very much improved the quality of the learning activity.

Students provided 160 daily and capstone journal entries in which they were asked to address the following prompts: What are your (reflective) thoughts about today's learning experiences? How did today's experience(s) build upon previous learning experiences (e.g., the connections you are seeing/making)? Describe progress you are making toward your learning goals. Describe progress you are making toward program goals.

Discourse analysis of the journal entries provides evidence of growing awareness of self-efficacy and learning. For example, one student, through the use of metaphor, indicates a positive experience while still acknowledging challenges:

> This whole week was a great opportunity to stretch my wings and try to fly a little for the first time. I feel like the Wright brothers. My first flights are very short and bumpy, but one day, I'm really going to make it work and I'll walk into the room thinking "I can help this person" rather than "oh god, please don't let me hurt them!" (S3)

The same student, while hedging on qualifications and exhibiting stake inoculation (i.e., not claiming competencies not yet held), shares a success story of reaching the same conclusion as an attending physician:

> While diagnosing is not really a skill we're expected to have mastered yet, I think it's tremendously useful to push us to try and think it through. I may not be brilliant and quick yet, but I did come to the same conclusion as Dr. X. (S3)

Another student indicated a shift in perception regarding the institutionally conferred power structure:

> I learned to be more critical about data and practices that were more based on tradition than research. Since starting medical school, we have been bombarded with so much information that I have not been able to question the validity of the material. Honestly I have assumed that everything we have been taught must be correct because the material is being presented by clinicians and PhDs who have more experience. It seems in medicine there is a hierarchy and sometimes information is just taken to be true just based on the fact that it comes from your superior and you don't want to fail because you didn't do what they thought was right. (S6)

Discussion

This study explored the use of a new learning management system in conjunction with an innovative curriculum based on self-regulated learning. The survey data indicates that although use is not primarily student-initiated, student learning can be facilitated by a learning management system "tuned" to self-regulated learning. The preliminary analysis of student journals demonstrates evidence of growing self-efficacy and learning. Future work will include more detailed discourse analysis of student journals and provide further evidence from the surveys, student interviews, and review of the broad range of artifacts generated during the pilot. Standardized test scores will also be incorporated into the analysis, facilitating a longitudinal assessment of the intervention.

Although generalizability is not a top goal for this project, we anticipate that understanding the experience of a specific group of medical students will inform larger-scale follow-up initiatives. For example, a subset of the LMS tools are currently being deployed to all 170 first year medical students to support outcomes-based collaborative learning around patient cases. This pilot will inform surveys of that larger population. As other disciplines move to outcomes-based education, these studies will inform a broader movement to support self-regulated learning and provide input to the design of student-centered learning management systems.

References

Dalsgaard, C. (2006). Social software: E-learning beyond learning management systems. *European Journal of Open, Distance and E-Learning*, 2006 (II). Retrieved May 2, 2009 from http://www.eurodl.org/materials/contrib/2006/Christian_Dalsgaard.htm

Flexner, A. (1910). *Medical Education in the United States and Canada: A Report to the Carnegie Foundation for the Advancement of Teaching*. New York, NY.

Pintrich, P., & De Groot, E. (1990). Motivational and Self-Regulated Learning Components of Classroom Academic Performance. *Journal of Educational Psychology*, 82(1): 33-40.

Schunk, D. (1985). Self-efficacy and classroom learning. *Psychology in the Schools*, 22: 208-223.

White, B.C., & Gruppen, L.D. (2007). *Self-regulated Learning in Medical Education*. Edinburgh: Association for the Study of Medical Education.

Zimmerman, B., & Bandura, A. (1994). Impact of Self-Regulatory Influences on Writing Course Attainment. *American Educational Research Journal*, 30(4): 845-862.

Finding Essential Complexity for Learning in Virtual Worlds

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Abstract: This theoretical paper introduces one possible avenue for measuring learner performance in virtual worlds, intended to leverage these virtual worlds as learning systems that can provide individualized learning experiences at an appropriate level of complexity for any given learner. First, we extensively define essential complexity. Then, we describe an assessment framework for finding this essential complexity in a virtual world, using a variety of embedded measurement techniques.

Introduction

As we face an increasingly complex world of nested, interacting systems (e.g., biological, ecological, physical, social, economic, etc.), a need for approaches to learning that better prepare us to engage with these systems is becoming increasingly apparent. The purpose of this article is to formalize one possible approach to the creation of an improved learning system that can prepare humans to understand and interact with an ever-changing world and its inhabitants using dynamic learning scenarios (or quests) embedded in meso-immersive (Moreno & Mayer, 2002) virtual inquiry environments. These dynamic learning scenarios would be delivered in these virtual inquiry environments at a level of complexity that is determined to be essential for a given individual learner at that time – *essential complexity*.

We provide a detailed definition of essential complexity, as manifest in three experiential forms for the individual learner: *content, process,* and *context*. We then describe an evidence-centered assessment framework for finding essential complexity for any given learner completing tasks during a learning quest based in a virtual world, using unobtrusive, or stealth (embedded) instruments designed to measure an individual learner's perceived cognitive load (in the form of mental effort).

Briefly, meso-immersive virtual worlds are immersive, game-like 3D environments housed within a computer application, presented to the learner on a 2D computer display monitor. The learner is capable of performing any number of interactive tasks by controlling the physical movement of an avatar within this immersive 3D environment.

Defining Essential Complexity

For the purposes of this paper, essential complexity is an appropriate level of complexity – of content, process, and context – for a given person in a given virtual learning environment at a given point in time.

Content Complexity

Essential content complexity is the appropriate level of content difficulty for a given learner at a given point in time during an interactive learning experience within a virtual world. Specifically, content difficulty is the range of learner difficulty in understanding the curricular content being delivered via an interactive scenario in a virtual world. From this curricular perspective, this concept of content difficulty is essentially nothing new in the field of educational research, as countless theories and studies have been created regarding appropriate content difficulty for learners with different levels of expertise or prior knowledge within a given subject domain.

Process Complexity

Essential process complexity is the appropriate level of task difficulty for a given learner – based on Vygotsky's (1978) zone of proximal development theory – at a given point in time during an interactive learning experience within a virtual world. Specifically, task difficulty is the range of learner difficulty in completing the multitude of tasks inherent in accomplishing the goals set forth within an interactive scenario/quest in a virtual world. A simplistic example of the sorts of tasks that are inherent in these quests can be found within a courier quest, which typically consists of three phases: obtain a package, transport that package, and deposit that package with its intended recipient. A package transportation task with higher levels of task difficulty might require the learner to traverse a more harrowing path with higher numbers of obstacles of increased process complexity.

Context Complexity

Essential context complexity is the appropriate level of situated complexity (of the immersive environment) for a given learner at a given point in time during an interactive learning experience within a virtual world. Specifically, situated complexity is the level of complexity inherent in the details of the environmental affordances (e.g., Gibson, 1986) provided to the learner in the virtual world as he or she completes a quest. A simple example of high situated complexity during a quest in a virtual world is increased (potential) distractions for the learner through the addition of interactive and non-interactive in-world objects which possess increased levels of realism – ripe for task-extraneous exploration by the learner.

Finding Essential Complexity

Before we can maintain essential complexity in a virtual world for any given learner, we must find an appropriate level of complexity to deliver to that learner. To find this essential complexity, instrumentation must be developed to gather evidence through measurement, allowing for assessment of any learner's current ability levels (or expertise) concerning content, context, and process complexity.

To find essential content complexity, a learner's expertise in the subject domain(s) of the given content must be assessed. To find essential process complexity, a learner's expertise in the completion of any and all tasks inherent in the learning quest must be assessed. To find essential context complexity, a learner's expertise in contextual awareness of his or her in-world surroundings while completing the quest – as those surroundings pertain to an understanding of both the pertinent learning content, as well as the tasks necessary for completing the objectives of the quest. The activities and work products associated with content, process, and context complexity can serve as a framework for measuring appropriate levels of each for a given learner.

Table 1. Dyadic and triadic learning quest activities

Dyadic	Triadic
Approach Object	Communication About Object Movement
Depart Object	Communication About Human Movement
Projectile	Communication About NPC Movement
Automaton	Communication While Moving Object(s)
Carry Object	Complex Demonstration(s)
Push/Roll/Drag Object	Complex Sign/Signal Creation
Simple Demonstration	
Communication About Player Movement	
Simple Sign/Signal Creation	
Communication About Object(s)	

Conclusion

Once we are capable of unobtrusively collecting evidence of learner performance *in the moment*, we can then design back-end computational logic systems that can make just-in-time assessment decisions about a given learner's measured performance. Designing such assessment systems will allow us to build interactive learning scenarios in meso-immersive 3D virtual environments that are capable of *maintaining* essential complexity for the individual learner. In essence, one could build virtual environments that are truly *smart worlds* – changing themselves dynamically to reflect instantaneous assessment decisions made by the intelligent systems driving every aspect of the learner's virtual experience, including content, process, and context complexity.

References

Gibson, J. J. (1986). *The ecological approach to visual perception.* Hillsdale, NJ: Lawrence Earlbaum Associates, Inc.

Moreno, R., & Mayer, R. E. (2002). Learning science in virtual reality multimedia environments: Role of methods and media. Journal of Educational Psychology, 94(3), 598-610.

Vygotsky, L. S. (1978). *Mind in society: Development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Overherd: Designing Information Visualizations to Make Sense of Student's Online Discussions

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Abstract: Overherd is an information visualization tool that makes patterns of interaction and activity in online discussion boards visible so that instructors can more easily analyze their students' contributions. Our system uses the forums tool from the Sakai learning management system (LMS) to create visual representations of online behavior. We describe the design and development of Overherd, and provide design recommendations for "mashups" that extend the functionality of LMS yet rely on existing data within these learning environments.

Introduction and Motivation

With the nearly ubiquitous use of Learning Management Systems (LMS) in higher education, instructors are increasingly turning to online discussion boards to augment classroom discussion – some even require that students participate to earn part of their grade. In this form of "blended learning" (Garrison & Kanuka, 2004), online discussion boards provide a number of advantages for both students and teachers (see, e.g., Xie, 2006), including improved student performance (Krentler & Willis-Flurry, 2005). However, discussion boards present a number of problems as well. For instance, making sense of the posts in an online discussion board can be difficult, even when the conversation is threaded (Kay, 2006). The general use statistics most boards make easily available, such as counts of posts or words, are poor measures of the quality of learning taking place in those discussions (Mazzolini & Madison, 2005) and incorporating online discussions into existing teaching practices can increase the course's workload for both students and instructors (Brush, et al., 2002). In an effort to help instructors make sense of the discussions happening on a board and to ease their workload, we designed an information visualization tool called Overherd. We designed Overherd using the metaphor of herd behavior to visualize what students are talking about by providing different views that show aggregation patters of students, topic, and keywords. The goal of Overherd is to make it easier for instructors to get an overview of what their students are talking about in online discussions by displaying visualizations that include post content, author information, and connections among posts (e.g., replies). These visualizations allow instructors to answer questions such as, "Are students using new terms introduced in class?" and "What course concepts are students most interested in discussing?" Overherd enables instructors to check for students' understanding and to diagnose topics that may need additional discussion during face-to-face instruction.

Designing and Studying Overherd

Overherd is an extension of a Sakai-based LMS that includes a Forums tool for online discussions. In designing Overherd, we had very specific users and goals in mind – instructors of large lecture courses who used online discussions to extend classroom instruction. By limiting our design space, we were able to build a flexible platform that can still be extended to meet the goals of additional users in the future. In order to ground our design, we interviewed four instructors about their use of online discussion boards and later discussed paper prototypes of our designs with them. Overherd's goals are to

- facilitate faculty exploration of their classes' overall understandings of a concept or concepts, and
- assess student contributions and understanding for grading purposes.

In order to address these goals, Overherd displays visualizations that include both content (e.g., the text of individual posts) and context (e.g., author information, timestamps). Table 1 provides an overview of the specific needs each visualization is designed to address. Figure 1 shows the design of Overherd.

Overherd will be evaluated in two stages: first, a pilot user study where we display data from a completed course and ask instructors to evaluate the tool and second, a field study where Overherd will be deployed in several courses. These studies will explore whether Overherd helps instructors make sense of their students' online discussions and reduces the instructors' workloads.

Table 1: Addressing user needs with visualizations

User Need	Visualization
Overview of topics being discussed	Treemap organized by term or person
Determine which students use which terms	Term/person node diagram
See lists of posts that meet instructor's search criteria	Clustered list window
Read posts that meet criteria	Prose view window

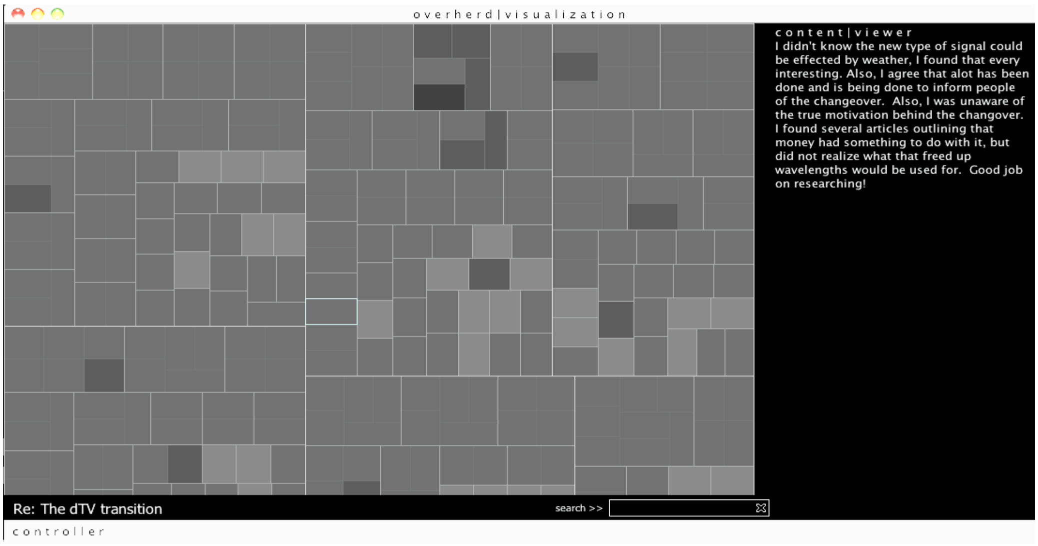

Figure 1. Overherd Interface v0.1

Mashups and Learning Management Systems

Many LMS such as Sakai, Moodle, or Blackboard provide tools that support discussion management. Because LMS are enterprise systems – whole campuses rely on their stability and infrastructure – it is difficult to experiment with new features and add-ons within the LMS itself (Severance, Hardin, & White, 2008). LMS capture and generate large amounts of data about use and content but do not provide easy access to or manipulation of that data outside the LMS. As technical barriers to building and experimenting with web applications decrease, the importance and usefulness of an application programming interface (API) for making LMS data available increases and creates opportunities for extending the tool sets available to support learning.

Future Research

Our future work will explore how instructors use Overherd to see whether it meets the goals of 1) allowing instructors to more easily get an overview of online discussions, and 2) reducing the overhead required for using online discussions. How instructors should participate in online discussions with their students is an open question (see Mazzolini and Maddison, 2005) Overherd will help answer. We will also explore the use of visualizations with students. A future version of Overherd will be student-focused and will allow students to search for terms and concepts within the discussion. We will explore whether those visualizations help students with self assessment and in finding answers to their questions about course concepts.

Overherd is a technical research project as well, and we will continue to study the development of information visualizations for use in learning environments and to develop mashup tools that extend learning management systems. For example, future work will explore best practices for APIs that make LMS data available to external applications while protecting the personal and copyrighted information they contain. The lessons learned from Overherd's development and field study will also inform future research on the usefulness of information visualization for other online discussions, such as support forums and email archives.

References

Brush, A. J. B., Bargeron, D., Grudin, J., Borning, A., and Gupta, A. (2002). Supporting Interaction Outside of Class: Anchored Discussion vs. Discussion Boards. *Proceedings of CSCL 2002*, 425-434.

Garrison, D. R.; H. Kanuka (2004). "Blended learning: Uncovering its transformative potential in higher education". *The Internet and Higher Education, 7* (2), 95-105.

Kay, R.H. (2006). Developing a comprehensive metric for assessing discussion board effectiveness. *British Journal of Educational Technology*, *37*(5), 761-783.

Krentler, K.A. Willis-Flurry, L.A. (2005). Does Technology Enhance Actual Student Learning? The Case of Online Discussion Boards. *Journal of Education for Business*, 80(6), 316-321

Mazzolini, M. and Maddison, S. (2005). When to jump in: The role of the instructor in online discussion forums. *Computers & Education, 49*(2), 193-213.

Severance, C., Hardin, J. & Whyte, A. (2008). The coming functionality mash-up in Personal Learning Environments. *Interactive Learning Environments*, *16* (1), 47-62.

Xie, K., Debacker, T.K., and Ferguson, C. (2006). Extending the traditional classroom through online discussion: The role of student motivation. *Journal of Educational Computing Research*, *34*(1), 67-89.

Out-of-School Virtual Worlds Based Programs: A Cross-Case Analysis

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Abstract: This poster presents a cross-case analysis conducted on two out-of-school programs based on virtual environments: Global Kid's "I Dig Science" curriculum in *Teen Second Life* and the GLS "casual learning lab" based on the online game *World of Warcraft*. Using a coding framework representing the shared instructional goals of the programs to analyze ethnographic data from both sites, we compare the nature of learning in the two contexts.

There is a rising interest in out-of-school programs for informal learning as a way to complement (if not supplement) formal learning in classrooms. Recent trends toward extension of the school day in America coupled with an increased desire to not simply do more of the same have led to increased attention to informal learning programs in sites such as boys and girls clubs, local libraries, and both on- and off-campus initiatives. Coupled with this rising interest in informal education programs has been in increased interest in the use of online interactive technologies and virtual worlds. Commercial worlds such as *Second Life*, *World of Warcraft*, and *Whyville* – along with intentional learning environments like *Quest Atlantis* (Barab, Arcici, & Jackson, 2005) and *River City* (Dede, Ketelhut, & Ruess, 2003)–have become "evocative objects" for educators interested in technology as a means for fostering social interaction, increasing motivation and engagement, and enabling quasi-authentic inquiry work in the context of virtual environments instead of real ones. Yet, we have few empirically documented examples of programs leveraging existing commercial virtual spaces toward educational ends save the work of Kafai and colleagues (Neulight et al, 2007). This poster reports on a cross-case analysis conducted on two out-of-school programs based on virtual environments. The sites studied in this work – Global Kid's (GK) "I Dig Zambia" curriculum in the context of the virtual platform *Teen Second Life* and the Games, Learning & Society (GLS) Program's "casual learning lab" based on the massively multiplayer online game *World of Warcraft* – were selected for their comparable use of technology platform yet contrasting approaches to instructional design. Using a shared theoretical framework based on the instructional goals of both programs to analyze ethnographic data from both sites, we aim to tease out the similarities and differences in the forms of learning that took place in each context. We present preliminary findings from this research, highlighting the shift in research focus or "quintain" (Stake, 2006) from "affordances and constraints of virtual worlds platforms" to "situated comparison of intentional (GK) versus interest-driven (GLS) learning models."

Case One: Global Kids "I Dig Zambia" in *Teen Second Life*

Global Kids is an independent non-profit organization with a mission to educate and inspire urban youth to become successful global citizens and community leaders. Toward this end, they organize out of school programs and experiences, including intensive summer camps, to educate youth about critical international and public policy issues and to inspire them to take action. The data we analyzed for this cross-case analysis was drawn from their 2009 summer camp entitled "I Dig Zambia." "I Dig Zambia" brought together 19 minority adolescents from Chicago and New York for two weeks to learn about paleontology, biology, and Zambian culture and politics in *Teen Second Life.* This intentional learning environment included structured activities designed to give participants an opportunity to develop their 21st century skills, social interactions with practicing paleontologists, and virtual world exhibits where youth presented their culminating work as well as blogposts which added a reflective writing component to their daily activities.

Case Two: GLS Casual Learning Lab Based on *World of Warcraft*

The GLS casual learning lab based on *World of Warcraft* was an eight-month after school program targeting 22 adolescent boys that were disengaged (and frequently failing) in school. The goal of the GLS Casual Learning Lab was to explore ways that instructional designers might leverage adolescents' existing interests in games in order to engage them in practices that are both aligned with schools and meaningful in their everyday offline lives. Participants and research staff met regularly in-game during the week for regular gaming using "guild" functions to structure play and once a month for face-to-face Saturday pizza parties on campus that enabled more structured data collection activities such as focus group discussions and interviews. Based on a general model of "interest-driven learning," research staff acted as informal mentors rather than instructors with all content instruction arising only on demand, in the context of authentic gaming practice.

Methods: Data Collection & Analysis

Ethnographic data collection methods (Hammersley & Atkinson, 1986) were used across both in-game and face-to-face contexts at both sites. Data collection included multimodal fieldnotes, in-game chatlogs, videotaped and transcribed face-to-face discussions, and participants' blog (GK) and forum (GLS) posts. The coding scheme used for this analysis (see Table 1) was constructed out of the instructional goals of each program and functioned as a shared framework for tracing the emergence of key practices and dispositions within each site. Codes were negotiated between the two program directors, then piloted, and then refined into a final set of 11 themes total with 44 subcodes nested within theme. A team of eight researchers then coded the entire data corpus from both sites using NVivo. Interrater reliability, calculated on 10% of the data corpus, was 98%.

Thematic Comparisons and Conclusions

Table 1 presents the 9 main analytic themes highlighting the main contrasts between the two programs in light of their disparate approaches to learning (i.e. "intentional" versus "interest-driven").

Table 1: Main contrasts between the two cases based on the analytic framework used

Analytic Theme	GK "I Dig Science"	GLS Casual Learning Lab
Argument	Re-voicing techniques used by staff to coordinate claims within a framework	Collective, little structural coherence beyond sequential ordering of claims
Problem-Solving	Getting the answer right (e.g. matching fossil findings to the teacher's model)	Finding a "good enough" (not necessarily "best fit") solution
Reading	Program selected, coherent	User-driven and organic, yet idiosyncratic
Information Literacy	Staff are main resource; evaluation, interpretation, and synthesis evidenced in reflective blogposts	Peers are main resource; access tied to social/ cultural capital
Digital Media Literacy	Media navigation is highly scaffolded with higher rate of "on task" behaviors	Frequent transmedia navigation made coherent by individual interest not task
Design Thinking	Design critiques focused on the technical not social; re/design rare	Design critiques focused on the technical not social; re/design rare
Model Based Reasoning	Models designed into activity; function to coordinate discursive argumentation	Most frequently in relation to "talent builds" system; function to coordinate discursive argumentation
Cross Cultural Fluency	Moderated, "safe space"	Spontaneous & volatile
Workplace Literacy	Domain Specific (i.e., paleontology related)	Domain General (e.g. goal setting, time management)

One conclusion that can be drawn from this analysis is that designers of out-of-school environments that leverage virtual worlds for learning must take seriously the need to balance standardization with customization. A program designed for intentional learning offers structured goals with equal outcomes but runs the risk of alienating students from their own learning preferences. On the other hand, an interest-driven program gives the students opportunity to pursue their own interests but at the risk of narrowing their exposure to new concepts outside their immediate interests. Positioning staff as nodes of equal status rather than conversational hub allows the participants to develop systems of individual expertise where their social network as a whole can function as the thinking apparatus through discussions. However, regardless of the program design, the facilitation of participant discussions by staff using revoicing techniques appears important for fostering and sustaining more sophisticated forms of discursive argument. Finally, having participants write reflections on their virtual world experiences was a powerful activity implemented in both programs. In GK, it functioned as a way to engage in informal formative assessment and fostered more sophisticated information literacy practices; in GLS, it provided opportunity for more complex forms of metacognitive processing.

References

Barab, S., Arcici, A., & Jackson, C. (2005). Eat your vegetables and do your homework: A design-based investigation of enjoyment and meaning in learning. *Educational Technology, 45*(1), 15-21.

Dede, C., Ketelhut, D. & Ruess, K. (2003). Motivation, usability, and learning outcomes in a prototype museum-based multiuser virtual environment. In P. Bell, R. Stevens, & T. Satwicz, (Eds.), *Proceedings of the Fifth ICLS*. Mahwah, NJ: Erlbaum.

Hammersley, M. & Atkinson, P. (1986). *Ethnography: Principles in practice (2nd ed.).* London: Routledge.

Neulight, N. Kafai, Y.B., Kao, L., Foley, B., & Galas, C. (2007). Children's participation in a virtual epidemic in the science classroom. *Journal of Science Education and Technology, 16*(1), 47-58.

Stake, R.E . (2006). *Multiple case study analysis*. New York: Guilford Press.

Improving the Language Ability of Deaf Signing Children through an Interactive American Sign Language-Based Video Game

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Abstract: We present the design of an interactive computer game-based intervention, CopyCat, in which deaf children use sign language to direct the actions of a character in the game. We conducted a study to quantify the game's impact on expressive language development using twelve participants from a local school for the deaf. Learners in the experimental group improved significantly in their receptive, expressive, and sentence repetition abilities as opposed to those in the control group.

Motivation

Ninety percent of deaf children are born to hearing parents (Gallaudet, 2001). These parents may not know sign language, or have low levels of proficiency. Deaf children of hearing parents develop language in the same sequence as deaf children of deaf parents and hearing children of hearing parents, but at a much slower pace. The slow language development for these children has been attributed to incomplete language models and a lack of linguistic interaction (Spencer & Lederberg, 1997). CopyCat seeks to create an interactive, entertaining way to provide additional language exposure and practice for deaf children.

Game Design and Interaction Model

CopyCat includes six language learning games for children ages six to eleven. We used computer-assisted language learning practices (Warschauer, 1996) and research on child-adult interactions (Spencer & Lederberg, 1997; Schiefulbusch & Bricker, 1981) to help design these games. Each game entails a quest by the main character to collect items to remedy a problem, such as rescuing kittens from a villain. Children tell the main character what to do via sign language. Figure 1 shows the CopyCat interface. The main game screen is indicated by the letter A. The obstacle the child must help the main character overcome (the phrase that the child must sign) is indicated by B. In this case, the child must sign, SNAKE-UNDER-CHAIR. Before signing, the children must push a "talk" button (C) to "attract the hero's attention" and to activate the automatic sign language recognition system. The children can view themselves directly on the computer as they are signing (D). When they are finished, they push the "talk" button (C) again, stopping the automatic recognition system. If the children are uncertain what to sign, they can click a "help" button (E) to see the "tutor" (F) demonstrate the required phrase. Our tutor performs the role of the good adult language model (Schiefulbusch & Bricker, 1981). The tutor is always available and responds in an appropriate linguistic manner. The tutor is also extremely patient as the children can ask for help as many times as they like, and the tutor never becomes tired or frustrated.

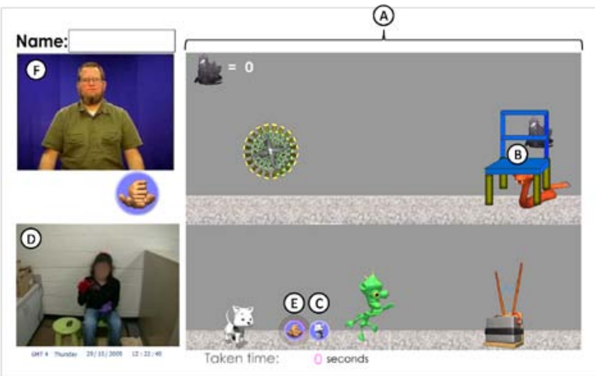

Figure 1. The CopyCat Interface (see text for description).

After the child signs a phrase, the sign language recognition system evaluates the child's utterance to determine its accuracy. Features derived from computer vision, and motion sensors embedded in gloves worn by the child, supply the recognizer with information of the child's signed phrase, similar to (Brashear et al., 2006). If the child's utterance is incorrect, a question mark appears above the character's head, indicating that the he did not understand the child's sign. The child must try again to communicate until the computer recognition system judges the sign to be of sufficient clarity, but is limited to five attempts to prevent the child from becoming frustrated. All game sentences are of the structure Subject-Preposition-Object. There were twenty 3-sign sentences, twenty 4-sign sentences, and twenty 5-sign sentences.

Study

Twelve participants between the ages of six and eleven were recruited at a local residential school for the deaf. Participants were asked to configure toys based on signed instruction (receptive); express an event depicted in a stop-motion animation (expressive); and repeat a signed phrase (sentence repetition), at both the beginning and end of the study. Most vocabulary used in the pre and post tests was not used within CopyCat. A one-tailed, one-way between-groups analysis of covariance was conducted to compare the effect of using CopyCat on the learners' receptive, expressive and repetition test scores. After adjusting for pre-intervention scores, there was a significant difference between the control and experimental groups on post-intervention scores for all three tests: the receptive language test $F(1, 9) = 11.83$, $p < 0.05$, partial eta squared = 0.57, expressive language test $F(1, 9) = 8.29$, $p < 0.05$, partial eta squared = 0.48, and the sentence repetition test $F(1, 9) = 3.6$, $p < 0.05$, partial eta squared = 0.29. There was a strong relationship between the pre-intervention and post-intervention scores on all three tests. The learners who played CopyCat improved their test scores on all three measures significantly more than the learners who did not. Table 1 shows the mean scores on each of the three tests for both groups at the beginning and end of the study.

Table 1. Table of Means for Pre and Post Intervention Scores

Test	*Group*	*N*	*Pretest M (SD)*	*Post-test M (SD)*
Receptive Language	Control	6	4.00 (4.69)	4.50 (5.21)
	Experimental	6	5.17 (3.66)	8.83 (5.04)
Expressive Language	Control	6	5.50 (6.32)	7.33 (5.05)
	Experimental	6	4.50 (3.39)	10.33 (4.37)
Sentence Repetition	Control	6	6.67 (4.84)	7.33 (5.05)
	Experimental	6	5.17 (2.79)	7.83 (3.37)

Conclusion

CopyCat demonstrates that automatic sign language recognition is of sufficient quality to be used in interactive games with positive educational effects. While CopyCat is intended to supplement, not replace, high-quality adult-child sign language interaction, its interaction method provides a useful computer-based method for rehearsing language skills.

References

Gallaudet Research Institute. Regions regional and national summary report of data from the 1999-2000 annual survey of deaf and hard of hearing children and youth. Technical report, Gallaudet University, Washington, D. C., January 2001.

Spencer, P. & Lederberg, A. (1997). Different modes, different models: Communication and language of young deaf children and their mothers. In L. Adamson and M. Romski (Eds.) *Communication and Language: Discoveries from atypical development* (pp. 203-230). Baltimore: Paul H. Brookes.

Schiefulbusch, R.L. & Bricker, D.D. (1981). *Early Language: Acquisition and Intervention.* Baltimore: University Park Press.

Warschauer M. (1996). "Computer Assisted Language Learning: an Introduction". In Fotos S. (Ed.), *Multimedia Language Teaching* (pp. 3-20). Tokyo: Logos International.

Brashear, H., Henderson, V., Park, K., Hamilton, H., Lee, S., & Starner, T. (2006). American sign language recognition in game development for deaf children. In *Proceedings of the 8th International ACM SIGACCESS Conference on Computers and Accessibility* (pp. 79-86). Portland, Oregon, USA: ACM.

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Using the Activity Model of Inquiry to develop undergraduate students' views of the scientific inquiry process

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Abstract: The *Activity Model of Inquiry* (Harwood, 2004) is a theoretically-grounded and empirically-derived model of scientific inquiry. This research examines how undergraduate students' views of scientific inquiry shift after introduction of the *Activity Model of Inquiry* in a general chemistry course. Students are asked to respond to essay prompts and a pre- and post-questionnaire. Preliminary findings show shifts from a naïve view to a more informed view of nature of scientific inquiry for some students.

Introduction and Rationale

If chemistry taught in the classroom is to add to the public's understanding of science, school science must "develop students' understanding of the scientific enterprise itself, the aims and purposes of scientific work, and the nature of the knowledge it produces" (Driver, Leach, Millar, & Scott, 1996). Many students come into the classroom with a particular image of science and how scientists conduct science that does not reflect the enterprise accurately, often because they do not understand the processes of sciences and the creation of scientific knowledge, which compose nature of science (NOS). Understanding NOS is important, for it has been noted, "an appropriate understanding of NOS will allow students to make more informed decisions on science-based issues in their daily lives" (Ibrahim, Buffler, & Lubben, 2009). However, what many students know about NOS comes from the media, everyday experiences, traditional presentations of "the" scientific method , and technology (Ryder, 1999) and these experiences provide a misleading foundation for becoming scientifically literate.

One way to make NOS explicit is to use a thinking frame. Thinking frames " guide the process of thought; supporting, organizing, and catalyzing that process" (Perkins, 1986). Commonly, teachers use the traditional scientific method (TSM) as a thinking frame to teach the process of science. However, there is a lot of dissatisfaction with the TSM model, for it includes an overall step-by-step linear view of the scientific process and lacks any theoretical, cultural, or social aspect to the creation of scientific knowledge. This is inaccurate both because of the non-linear aspect of many scientific inquiries and the fact that all knowledge should be thought of as a means for meeting human needs. Omitting the latter aspect, it has been argued, is both false and less likely to engage learners (Rudolph, 2005).

William Harwood's (2004) *Activity Model of Inquiry* is a recent, data-based model that may have the instructional potential as a thinking frame for teaching nature of science aspects. It was developed from interviews with fifty two faculty members across nine disciplines at a research university (Harwood, Reiff, & Phillipson, 2002). Within the model, there are ten activities in a web-like structure (Figure 1). There is no unique pathway for inquiry; students chose what to do next based on what they need. Questions are in the middle suggesting them as the central feature of inquiry. Questions include general and divergent questions that help frame the inquiry. In addition, the *Activity Model of Inquiry* has significant potential in discussing the aspects of NOS.

The research question for this study is: what happens with the *Activity Model of Inquiry* when using it as an instructional tool?

Figure 1.
Harwood Activity Model

Methodology

This research study uses an interpretive qualitative framework and includes a design component. Thirteen students provided consent within a first semester general chemistry course at an urban community college where the author was the instructor. Assignments relevant to NOS were a standardized questionnaire given at the beginning and end of the semester and four course-related writing assignments given throughout the semester. Assignments were chosen using a constructivist perspective. That is, knowledge is constructed from previous experiences (Bransford, 2000, p. 11). All students completed the Views of Nature of Science questionnaire Form-C (Lederman, Abd-El-Khalick, Bell, &

Schwartz, 2002), which probe for understandings of the empirical, tentative, theory-laden, creative and imaginative, and social and cultural embedded-ness nature of scientific knowledge, as well as, the myth of a universal scientific method, the difference between scientific laws and theories, and students' overall view of science. On the second day of class, students were asked to draw their model of the process of science. Students were then introduced to the *Activity Model of Inquiry*. Writing assignments were used as a means of eliciting students' evolution of understanding around the myth of the scientific method, which is the focus of this paper. The first writing assignment asked students to describe how, in their view, scientific knowledge is created and what approach scientists take to create it. The second and third writing assignments asked the students to interact with the *Activity Model of Inquiry*. Students were to analyze a scientific news article and their own laboratory work using the *Activity Model of Inquiry*. The fourth writing assignment prompted students to reflect on their understanding of science and how, if at all, their view had changed from the beginning of the semester. Instructor lesson plans and reflections were collected to inform further implementations.

Analysis is being conducted using an interpretive framework. The pre- and post-questionnaire responses will be coded using Lederman, et al. (2002) coding scheme. Follow-up interviews were conducted to validate the responses. The writing assignments have been coded for language and argument as well as students' descriptions of the myth of the scientific method and will later be coded for other NOS aspects. The instructor's lesson plans and reflections will be analyzed for what worked well versus what worked poorly.

Findings and Discussion

Preliminary findings demonstrate the results of the analytic framework applied to this student data. To answer the research question, four student's responses are highlighted. Two student's responses show a typical change. They began the semester thinking all science follows the TSM. Both of their illustrations of the process of scientific inquiry depicted a linear process. However, toward the end of the semester the students began to incorporate *Activity Model of Inquiry* components in their responses, particularly the Communicating With Others component. Some students also developed more informed views regarding the different approaches taken to solve a scientific problem and that there is freedom within this process. One student showed a significant change in her view of the myth of a scientific method. Prior to introduction of the *Activity Model of Inquiry*, this student listed steps of the TSM to describe scientific investigations. However, at the end of the semester she stated, "no set order of procedure" but rather "based off our convenience" and "now I know experiments are very open ended." The fourth student illustrates a case where no changes were observed. For both the pre- and post-questionnaire, she responded that experiments are based off of the TSM and listed the steps of the TSM. These results suggest that the *Activity Model of Inquiry* can support shifts but also reminds us that major changes in deeply helps beliefs are difficult to change in a short one-semester experience.

References

Bransford, J. D., Brown, A.L., and Cocking, R.R. (Ed.). (2000). *How People Learn: Brain, Mind, Experience, and School. Washington, D.C.*: National Research Council.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Buckingham, PA: Open University Press.

Harwood, W. S. (2004). A new model for inquiry. Is the scientific method dead? *Journal of College Science Teaching*, 33(7), 29-33.

Harwood, W. S., Reiff, R., & Phillipson, T. (2002). Scientists' conceptions of scientific inquiry: voices from the front. *Paper presented at the AETS Proceedings*.

Ibrahim, B., Buffler, A., & Lubben, F. (2009). Profiles of freshman physics students' views on the nature of science. *Journal of Research in Science Teaching*, 46(3), 248-264.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching,* 39(6), 497-521.

Perkins, D. N. (1986). Thinking frames. *Educational Leadership*, 43(8), 4-10.

Rudolph, J. L. (2005). Inquiry, instrumentalism, and the public understanding of science. *Science Education,* 89(5), 803-821.

Ryder, J., Leach, J., Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching*, 36(2), 210-219.

Cutting the Distance in Distance Learning: Perspectives on Effective Online Learning Environments

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Abstract: This qualitative research study informs the development and implementation of effective online learning environments by examining course content, sequencing, methods, and sociological approaches, as identified by students and instructors, which contributed to positive online learning experiences. Researchers interviewed 6 online course instructors and 9 adult students about their experiences in undergraduate and graduate level online degree programs. Using a Cognitive Apprenticeship Model to inform data analysis, findings revealed how various components of one online program provided students with an effective online learning experience. The study has implications for individuals who develop and/or teach online courses.

Introduction

Recently there has been an explosive growth in online distance learning that is "rapidly transforming post-secondary education" (Moller, Foshay, & Huett, 2008, p. 66). One of the greatest challenges for learning institutions and instructors when designing and implementing online courses is to "provide a sense of community with constructive feedback and provide open forthcoming communications as well as recognizing membership and feelings of friendship, cohesion, and satisfaction among learners" (Desai, Hart & Richards, 2009, p. 333). How to create the most effective, highly interactive, online social learning communities, however, is still a relatively new area of study. The purpose of this study was to explore, from both teacher and student perspectives, what constitutes effective online learning experiences.

Theoretical Framework

To explore the various components that make up an effective online learning community, the researchers turned to the Cognitive Apprenticeship Model (CAM). The CAM is grounded in the belief that when students are learning in an academic environment, they do not usually have access "to the cognitive problem solving processes of instructors as a basis for learning through observation and mimicry" (Collins, 2006, p. 48). Because of this, before apprenticeship methods can be applied by students to learn cognitive skills, the learning environment "has to be changed to make these internal thought processes externally visible" (p. 48). The CAM is designed so that these cognitive processes can be brought into the open where individuals can "observe, enact, and practice them" (p. 48). According to the model, there are four dimensions that constitute any learning environment: content, method, sequencing, and sociology.

Methodology

Researchers interviewed 9 adult students who had completed online degree or certificate programs in different fields of study (e.g., education, nursing, business) and 6 course instructors who had experience teaching online courses. Prior to participating in a one, 60-minute interview, participants shared relevant course materials with the researchers, including such artifacts as course syllabi and assignment descriptions. Both deductive and inductive analyses were conducted using constant comparative methods (Glaser & Strauss, 1965). Researchers coded interview transcripts using the Cognitive Apprenticeship's "content," "method," "sequencing" and "sociology" categories for deductive coding. They also noted other recurring themes, reached consensus on new coding categories, and revisited the data multiple times to code for new categories.

Findings

Findings revealed that in most of the online courses and programs, there was an emphasis on text-based content, individual learning, and limited interaction among students. Most students reported feeling disconnected with their instructors, course content, and fellow classmates in these programs which favored individual, text-based activities over more collaborative, multimodal ones. One program in higher education, however, was an exception to this model and is the focus of this paper.

The *Content* for the program in higher education emphasized the knowledge and skills that are needed to guide and lead complex, dynamic institutions. This Masters program allowed students to specialize in areas such as student affairs and community college leadership. Using a backward design model based on desired learning outcomes, program creators turned to professionals in the field to assist in determining the subject matter and skill sets that students needed to be prepared for real-life work situations. Course content was based not only on domain knowledge but also on "heuristic" tasks which "mimic" real-life work responsibilities, enabling students to gain feedback from professionals in the field. Dr. Karrie Bates, designer of the program and course instructor, explained how one activity in a statistics course included obtaining instruction from a professor, creating a spreadsheet, and then performing a "real-world" task using ANOVA. Students performed this task in Wimba, a live virtual classroom, and an outside expert was present, along with the instructor, to provide students with additional advice and instruction. In this way, students were "apprenticed" via the course content and design, ensuring they could apply such knowledge in real-world situations. Courses followed a structure where instructors provided training, engaged students in learning simulations, and then emphasized career placement, advancement, or transition.

The *sequencing* of the program consisted of a total of 45 credits culminating with a final co-op experience. Courses ran for 10 weeks in the fall, winter, spring and summer, meeting on a Wednesday to Wednesday schedule so that students could maximize the weekend after receiving instruction. Because courses for the program were created through backward design, they were sequenced so that the content and skills developed in each course built upon one other. In order to support students who had been out of school for an extensive amount of time, the program offered online class sessions that taught students where to go and whom to contact for ongoing support and assistance. This included introducing them, by their second week in the program, to university librarians, technology support staff, and individuals who worked in the university's career development center.

Findings related to *method* and *sociology* were interconnected and difficult to separate. Dr. Bates explained that one of her goals for the program was to find ways to "bring the campus to the students" and to give the online experience "a more human feel," something that she felt was lacking in many online programs. To accomplish this, students entered the program as a cohort, participated in online social events, and engaged in online simulations and a co-op experience, allowing them to interact with others and engage in authentic learning experiences. One student, Edna, explained how these activities allowed her to interact with many people in higher education, allowing her to learn more about the field. She and another student confirmed how technological tools such as Wimba fostered and mediated social, online experiences. They described how instructors added a more "human touch" to the program by recording voice comments on their papers, creating assignments that fostered interaction with other professionals in higher education, and using audio-recorded weekly wrap-ups to highlight "key learning points." By using tools like Wimba, instructors were able to create social learning environments that allowed them to model and scaffold student learning while also allowing students to demonstrate and articulate what they learned.

Conclusion

This study illustrates how the Cognitive Apprentice Model provides a useful lens to understand, evaluate, and develop interactive, online learning communities. It challenges instructors and curriculum designers to consider the authentic needs of their students and communities while designing programs. The study highlights how technology can be used to support social learning, moving beyond text-based to more multimodal ways of knowing. It also shows how class assignments can mirror real-world application while scaffolding student learning. Additional research, however, needs to explore how technology can most effectively be used to enhance online teaching and learning. Researchers might also want to investigate how universities can better support faculty in acquiring the knowledge, skills, and dispositions that are needed for building effective online learning communities. Finally, it is essential that researchers come to understand why some educators are choosing to use technologies that promote student interaction, social engagement, and multimodal ways of knowing while others are not.

References

Casey, D. (2008). A journey to legitimacy: The historical development of distance education through technology. *TechTrends*, March/April, *52(2)*, 45-51.

Collins, A. (2006). Cognitive Apprenticeship. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 47-60). New York: Cambridge University Press.

Desai, M., Hart, J., & Richards, T. (2009). E-Learning: Paradigm shift in education. Education, 129/2, 327-334.

Glaser, B., & Strauss, A. (1965). Awareness of Dying. Chicago: Aldine Publishers.

Moller, L., Foshay, W., & Huett, J. (2008). The evolution of distance education: Implications for instructional design on the potential of the Web. TechTrends, July/August, 52(4), 66-70.

What makes a "good" scientific question? Supporting independent student-driven inquiry

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Abstract: Students rarely have the opportunity to pose scientific questions or participate in research design. In this study, we identify the criteria that scientists used to guide a group of seven undergraduate students during an extended phase of project articulation. We categorize the criteria according to epistemic and social dimensions and describe the ways in which the students were able to reason with these criteria as they developed their question and research plan.

Rationale

It is rare for undergraduate students to be given the responsibility of articulating a novel scientific question. When students are asked to do so, they are rarely given the appropriate guidance, leading them to pose arbitrary or trivial questions (Windschitl, Thompson, & Braaten, 2008). Part of the difficulty is that the criteria for developing a "good" scientific question are embedded within a community of practice of which undergraduates are not yet members (Lave & Wenger, 1991). Undertaking the difficult task of initiating a new research project requires repeated exposure to the norms and strategies used by the scientific community, rather than simply following an algorithmic "Scientific Method" (Chinn & Malhotra, 2002). We believe that when students are invited to participate in this community they gain opportunities to both engage in sophisticated scientific reasoning and develop their understanding of the nature of science - two key aspects of scientific literacy (AAAS, 1993). With these learning goals in mind, we investigate how faculty can productively support student-driven inquiry.

Study Context

In this research we had the unique opportunity to observe how a group of four scientists helped a group of seven undergraduates define and design a research project in mathematical biology. The context of this work was the Collaborative Learning at the Interface of Mathematics and Biology (CLIMB) program, a yearlong, NSF- sponsored traineeship for undergraduates. The CLIMB students worked collaboratively to solve modeling problems throughout the year and were responsible for executing a novel, model-based research project over the summer. In this study, we categorize the ways in which faculty mentors communicated scientific norms to guide students' progress over the course of the three months preceding the summer research project. We also track how the CLIMB cohort was able to attend to those criteria, identifying the successes and challenges facing the students in this difficult task.

Methods and Analysis

Our data set included detailed field notes of all student-faculty interactions, semi-structured interviews with both students and faculty, and students' written research proposal with faculty comments. We used field notes to both categorize faculty mentors' discourse related to project design as well as student reactions to their suggestions. In our analysis we used a grounded theory approach to develop categories, which were further corroborated by interviews with faculty. We then revisited field notes, the research proposal, and interview data from the CLIMB students to assess the degree to which they, as a group, were able to attend to each of these criteria.

Findings

We identified six criteria articulated by the science faculty, which we grouped into two broad categories: 1) *Epistemic Criteria* – in which faculty focused students' attention on the type of knowledge they sought to generate, and 2) *Social Criteria* – in which faculty emphasized the subjective nature of achieving consensus. We provide a brief description of each criterion grounded in examples from our field notes. It is important to note that we highlight these criteria because they emerged repeatedly throughout the project articulation phase, often in interaction with one another, highlighting the dynamic process of defining and refining a research project. Finally, we briefly comment on the extent to which CLIMB students were able to attend to these criteria.

Epistemic Criteria

1a. Consider the data patterns that need explaining. Faculty mentors urged students to ground their research project in a biological pattern in need of an explanation. When students expressed an interest in modeling either influenza (flu) or measles, faculty asked, "Are there patterns?" Students found that the yearly patterns exhibited by flu were too complex to reveal obvious patterns. This led them to focus on measles vaccination patterns in the UK, for which data on disease prevalence and vaccination were available. In general, finding data was not a major challenge for students, but understanding what about that data needed explaining required that they attend to other criteria. *1b. Consider the appropriate methods.* The students were urged to think about the modeling approach they would undertake simultaneously with refining their question. Faculty discouraged questions that were descriptive or statistical in nature, such as, "will measles prevalence continue to rise?" Instead, they pushed students to think about the *mechanism* they would build into their model. This prompted the students to consider mechanisms of disease transmission. Considering the mechanisms that drive patterns was more difficult for students; they often asked empirical or statistical questions instead of focusing on the underlying theoretical model. *1c. Evaluate existing models.* To guide students towards theory, faculty pointed them to the existing literature and asked them to evaluate the theoretical soundness and the empirical accuracy of prior models as a basis for their own research. This led students to understand that measles models should theoretically include age-structure to account for population heterogeneity in infection susceptibility. Students also considered a model of human behavior that relied solely on dyadic information transmission, which led them to think about adding direct learning from the environment into their model. Students were quite successful at finding gaps in existing research, but were less discriminating about which of these were most important. They had to overcome a tendency to add things into their model simply because "they had not been done before." *1d. Imagine the possible results*. Faculty urged students to "imagine what the results might look like." Students created a long list of possible components to add to their model, but the faculty mentors asked them to focus on the components that would make a difference in the results. This was especially difficult for students who instead tended to focus on adding in model criteria because others had added them or because they made the model "more realistic." It was primarily in retrospect that students were able to see that some aspects of their model (such as age-structure) did not significantly alter the model results, while others (such as the structure of information transfer) had a significant impact. In response, some of the students modified their understanding of the research question even as they were preparing to present their results.

Social Criteria

2a. Do what is "worthwhile." Faculty mentors urged students to choose a problem that would engage them throughout the summer. The mentors were willing to admit that this was a somewhat subjective decision, suggesting, "do what motivates *you*." While students were initially hesitant about pursuing a disease model (because the previous year's cohort had already done so) they ultimately agreed that they wanted to pursue a project with social relevance. This helped them narrow down their options substantially. *2b. Do what is practical.* Faculty encouraged students to bound the problem space in accordance with time and resources. Students decided to leave out many components of their original model in the interest of tractability. However, they were later encouraged to assess the epistemic implications of these decisions. For example, students were asked to explain why they ignored immigration but included age-structure – a task they found much more difficult. This is just one example of how each of these categories, both epistemic and social, overlapped and interacted with one another throughout the process, again emphasizing the need for students to consider many of these criteria simultaneously.

Implications

Throughout the process of project articulation, faculty mentors provided many opportunities for students to consider the social and epistemic criteria used by the scientific community. In general, the group was able to identify interesting questions, but students had more difficulty articulating the significance of questions that arose as they moved into model construction. This result suggests that students need to be continually reminded to think deeply about their research question even as they move into later stages of research. Future research will address the extent to which exposure to these epistemic and social criteria has lasting impacts on students' images of science.

References

AAAS. 1993. *Benchmarks for scientific literacy*. New York: Oxford University Press.

Chinn, C. & Malhotra, B. 2002. Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*(2), 175-218.

Lave, J. & Wenger, E. 1991. *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Windschitl, M., Thompson, J. & Braaten, M. 2008. How novice science teachers appropriate epistemic discourses around model-based inquiry for use in classrooms. *Cognition and Instruction, 26*(3), 310-378.

Anomalous Graph Data and Claim Revision During Argumentation

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Abstract: The discourse practice of scientific argumentation requires individuals to consider anomalous data in light of existing claims that have been made. The extent to which students must be taught to revise their claims has been a subject of disagreement in the literature. In this poster, we use correlations and transcript excerpts to examine the relationship between the physical presence of referenced data and students' willingness to respond to anomalous data by revising their claims.

Introduction

Scientific argumentation is seen as an important disciplinary discourse practice for students of science because it facilitates students' collaborative sensemaking (Duschl, Schweingruber, & Shouse, 2007). However, it rarely occurs in science classrooms (Driver, Newton, & Osborne, 2000). One challenge facing students as they engage in this complex practice rests in their response to anomalous data. In particular, when presented with anomalous data, students reinterpret the data to align with their original claims rather than revising them (e.g., Kuhn, 1989). This suggests that students will not successfully use scientific argumentation as a context for collaborative sensemaking. Instructionally, this implies that students must be explicitly taught to reconcile their initial claims with anomalous data so that they can learn from argumentative interactions. However, other researchers (e.g., Engle & Conant, 2002) have witnessed students productively working with and incorporating anomalous data during argumentative discussions, without explicit instruction on how to do so. In addition, Hammer and van Zee (2006) have documented students as young as kindergartners "reconciling inconsistencies" when their personal theories contradict their observations of particular phenomena; the students they observed were quite capable of revising their claims in response to contradictory evidence.

The current study takes some initial steps towards reconciling these opposing observations by examining the context in which students are faced with and respond to anomalous data. We enter this study with the hypothesis that the source of the anomalous data will influence the students' responses to it. In particular, work such as Hug and McNeill (2008) demonstrates that students work with first- and second-hand data in very different ways. Thus, this poster focuses on whether and how the presence of the data (if it is something the students can see first-hand or if it is something that is reported to them by another individual) affects their response to and engagement with anomalous data.

Data Sources

The data for this analysis comes from video-recorded observations of a researcher-designed, 6th grade ecosystems unit (Finn et al., 2006) that was implemented in a self-contained classroom at a 100% African-American charter school. As part of the curriculum, students worked with a simulated ecosystem built in the NetLogo modeling environment (Wilensky, 1999). Toward the end of their work with NetLogo, pairs of students used NetLogo's dynamically generated population graphs to determine what organism in that simulated ecosystem (foxes, rabbits, or grass) was being eaten by an unknown invasive species. Following this, the pairs joined with another pair in the class. That foursome was then asked to agree on what the invader ate. Video recordings of two pairs and two foursome discussions were transcribed and analyzed for this current study.

Analytic Process

Data analysis consisted of a line-by-line examination of the students' evolving arguments about the model. We began by identifying instances in which students presented counter or anomalous evidence. We then coded the students' responses to that evidence. Based on the students' general tendencies, we identified 4 responses to the anomalous evidence: ignoring it, rejecting it, reinterpreting it so that it supported the original claim and revising the original claim. These correspond to a subset of the responses identified in Chinn and Brewer's study (1998). In addition, we coded for whether the students were discussing first- or second-hand data. Second-hand data included graphs individual students had observed earlier and were reporting to their group without showing them. First-hand data were visible graphs displayed on the simulation software; they were public objects that were physically present for discussion by the group. Coding of both the origins of the data and student responses to data was done in a binary fashion: an utterance was given a "1" or a "0" for whether each possible behavior (i.e., rejecting anomalous data, presenting first-hand data, etc.) was present in the utterance.

Once coding had been completed, un-coded utterances (typically involving content related to classroom management or digressions) were removed. This produced a large matrix of 1's and 0's. We used this matrix and devised a 'moving window' analysis in which we examined each turn of talk in combination with the four turns of talk that followed it. For each 'window' we calculated the total number of each possible discursive behavior present in the window. This moving window analysis was key to examining the relationship between the students' responses to anomalous data and the form of that data: the anomalous data was invariably presented by one student and responded to by another. Summing across a span of utterances enabled us to examine these interactions. Correlations were run on the 'moving window' sums, and passages with high moving window scores were revisited for further interpretive analysis.

Findings

This analysis reveals that utterances that involved first-hand data (i.e., "the population is dropping here in this graph") were positively correlated with student reinterpretation of anomalous data ($r = 0.224$; $n = 188$; $p < 0.005$). Moreover, there was a positive correlation between students discussing second-hand data (i.e., "when I did it earlier, the population dropped") and students rejecting anomalous data points ($r = 0.456$; $n = 188$; $r < 0.005$). For example, when one student pair was working with the model, Tyler said he had seen a graph earlier in which the rabbit population decreased (implying that the invasive species was eating rabbits), Kendra (who believed the invader ate grass) responded, "okay, I don't need to hear yo' story no more." In this, and similar instances, second-hand reports of data were dismissed or disregarded even if relevant to the current discussion. This suggests that students were more willing to discuss their various interpretations of data they could see than they were of data that one member was reporting.

In addition, there was a positive correlation between first-hand data and student revision of their claims ($r = 0.153$; $n = 188$; $p < 0.05$). For example, once directed toward first-hand data by his partner, Jonathan revised his claim: he began claiming that the invader ate grass and concluded that it ate rabbits and grass. In contrast there was a negative correlation between the students' second-hand reports of data they had observed and student revision of claims ($r = -0.218$; $n = 188$; $p < 0.005$). This suggests that students were more likely to find first-hand data compelling and revise their claims accordingly than they were with second-hand data

Discussion

Combining these relationships suggests that the context and materials present in the discussion influence the frequency with which students engage with and discuss contradictory data. In these classroom observations, we see that the presence of the data impacted whether students are more likely to engage with competing data points or to reject them out of hand. Thus, this paper suggests that students can and do revise their ideas in light of the evidence. That is, this is not a skill that they must be taught explicitly. It is, instead, something that we, as educators, must work to motivate by creating contexts in which it makes sense for students to substantively engage with the contradictory evidence. In this case, the presence of immediately accessible data seemed to positively influence this whereas second-hand reports of data appeared to have a limited observable influence.

Endnotes

(1) Both authors contributed equally and are listed in alphabetical order.

References

Chinn, C. A., & Brewer, W. F. (1998). An empicircal test of a taxonomy of responses to anomalous data in science. *Journal of Research on Science Teaching, 35*, 623-654.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*, 287-312.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. E. (Eds.). (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academies Press.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399-483.

Finn, L.-E., Kuhn, L., Whitcomb, J. L., Bruozas, M., & Reiser, B. J. (2006). Where have all the creatures gone? In J. Krajcik & B. J. Reiser (Eds.), *IQWST: Investigating and questioning our world through science and technology*. Evanston, IL: Northwestern University.

Hammer, D., & van Zee, E. H. (2006). *Seeing the science in children's thinking: Case studies of student inquiry in physical science*. Portsmouth, NH: Heinemann.

Hug, B., & McNeill, K. L. (2008). Use of first-hand and second-hand data in science: does data type influence classroom conversations? *International Journal of Science Education, 30*(13), 1725-1751.

Kuhn, D. (1989). Children and adults as intuitive scientists. *Psychological Review, 96*(4), 674-689.

Wilensky, U. (1999). NetLogo [Computer Program]: Center for Connected Learning and Computer-Based Modeling. Northwestern University, Evanston, IL.

Understanding Formative Instruction By Design

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Abstract: Formative instruction has proven to be a remarkably difficult practice to implement in schools. This paper explores teachers' thinking in their uses of a new data analysis tool to enact evidence-based instructional practices, describing possible relationships between teachers' existing beliefs, expertise, and routines and their construction of new practices. We show how current theories of assessment do not account for important aspects of formative instruction in practice.

Introduction

Despite considerable research about its importance, formative instruction (FI) has proven to be a remarkably difficult practice to implement in schools. FI refers to the practice of using evidence of student thinking and learning to responsively shape ongoing instruction to support content mastery by all students (Black and Wiliam, 1998b). Despite the recognition of FI's potential impact (Black & Wiliam, 1998a), we know little about how to enact it at scale.

This work explores teachers' thinking in their uses of a new data analysis tool to enact evidence-based instructional practices, describing possible relationships between teachers' existing beliefs, expertise, and routines and their construction of new practices.

Context of the Work

As part of a larger study about the integration of attention to literacy in content-area instruction, we created a set of online tools for participating teachers to use to analyze their own students' work, understand their students' thinking, and enact more responsive instruction. One of these online tools was annotation, which is the process of marking up a text in order to perform content analysis as well as reveal the meaning behind various textual features (Liu, 1996). As an activity that produces external representations about individual use of text, annotation seemed like an ideal window into student thinking. As part of the work, the teachers made annotation a routine component of reading in their classes.

We studied teachers' uses of the data analysis tools to observe their analytic strategies and how the specific cases of each teacher's particular enactment was related to his/her pre-existing routines, beliefs, and expertise. We analyzed each teacher's work qualitatively, using the Learning to Notice framework (van Es and Sherin, 2002) to identify important aspects of teachers' uses of information (how they called out details, interpreted those details, and reasoned about them using contextual knowledge) and the assessment triangle (Pellegrino, Chudowsky & Glaser, 2001) to characterize the kind of claims that teachers made, drawing comparisons between different segments within individual teachers' work (such as what they attended to and what claims they made during analysis) and between teachers.

In this poster, we will look at the work of two specific teachers, called Teacher1 and Teacher2. Both teachers were part of the same sixth grade teacher team at an ethnically and economically diverse Midwestern American K-8 school. Teacher1 taught science and social studies. Teacher2 taught English/ Language Arts. Both teachers had about five years of teaching experience, most of it in the same school.

Genetic Model of Formative Instruction.

As depicted in Figure 1, the system of practice reported on is the product of combining a set of *Base Instruction Practices* (i.e., the set of instructional routines teachers already had), drawing upon *Base Beliefs & Expertise* and *Base Texts*, with outside reform messages, *Annotation* and *Formative Instruction*. Teachers then reified *Annotation* by creating a set of *Classroom Annotation Procedures*. We expected that the canonical ways of annotating that teachers constructed and prescribed would not be random, but instead, draw upon their existing routines, expertise, beliefs, etc. We anticipated that the ways they did so might parallel aspects of their existing practice. We wanted to understand how teachers drew upon these same base details when analyzing student work, reasoning about its implications for subsequent instruction, and teaching.

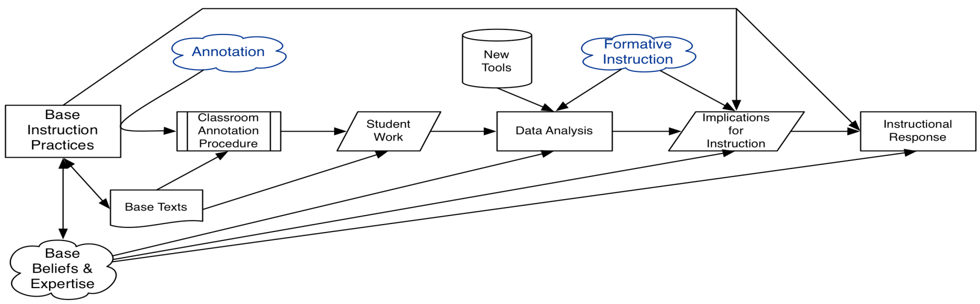

Figure 1. Model of Adaptation & Implementation

Case of Teacher1

Both teachers' adaptations of annotation seemed to mirror their base instructional practices and beliefs. Teacher1's adaptation of annotation was to instruct her students to annotate each section heading with a question inspired by the heading, and then to annotate any text within the following section that answered the question with a short comment. Teacher1's classroom instruction made frequent use of questions to elicit information about student thinking and she canonized annotation in a manner that was question-centric. Teacher1 discussed, in the abstract, the importance of engaging every student in instruction and, when she analyzed students' data, she attended primarily to evidence of students' engagement. At the same time, she could not conclusively determine from the data whether students correctly understood the texts' content. She noted that whether they did the annotation correctly was less important than whether they were engaged or not. In class, Teacher1 used her recollection of the data to reason about students' classroom participation and the effectiveness of her own instructional decisions.

Case of Teacher2

Teacher2's classroom instruction was primarily lecture driven, with Teacher2 delivering content in a manner he could know, a priori, to be the one best way. His adaptation of annotation was intentionally homogeneous, with all students expected to highlight the same details. His analysis of students' annotations was, accordingly, largely consumed with whether students annotated the right things. Whereas Teacher1 had regarded pinkness on the heatmap as "what you would expect", Teacher2 recognized it as problematic. He expected his students to annotate all of the same things (which would result in dark red shading). When Teacher2 noted mistakes in students' work, he did not seem to realize ways in which they possibly indicated other legitimate interpretations of text, even when his students explained their thinking to him.

Issues Raised

The purpose of the work here was to develop some rudimentary knowledge about how teachers could use annotation data to understand their students' thinking, how technological tools could help them to do so, and how teachers' choices about how to understand student thinking through annotation can be informed by teachers' existing routines and knowledge.

Indeed this work highlights further challenges to current assessment theory. For example, we can not assume that it is possible to know what mastery looks like, as many assessment theories assume. In addition, much of the current assessment theory ignores students' engagement and motivation. This is important since this information can be interesting and useful for teachers.

References

Black, P., & Wiliam, D. (1998a). Assessment and classroom learning. *Assessment in Education: Principles, Policy, and Practice*, 5 (1), 7-74

Black, P., & Wiliam, D. (1998b). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan*, 80 (2), 139-148.

Liu, K. (1996). Annotation as an index to critical writing. *Urban Education*, 41, 192-207

Pellegrino, J., Chudowsky, N., & Glaser, R. (2001). *Knowing What Students Know: The Science and Design of Educational Assessment*. Washington, DC: National Academy Press.

van Es, E., & Sherin, M. (2002). Learning To Notice: Scaffolding New Teachers. *Journal of Technology and Teacher Education*, 10 (4), 571–96.

The Effect of Curricular Elements on Student Interest in Science

Abstract: Enhancing student interest in science is a critical goal for science education. However, little is known about what makes science interesting to the students. This study examined the effect of three curricular elements (topic, activity, and learning goal) on student interest in science. The results suggest significant effect of activity types, among which the "hands-on" and technology-based ones tend to elicit higher interest.

Introduction

Scholars have pointed out in recent years that students are becoming uninterested or losing interest in school learning, particularly in areas of math and science. This is alarming because research has shown that interest leads to effective learning processes, and has strong positive impact on various learning outcomes (Renninger, Hidi, & Krapp, 1992). Thus, a critical goal of education should be to enhance students' interest in science.

What might explain our schools' ineffectiveness in maintaining student interest is the lack of knowledge regarding what makes science interesting (or not). Much of prior research has focused on examining the features of perceptual stimuli (Berlyne, 1960) and texts (Hidi & Baird, 1986) that influence people's interestingness judgments. Studies that are more relevant to science interest have only begun to identify the science topics or instructional activities (Jenkin & Nelson, 2005; Palmer, 2009) of high or low interest to young students. We believe these approaches are insufficient given the complexity of real classrooms. What we need is to examine variables that possibly influence student interest together, instead of in isolation, as students' interest is most likely the outcome of their simultaneous interactions with all of these variables.

We report here some of the quantitative findings from a study of the independent and interactive effects of curricular elements on student interest in science in the school context. Specifically, three elements were examined — content topic, activity, and learning goal. They are chosen because they are present in most (if not all) learning scenarios, and they can be easily manipulated by educators.

Methods

Five hundred thirty three middle school students from a suburban district near a major Midwest city participated in this study. We chose to focus on middle school grades because they have been suggested to be the age when academic interest begins to decline. Thus it is critical to understand what makes science interesting to these students, and consequently how to keep them interested. The demographic make-up (gender, minority status) of the participants is quite diverse, which is representative of student population in the particular school district.

The data and results reported here are based on a questionnaire completed by all participants. The questionnaire presented students with 100 instructional episodes (IEs) — instructional periods devoted specific content or skill. Each IE is designed such that it represents a unique combination of curricular elements — a topic, an activity type, and a learning goal category. Four topics chosen from the biology domain, five activity types, and seven learning goal categories were embedded in the IEs. For example, the IE "Look at real data on polar bears to see if global warming is hurting the ecosystem at the north pole" represents the topic "ecosystems", the activity type "design/conduct investigation without scientific instruments or interactive technology", and the learning goal "societal impact". One fourth of the IEs (n=25) are under the same topic, and IEs under every topic share the same activity-goal structure (i.e., item 3 under the topic "ecosystems" represents the same activity type and learning goal category as item 3 under the topic "cells"). The IEs, though hypothetical, were designed to resemble the actual IEs that take place in participants' science classes. Students were asked to rate how interesting they thought each IE was using a 1-6 scale (6 being the most interesting).

Results

Factor analysis was conducted to explore the structure of the questionnaire data. Hierarchical linear modeling (HLM) models were run to further examine the effect of the curricular elements (and their categories). HLM is appropriate in this case because the ratings of the questionnaire items are nested within individual students. In other words, the variance between the item ratings was due to not only item differences but also individual differences.

Factor Analysis

The questionnaire data were transformed two ways to understand the embedded structure. First, for each student, the ratings of items of the same activity-goal combination (i.e., across topics) were averaged to generate an "item-average" score. A comparison of the "item-average" scores shows a great degree of variation, suggesting that the variance between the item ratings could be attributed to the activity types and/or learning goal categories. Second, the ratings of items under the same topic (i.e., across activity-goal combinations) were averaged to generate a "topic-average" score. The comparison of these scores, however, did not show much variation, with the only notable difference being that the average rating of items under the topic "human body systems" was slightly higher than that of other topics ("cells", "Ecosystems", and "Diversity of living things").

As much of the variance existed for the "item-average" scores, a principal axis factor analysis was done on these scores. Three factors were extracted (scree plot and factor loadings are not shown here due to limited space), and the activity types and learning goal categories of the items loaded on each factor are listed in Table 1. The results suggest that the variance explained by the activity-goal combinations is attributable to activity only, not learning goal. Furthermore, it seems that students did not perceive the differences between the original five activity types; rather, they grouped them into three new categories — purely cognitive, technology-based, and hands-on. Students' interest varied primarily depending on the activity type represented in each IE.

Table 1: Factor analysis results interpretation for "item-average" scores.

	Factor 1	Factor 2	Factor 3
Activity types	Brainstorm/Discuss; Receive information passively	Design/Conduct investigation *with* technology	Design/Conduct investigation *without* technology; Create product(s)
Learning goal categories	All categories; No pattern	All categories; No pattern	All categories; No pattern
Interpretation	"Purely cognitive" activities (PureCog)	"Technology-based activities (Tech)	"Hands-on" activities (HandsOn)

Hierarchical Linear Modeling (HLM)

HLM models including the "human body system" (Human) topic and the "Tech" and "HandsOn" activity types as level 1 predictors were run. The significant coefficients for these variables (Table 2) confirm that students on average perceived IEs dealing with human to be slightly more interesting, and suggest that the average interest in IEs involving hands-on and technology-based activities is higher than purely cognitive activities. Compared to the variance component to the model without any predictors, these variables explained approximately 14% of the level 1 variance (the majority of which was due to the activity type predictors), which is significant.

Table 2: HLM model output.

Fixed effect		Coefficient *(*p<0.05)*	SE
For interest intercept	Intercept	3.64*	0.04
For Human slope	Intercept	0.17*	0.03
For HandsOn slope	Intercept	0.50*	0.03
For Tech slope	Intercept	0.68*	0.03
Random effect		SD	Variance component
Intercept		0.84	0.71
Level 1		1.31	1.71

Discussion

The results confirmed that the curricular elements examined in the study indeed contribute substantially to students' interest in science IEs. It is interesting that among the three elements, only activity exerted significant effect, whereas topic and learning goal had little or no effect. With much of the current emphasis on content choices and the embedment of learning goals or driving questions in curriculum, this finding raises the need to focus more on what activities to include in a curriculum, and how students perceive such activities.

The finding that students tend to be more interested in IEs that are hands-on or involve technology is not surprising, but it contrasts with our observation of participants' actual science classes (details presented elsewhere) where few IEs fell into these categories. Therefore, one way to enhance student interest (and hence performance) in science is to restructure the classes to incorporate more opportunities of such nature.

References

Berlyne, D. E. (1960). *Conflict, arousal, and curiosity*. New York, McGraw-Hill.

Hidi, S. & Baird, W. (1986). Interestingness – A neglected variable in discourse processing. *Cognitive Science,* 10, 179-194.

Jenkins, E. W., & Nelson, N. W. (2005). Important but not for me: students' attitudes towards secondary school science in England. Research in Science and Technological Education, 23 (1), 41-57.

Palmer, D. H. (2009). Student interest generated during an inquiry skills lesson. *Journal of Research in Science Teaching*, 46(2), 147-165.

Renninger, K. A., Hidi, S., & Krapp, A. (1992). *The role of interest in learning and development*. Hillsdale, N.J., L. Erlbaum Associates.

Using Design Personas to Inform Refinements to Software for Science Learning

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Abstract: Design personas are a technique of participatory design intended to provide design teams with memorable, vivid representations of users' needs and practices. In this paper, we describe the process of creating personas to inform refinements to the design of software designed to help elementary students create concept maps of science topics they were studying. Drawing from interviews with children, parents, and teachers, the aim of these personas was to help the design team develop refinements to help children use the software effectively if it were to be assigned as homework.

Context

In this study we used *design personas* (Courage, 2005; Pruitt, 2006) to help a design team improve software intended to promote upper elementary school students' conceptual learning in science. Design personas are vivid representations of users' needs and practices, embodied in characters designers can relate to and utilize as they discuss design requirements and refinements (Grudin & Pruitt, 2002). Personas give designers powerful means to reason about design issues (Cooper, 2004; Dantin, 2005; Nieters, Ivaturi, & Ahmed 2007). The personas involve students in the design process in a way that accounts for children as a special user group (Bruckman & Bandlow, 2003), and emphasizes the roles they play in the design process (Druin, 2002).

The study focused on *Teachable Agents* (TA), a software that enables students to create an agent and to teach it science content through the creation of concept maps that constitute the agent's brain. The software has different feedback features and the students can also have their agents participate in a game show to test their agent's knowledge (Chase, Chin, Oppezzo, & Schwartz, in press). Tested initially in laboratories and recently in classrooms, the team that developed the software is interested in extending its use into home settings; to see whether it will help students learn more by engaging with the concepts in multiple contexts.

Approach to Developing Design Personas

A challenge of this particular design effort was to conceive how elementary-aged children engaged in multiple contexts, including school and home. Our personas describe learning dispositions, likes, technology use, and parental involvement associated with different activities. By characterizing the learning dispositions of children in different contexts, we aimed to provide the design team with a better sense of children's motivational goals (Ames & Archer, 1988; Pintrich & Schrauben, 1992; Urdan & Maehr, 1995) as well as other data that could inform the design of particular features to appeal to a diversity of children. By considering parents' involvement in different activities, we sought to anticipate issues that could arise from assigning TA as homework, given parents' and children's preferences for mutual engagement in homework and technology-based activities.

To develop the personas, we conducted case studies of 10 students in which we compared the data about their informal activities with how they engaged in TA. We conducted two 1-hour long interviews with each student and two with their parents. We also incorporated data from logs about their engagement with four TA-specific features: chat, feedback via a grid showing correct and incorrect links between concepts, game show, and concept map edits. Each of the four design personas aggregated data from 2 to 3 students.

Samples of Design Personas

The design personas focused on user type characteristics that were deemed most relevant to TA-specific features mentioned above. The following are excerpts from the four design personas that were created.

Brainy Bethany loves learning about new things. Being very inquiry-oriented, she is comfortable not knowing the end result of an information-finding effort and does not limit herself to one form of finding information. Bethany feels she knows her mind very well, and she is constantly reasoning about her surroundings.

Social Susie is motivated by social participation in virtually all her activities. She can be sensitive to critique but she also very reliant on others' input and opinions and relies quite a bit on guidance from adults. She prefers practicing instead of advancing to more complex levels of learning. Even though she participates in many sports, she is not motivated by competition at all.

Hangback Hubert wants to do well, and he worries about failing in front of others. Hubert depends on the guidance, structuring, and feedback from others and gets overwhelmed and anxious in an open-ended environment. He needs clearly articulated goals but he can also be motivated by intellectually stimulating aspects such as puzzles and strategy-like activities. He is not very competitive,

Gamer Gabe makes a game of whatever he is doing, which gives him a strong sense of agency in the world. Gabe likes to get things right. He doesn't so much like "learning" the varied games he plays (videogames, computer games, puzzles, board games), but is rather driven by a need for novelty. He finds homework boring, because it's repetitive. Gabe is social, but prefers smaller, trusted groups of people, especially when the social context is activity-centered (like playing games together, for example).

Implications for Refining the Design of the Software

For each of the personas developed, our team generated suggestions for design implementations. Overall, the user profiles represented by the personas suggest more integration of TA's main features and more flexibility in their particular functionalities.

The chat feature is not likely to appeal to *Bethany* in the same way it might others, because she is an independent learner and seeks help efficiently on her own. Likewise, Bethany would likely see through the game show; instead of using it as a motivating vehicle for improvement, she is likely to discover and use alternate methods of getting feedback to check to see if the links she has made between science concepts are correct. If the design team incorporated additional ways for Bethany to search for information outside the site that could help her learn about the concepts, the software might be more appealing to her.

Personalizing the agent and integrating it more in the TA landscape might be more motivating for *Susie*. It would probably help her to de-emphasize the competitive aspect of the game show and make it more social. Susie's sensibility toward criticism may be dealt with by making the agent more "alive" and strengthening its role as ego buffer

Hubert would likely prefer to communicate with friends and others that he already trusts. Perhaps the grid in its present form is too much like a grade for Hubert, leading him to focus more on the game show, where the outcome reflects less on him directly and more on his agent. If it was possible for the game show to retain its quality of high structure but integrate it more with other features, it could provide opportunities for Hubert to involve himself with his map and his agent's learning in a more productive way.

As a sophisticated gamer who takes interest in game-specific problem solving strategies, *Gabe* might benefit from integrating the game show strategy with the agent's knowledge. To leverage learning goals against achievement and game strategy goals for Gabe, TA might shift the balance from the explicit achievement functions and capitalize more on strategy and game playing features with learning goals.

The best test of personas' usefulness is whether the software refinements lead to the desired engagement with the key aspects of what makes the software a powerful learning tool. Such a study is planned for the 2009-10 school year, as a collaborative endeavor between our research team and the design team.

References

Ames, C., & Archer, J. (1988). Achievement goals in the classroom: Students' learning strategies and motivation processes. Journal of Educational Psychology, 80(3), 260-267.

Bruckman, A., Bandlow, A., 2003. HCI For Kids. In: Jacko, J., Sears, A. (Eds.), Human–Computer Interaction Handbook, Lawrence Erlbaum, Hillsdale, NJ, pp. 428–440.

Chase, C., Chin, D. B., Oppezzo, M., & Schwartz, D. L. (in press). Teachable agents and the protege effect: Increasing effort towards learning. Journal of Science Education and Technology.

Courage, C. a. K. B. (2005). Understanding your Users. A Practical Guide to User Requirements. San Francisco: Morgan Kaufmann Publishers.

Druin, A., 2002. The role of children in the design of new technology. Behaviour and Information Technology 21(1), 1–25.

Pintrich, P. R., & Schrauben, B. (1992). Students' motivational beliefs and their cognitive engagement in classroom academic tasks. In D. Schunk & J. Meece (Eds.), Student perceptions in the classroom: Causes and consequences (pp. 149-183). Hillsdale, NJ: Erlbaum.

Pruitt, J., S. and Tamara Adlin (Ed.). (2006). The Persona Lifecycle. Keeping People in Mind throughout Product Design. San Francisco: Morgan Kaufman Publishers.

Urdan, T. C., & Maehr, M. L. (1995). Beyond a two-goal theory of motivation and achievement: A case for social goals. Review of Educational Research, 65(3), 213-214.

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Learning to Categorize Word Problems: Effects of Practice Schedules

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Abstract: Participants learned to categorize and solve probability word problems by studying worked examples and solving practice problems. The examples and problems were ordered according to either a blocked (sequential examples of the same problem category) or mixed (intermixed examples of different problem categories) schedule. Preliminary results suggest that when categorizing problems the blocked schedule might facilitate immediate performance, whereas the mixed schedule might facilitate delayed performance.

Introduction

Solving word problems in science, technology, engineering, and mathematics (STEM) domains often requires determining the category of the word problem as a first step (e.g., selecting the relevant formulas or algorithm to solve the problem). Accurate categorization is difficult for novices because they have an incomplete base of conceptual categories and tend to concentrate on surface features (Chi, Glaser, & Rees, 1982).

Attempts to improve learners' ability to categorize word problems can be informed by psychological research on concept learning. Novices are essentially learning how to classify the exemplars that they view (i.e., the word problems) as instances of different categories (i.e., the problem types). This issue can be framed as "How do novices build a conceptual structure based on viewing example instances and what conditions during study might affect those processes?"

One important study condition is the order of examples. The *practice schedule* in which learners study or solve word problems can be varied such that multiple example instances from the same problem category are either presented sequentially (i.e., a *blocked* schedule), or distributed among other problem category examples (i.e., a *mixed* schedule). Research suggests that practice schedule can affect learners' conceptual structures (Hiew, 1977) and categorization accuracy (Gane & Catrambone, 2009; Kornell & Bjork, 2008).

These practice schedule conditions are relevant to instructional designers. Consider the task of creating a textbook presentation or homework assignment to teach multiple types of probability word problems. Should the textbook present worked examples according to a blocked or a mixed schedule? Likewise, should students complete homework problems that are arranged in a blocked or mixed schedule? These decisions become more difficult because practice schedules can differentially affect immediate and delayed performance (Schmidt & Bjork, 1992). This study examines how blocked and mixed practice schedules affect novices' immediate and delayed performance of categorizing and solving probability word problems.

Method

Participants

Undergraduates from the Georgia Institute of Technology who had not taken a college-level probability or statistics course participated. Data collection is ongoing; to date, data from 36 participants have been analyzed.

Learning Materials

Participants studied four categories of probability word problems: permutation with replacement, permutation without replacement, combination with replacement, and combination without replacement. The learning materials consisted of four packets of word problems; each packet contained four worked examples followed by a *conventional problem* to solve. Thus, participants studied a total of 16 worked examples (four examples per category), and solved four conventional problems (one problem per category).

Worked examples had the word problem stem, a category label, the two features (*order*: permutation or combination, and *replacement*: with or without) that determine the category label, the category-appropriate formula, values inserted into the formula, calculations, and the final answer. Conventional problems had only the world problem stem.

Design

The practice schedule manipulation had two levels: blocked and mixed. The same set of 16 worked examples was used in the blocked and mixed conditions, only the order differed. The blocked order had four worked examples from the same category presented consecutively; the mixed order never repeated a worked example from the same category consecutively. These two orders were operationalized by including four examples of one category in a packet (blocked) or by including one example of each category in a packet (mixed). To reduce the influence of the *specific category ordering* used within the blocked and mixed schedules, we created two versions of each schedule with different category orders.

Procedure
After studying the example packets, participants completed use, access, and transfer tests, in that order. In the *access test* participants chose the appropriate formula (but did not solve) the word problem. In the *use test* the formula was given; participants inserted the values and calculated the final answer. The transfer test was formatted like the conventional problems; we manipulated transfer distance by varying the number of probabilities used to calculate the final answer. The access, use, and transfer tests used a mixed schedule. Participants returned for Session 2 after 48 hours and completed another set of access, use, and transfer tests.

Results
Preliminary results (n = 36) are reported, but data collection is ongoing. Random assignment appeared to equalize domain knowledge and mathematical skills; there were no significant differences between conditions on either the probability pretest or math pretest.

All participants in the blocked conditions categorized all of the conventional problems correctly (M = 4.0, SD = 0.0), whereas participants in the mixed conditions did not (M = 3.6, SD = 0.6), $F(1, 34) = 8.16$, $p < .01$. Practice schedule also affected categorization on the access tests. In Session 1, the blocked condition had higher categorization accuracy (M = 4.9, SD = 1.1) than the mixed condition (M = 4.5, SD = 1.3). In Session 2, however, the blocked condition (M = 3.9, SD = 2.1) had lower categorization accuracy than the mixed condition (M = 4.4, SD = 1.5). This reversal in means resulted in a significant interaction at the $\alpha = .10$ level, $F(1, 31) = 3.12$, $p = .09$. With a larger sample, we expect to find a significant interaction at a conventional α level. The use and transfer test results did not show stable trends. We await a larger sample to determine if practice schedule affects categorization accuracy on the transfer test; previous research (Gane & Catrambone, 2009) suggests a small effect.

Discussion
These preliminary results suggest that practice schedules might affect concept learning with word problems in STEM domains. Further, they suggest that this effect might change as a function of the retention interval. These results extend the general phenomenon of the *contextual interference effect* (Battig, 1979), to concept learning processes in a cognitive skill domain.

These results suggest that ideas from concept learning literature can inform instruction design decisions. For instance, to facilitate categorization while studying, a blocked schedule might be used. However, to improve delayed performance, a mixed schedule might be more effective. An interesting question is whether this type of ordering is practical to implement in a classroom environment, and how students' expectations of how lessons typically order materials (e.g., simple to complex, blocked first, then random, etc.) might affect their learning from different schedules.

We believe future work should focus on the processing differences between individuals in each condition. It would be helpful to collect qualitative data regarding whether participants in each condition are explicitly comparing worked examples to one another. Another interesting question is how individual differences in metacognitive processing might moderate practice schedule effects. For instance, individuals that effectively monitor their understanding and control their allocation of study effort might engage in the same type of processing regardless of the type of practice schedule.

References

Battig, W. F. (1979). The flexibility of human memory. In L. S. Cermak & F. I. M. Craik (Eds.), *Levels of processing in human memory* (p. 23-44). Hillsdale, NJ: Erlbaum.

Chi, M. T. H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence (Vol. 1)*. Hillsdale, NJ: Erlbaum.

Gane, B. D., & Catrambone, R. (2009, April). *Practice schedules in cognitive skill acquisition: Effects of example order on categorization and problem solving.* Paper presented at the American Educational Research Association annual meeting, San Diego, CA (AERA '09).

Hiew, C. C. (1977). Sequence effects in rule learning and conceptual generalization. *American Journal of Psychology, 90*, 207-218.

Kornell, N., & Bjork, R. A. (2008). Learning concepts and categories: Is spacing the "enemy of induction"? *Psychological Science, 19*, 585-592.

Schmidt, R. A., & Bjork, R. A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science, 3*, 207-217.

How does the use of analogical mapping as a scaffold for science learners' argumentation support their learning and talking about science?

Abstract: Analogical mapping is evaluated as a scaffold for small-group argumentation and learning. In this study, groups of four students are invited to analogically map simple machines while creating an argument about which two are most analogically similar. Qualitative and quantitative analysis of video and transcripts show dense argumentation with mutual understanding among students numerous claims. Fifteen out of eighteen claims were normative, suggesting student learning was directed toward functional features of simple machines.

Introduction

Informed by a social constructivist framework, recent research in science education research has focused on getting students to discuss possible scientific explanations and persuade one another of their correctness while at the same time attempting to understand a given scientific concept. This process has been referred to as argumentation. (Driver, Newton, & Osborne, 2000; Duschl, 2008; Kuhn, 1993)

Unfortunately, argumentation research has had only limited success. As educators we want students to discuss things in order to help them to understand. But, since they do not discuss well what they do not understand, a chicken-or-egg problem emerges, and the desired learning from argumentation does not occur. Thus, much research has been focused on scaffolding students in doing quality argumentation that leads to productive argumentation, learning, and understanding. (Sampson & Clark, 2008) These scaffolds can be thought of as temporary supports for students. (Wood, Bruner, & Ross, 1976) Various "scaffolds," or ways to support student argumentation, have been evaluated. (Jimenez-Aleixandre & Regosa, 2006).

The scaffold investigated in this research is that of analogy mapping. Gentner (1983) states that an *analogy* is "a comparison in which relational predicates, but few or no object attributes, can be mapped from [one scenario to another]" (p. 158) Relationships between scenarios can be mapped, whereas the things being related are different. The word "mapped" in this definition means an explicit correspondence made between two analogues.

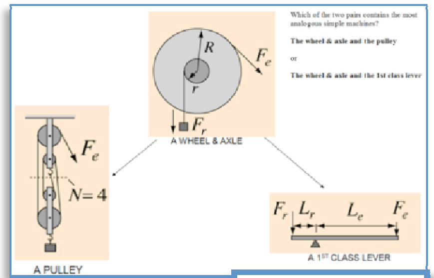
The research presented in this study is based on the belief that students learn and talk together more easily when comparing two (or more) things than when they speak about them in absolute terms. Research on training students on analogical mapping, as in the type of intervention discussed in this paper, has the potential to inform instruction, learning, and curricular development. Analogical mapping could easily be used on any elaborate conceptual analogies used in science classes, of which there are many (e.g., electricity:water, density:population density, cell:house). The fact that even simple machines can be considered analogically (they are usually not) speaks to the flexibility of analogical mapping to scaffold student argumentation and learning.

Methodology

This study took place in a science content course designed for pre-service elementary teachers. The course is offered by a large Mid-Atlantic university in the United States and was taught by the principal researcher. It was held twice weekly for 1.5 hours each period. All 24 students provided their permission to be in the study. Working in six groups of four, they were video and audio recorded during their argumentation process. They also created a PowerPoint presentation detailing their final argument statement. The video recording transcripts and PowerPoint slides containing their final arguments were primary sources of data.

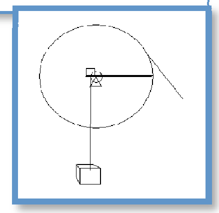
This study took place at the end of a four week unit on simple machines, including levers, gears, pulleys, and inclined planes. Before the test, this intervention was offered as a review activity in which the screw and wheel-and-axle were introduced. First, however, students received training on analogical mapping, in which they mapped analogical correspondences in three examples similar to those shown in table 1 but unrelated to simple machines. Next, students received a paper showing a wheel-and-axle, a lever, and a pulley. Students were invited to analogically map the simple machines (see figure 1) and generate an argument stating which machine was most analogically similar to the wheel-and-axle – the pulley or the lever. When groups finished their arguments, the activity was repeated with two similar prompts including different simple machine groups.

Design Rationale



Superficially, the pulley is similar to the wheel-and-axle, since both machines have round parts and have strings attached. Functionally, however, the lever and the wheel-and-axle are most similar. Note figure 2 in which a lever is shown superimposed on a wheel-and-axle. Table 1 lists the correspondences that students were expected to come across and discuss during their argumentation.

Table 1	
Wheel and Axle	**Lever**
Axis of Rotation	Fulcrum
Radius of Wheel (length)	Length of Effort Arm of Lever
Radius of Axle (length)	Length of Resistance Arm of Lever
Effort Distance	Effort Distance
Load	Load
Load Distance	Load Distance



It was expected that students might first consider that the wheel-and-axle and pulley are most analogically similar due to the superficial similarities. However, once students begin to generate a table of analogical mapping correspondences as in table 1, their argumentation would become scaffolded or guided by the triangulation imparted by the analogy. For example, once the axis of rotation is mapped to the fulcrum, it becomes easier to see that the effort arm length of the lever best corresponds to the wheel's radius.

Findings

Findings are summarized below:

1. Most claims made were analogical comparison based, suggesting the task did guide and scaffold students
2. The argumentation was dense with claims, rebuttals, and importantly, evidence of meaning sharing.
3. Most claims made in groups' final arguments emphasized function over superficial similarities and were scientifically normative (15 of 18 among all groups' claims).

Conclusion

We can infer from the findings that the analogical-mapping-based scaffold allowed for argumentation in a shared context that was accessible to students, since most claims were analogical comparison based and were picked up by student groups and made the subject of argumentation. Superficial similarities were most often dismissed in favor of more functional analogical similarities, suggesting that students were attending to and arguing about more pertinent features of the simple machines. Students argued about the relative strength of analogical mappings toward a more normative view of science and away from surface similarities. Attending more to deep structural features and less to superficial similarities is an important in focusing and improving argumentation and learning.

These preliminary results suggest that students were scaffolded in their argumentation and learning about simple machines by the analogical mapping activity. More work needs to be done on analyzing and coding what takes place during student argumentation in order to better understand how exactly the analogical mapping scaffolds and guides group argumentation and learning. Presenting content as an analogical mapping task to student groups to scaffold argumentation seems to scaffold argumentation by guiding and constraining it.

Works Cited

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the Norms of Scientific Argumentation in Classrooms *Science Education, 84*, 287-312.

Duschl, R. A. (2008). Quality Argumentation and Epistemic Criteria In S. Erduran & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in Science Education* (Vol. 35, pp. 159-175): Springer

Gentner, D. (1983). Structure-Mapping: A Theoretical Framework for Analogy. *Cognitive Science, 1983* (7), 155-170.

Jimenez-Aleixandre, M.-P., & Regosa, C. (2006). Contextualizing Practices Across Epistemic Levels in the Chemistry Laboratory *Science Education, 90*(4), 707-733.

Kuhn, D. (1993). Science as Argument: Implications for Teaching and Learning Scientific Thinking. *Science Education, 77*(3), 319-337.

Sampson, V., & Clark, D. B. (2008). Assessment of the Ways Students Generate Arguments in Science Education: Current Perspectives and Recommendations for Future Directions. *Science Education*.

Wood, D. J., Bruner, J. S., & Ross, G. (1976). The Role of Tutoring in Problem Solving. *Journal of Child Psychology and Psychiatry, 17*, 89-100.

Community Knowledge Advancement and Individual Learning

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Abstract: This paper reports on a preliminary attempt to examine the relationship between community knowledge advancement and advances in understanding made by individual learners based on Popper's (1971) Darwinian theory of knowledge and the view that theoretical, more abstract knowledge is at a higher level than specialized instances of that knowledge. The study is carried out using online discourse data collected over a period of about two weeks in the context of an international knowledge-building program.

Introduction

Knowledge building (KB) as proposed by Scardamalia and Bereiter (1999, 2003) is both a theory about how human knowledge is created through intentional collaborative efforts of communities to extend the frontiers of knowledge and a theory that even young children can engage in KB and that learning in schools can take place through the process of knowledge building. This pedagogical approach directly addresses the need for education in the knowledge society to prepare learners to contribute to knowledge creation. There has been accumulated literature from different parts of the world that show students, including young elementary school children, can engage in KB (Messina, Reeve, & Scardamalia, 2003; Zhang, Scardamalia, Lamon, Messina, & Reeve, 2007).

Unlike learning organized in traditional classrooms, the KB process is necessarily an intentional community effort, and is not possible simply as an individual enterprise. In the KB literature, priority has been given to the description of knowledge advancement for the community and individual advancement through the process is less discussed. On the other hand, schools as social institutions are vested with the responsibility to ensure that individual learners achieve some baseline levels of knowledge and competence. How do individual and collective advances in knowledge and understanding relate to each other? What is the interplay between individual learner's changes in knowledge and understanding, and the knowledge advancement made by the entire class of students as they engage in learning activities designed on the basis of KB pedagogical principles? These are the questions explored in this paper. The context of this study is an international knowledge-building project centered on the theme of the sustainability of caves involving online asynchronous work on KF as well as face-to-face activities, including two field trips to limestone caves and experimental work on water samples collected from the caves. The study traces the knowledge advancement of the community as a whole, as well as those of 14 individual learners during the process.

Theoretical background

What counts as knowledge advancement? This paper takes, as its point of departure, Popper's (1971) view of knowledge growth as a process of *natural selection*. According to this view, knowledge always starts from problems, practical or theoretical ones, and grows through a process of conjectures and refutations as it proceeds from old problems to new problems. The knowledge at any point in time may be partial or inadequate for the problem at hand, and it grows by being corrected or modified. Popper argues that the process is one of *the natural selection of hypothesis* (authors' emphasis) – only those hypotheses that are able to show their comparative advantage in relation to others can survive while those hypotheses proven to be "unfit" through the process of criticism and refutation are eliminated. Scientific knowledge grows through the elimination of mistaken beliefs and unfit theories by the process of scientific criticism. In this study, we identify the idea units found in the learners' online KB discourse, examine whether we can see changes in the "population" of such idea units over time, and whether such changes do indicate the emergence and survival of "fitter" ideas when compared to advances as documented in the subject discipline itself. In keeping with the Darwinian evolutionary conception, we adopt the term "meme" first coined by Richard Dawkins (1976) to refer to the idea units.

Another idea put forward by Popper (1971) in the same work is the distinction between applied and pure knowledge (as in 'fundamental research') in terms of the structure of knowledge. The former becoming more different and specialized as it grows while the latter grows towards increasing integration and unified theories. A large part of the knowledge as specified in school curricula also falls into the latter category – focusing on understanding that can answer how and why questions in the specific disciplinary area covered. Here, Biggs' SOLO taxonomy (Biggs & Collis, 1982) is used as an appropriate analysis scheme to discriminate levels of increasing integration and complexity in students' understanding and presentation of a subject.

Study context

In this study, since we are primarily examining the ideas expressed by learners on the online platform Knowledge Forum®, we will restrict our exploration of individual and collective knowledge advancement to the realm of stateable knowledge. The context of this study is an event titled "Tomorrow's Innovators 2009" (TI2009) organized as part of the Knowledge Building International Program (KBIP during which students were to tackle the problem of the sustainability of caves). Students' work was categorized into four stages: project kick-off, pre-field trip asynchronous discussion, field trip and final day of intensive face-to-face and online work. For the part of this study concerned with the analysis of individual knowledge advancement, we focus on the online work of the 14 students from Hong Kong (7 were elementary school students from grades 5 and 6, and the remaining 7 were secondary school students from grades 8 and 9) as on average they have written more notes, all of which were written in English. We examine the knowledge advancement students made from two perspectives – the memes related to the subject matter content, in this case the sustainability of caves, and the levels of generalization as reflections by the structure of the notes using SOLO taxonomy.

Summary of findings and discussions

In this paper we examine the knowledge advancement of the community of learners taken as a whole, as well as a selection of individual learners as they engaged in knowledge building around the theme of sustainability of caves. We found that at the individual level, of the 14 Hong Kong students participating in the program, 11 showed some form of advancement. The most common is the increase in meme diversity (type I), and is found in the work of all of the 11 students who made some advancement. The other two forms are the emergence of higher-level memes (type II) and higher levels of structure and abstraction based on SOLO taxonomy (type III). Types II and III advancement do not appear to be hierarchically related. This way of examining knowledge advancement systematically at the individual level has not been reported in the work on knowledge building. It is very preliminary work and needs to be further explored, together with the collection of more information on student background characteristics in order to seek a better understanding of the conditions that would contribute to individual advances, including characteristics such as students' motivation in engaging in collaborative inquiry activities. We hope that this work will also stimulate debates and discussions on the appropriateness of the indicators we have selected for assessing knowledge advancement, as well as viable alternatives.

We have also examined the population distribution of memes and the mean SOLO level of the all students' notes written during the four stages of the TI2009 program. We find that the most "productive" period for the community in terms of increases in the diversity and levels of memes is stage 2, when the students were working asynchronously at their own time to look for information and discuss with each other their views. The three days of intensive face-to-face activity have contributed to students taking up the various memes circulating in the community and hence to the types I and II knowledge advances among individuals. However, there is no evidence that less "fit", lower level memes have become less popular or that any of the higher level memes have emerged as more dominant in terms of the total population of memes expressed by the students. These findings point to the importance of providing students with longer periods of asynchronous work for individual and social construction of understanding. Unfortunately the face-to-face work of the TI2009 program was not followed by an online asynchronous collaboration. These findings also indicate that collective knowledge advancement is possibly more difficult to achieve than individual advances.

References

Biggs, J. B., & Collis, K. F. (1982). *Evaluating the quality of learning: The SOLO taxonomy (Structure of the Observed Learning Outcome)*. Academic Pr.

Dawkins, R. (1976). chapter 11. Memes: the new replicators *The Selfish Gene*: Oxford University Press.

Messina, R., Reeve, R., & Scardamalia, M. (2003). Collaborative structures supporting knowledge building: Grade 4. *Annual meeting of the American Educational Research Association.*

Popper, K. (1971). Evolution and the Tree of Knowledge *Objective knowledge* (2nd ed.): Oxford University Press, USA.

Scardamalia, M., & Bereiter, C. (1999). Schools as Knowledge Building Organizations. In D. H. Keating, C. (Ed.), *Today's Children, Tomorrow's Society: the developmental health and wealth of nations* (pp. 274-289). NY: Guilford.

Scardamalia, M., & Bereiter, C. (2003). Knowledge Building. In *Encyclopedia of Education*. NY, USA: Macmillan Reference.

Zhang, J., Scardamalia, M., Lamon, M., Messina, R., & Reeve, R. (2007). Socio-cognitive dynamics of knowledge building in the work of nine- and ten-year-olds. *Educational Technology Research and Development*, 55(2), 117-145.

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Moving Towards Learning with One-to-One Laptop: A Longitudinal Case Study on Tools, People, and Institutions

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Abstract: The purpose of this study is to investigate how new learning possibilities could take place in environments where students are saturated with laptops. Specifically, this work draws upon in situ examples collected from three schools in Thailand over a one year period to highlight how the schools are evolving using a theoretical framework that treats change as a developmental process.

Overview

This paper is a result of Thailand's first longitudinal study of learning with one-to-one laptop. We offer an analysis of the case studies based on a theoretical framework offered by Papert and his colleagues. When looking at how schools are embracing or resisting change, Papert sees the process as developmental. That is, change itself is a learning process (Papert, 1997; Cavallo, 2004). Comparing this process to Piaget's notion of assimilation and accommodation, Papert suggests that it is normal for schools to initially resist innovation by assimilating the change into the exiting school structure (Papert, 2002). Resistance is essential for the eventual shift to a completely different way of thinking (accommodation). Thus, it is not so important whether or not a particular school is doing things "right" or "wrong". What really matters is that the school keeps moving forward in the development of their thinking.

The three schools involved in this work have used XO-1 laptops from the One Laptop per Child (OLPC) non-profit association for the entire duration of this study. The focus of this paper is, however, to present an analysis of learning opportunities with one-to-one computing and not on the particular benefits or drawbacks of the XO machine offered by OLPC. The intention is to put the spot light on the people and the institutional factors that play a significant role in the fate of one-to-one laptop programs regardless of the hardware choices.

The Pilot Schools

There were three schools involved in this work. The first site, Ban Samkha, is a small rural school while the later two sites, Ban Sankhumpang and Tessaban-4, are large urban schools. Ban Samkha school has twenty eight students and everyone have received a laptop. Ban Sankhumpang has received three hundred machines and they have been given to primary students from grads one to six. Tessaban-4 has experimented with one-to-one computing in two classes. They have forty seven laptops.

This work follows the development of learning activities from the participating schools over the course of one year, starting in August 2008. The data collected for this work was gathered from three main sources: my own observation from site visits, interview sessions with teachers and students, and written documents from student journals and teachers' monthly reports.

Case Studies

Household Accounting

In the late 1990s, Ban Samkha was suffering from debt problems and villagers who cannot manage their finances were losing their homes. The village responded by creating a local debt-relief fund for those in trouble. There was a condition that those who which to receive help must build up a good financial habit by keeping a log of their income and expenses. Given that many villagers were illiterate, their children became helpful in keeping the account book up to date (see Figure 1 left). This activity unsurprisingly led to the idea of using a computer spreadsheet. Since the students were allowed to take the laptops home, the spreadsheet idea really worked (Figure 1 right). Khru Srinuan, a teacher at the school, described that the parents immediately became interested in the idea. Being able to utilize the technology at home made the activity much more personal and lowered the existing metal barrier towards technology.

The Laptop Band

This activity involved students forming a band mixing the laptops with traditional Thai music instruments. The idea emerged after a group of students became fascinated using the laptop to create music. A parent who is a vocalist from a traditional Thai band saw what the students were doing and engaged them to sing along. The group then came up with an idea that the laptops can serve as instruments in the village's band. This band (see Figure 3) became extremely popular and they performed at many shows including a few in Bangkok.

Because the laptop band became rather popular, the two other schools in this pilot program took on the idea and created their own version of the band. However, these later bands were different. The activity was adapted from its original context of a small rural school to an urban setting with a much larger class size. The activity was not a failure. In fact, feedback from students and teachers were highly positive. But the quality and authenticity of the activity were different from Ban Samkha. The differences observed of the same activity in different schools show how learning is tightly coupled to the local context at which it takes place. Such learning activities do not transfer easily.

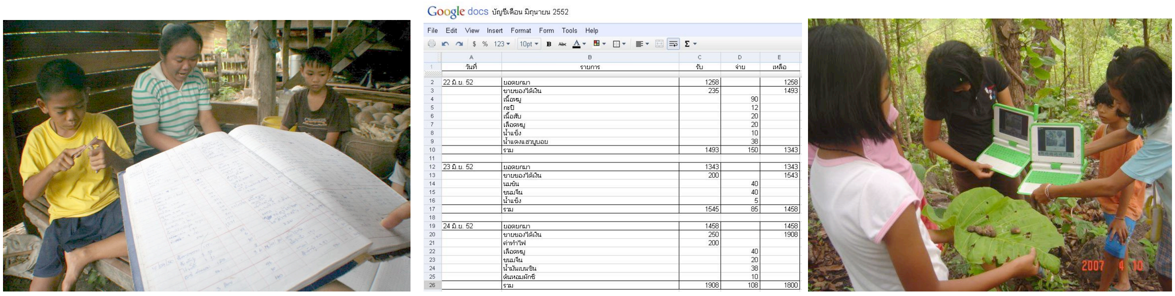

Figure 1. (Left) An account book logged by students. (Center) Example of an account book created in Google Docs. (Right) Students taking pictures with the laptop's built-in webcam.

Rich Media and Storytelling

Many teachers were able to utilize the fact that most students love the laptop's built-in camera to develop novel learning activities. For example, Khru Srinuan in Ban Samkha School organized a photography fieldtrip along the nearby mountain. The assignment was for the students to take pictures of plants or flowers that they do not recognize in the forest as shown in Figure 1 (right). They would then show the pictures to their friends and try to figure out what the plants are and write descriptions for others to later see. Other observed examples include video assays showing indigenous medicine using captured video interviews, stage acting using the computer screen for props and making sound effects, and making animated electronic cards for teachers and friends during the New Year's celebration.

Innovation as a Developmental Process

Despite the described case studies of how one-to-one laptop can open up new learning opportunities, it has been clear to the researcher that the schools' primary responsibility is to deliver the content defined in the national curriculum. Any intervention or innovation must first address how this ultimate responsibility can still be fulfilled. Curriculum mapping has been the most commonly used technique to deal with this issue. Teachers would evaluate students' projects and map what was learned to items in the curriculum. This method satisfied the school system while giving room for project-based activities. It is important to note that teachers do not see this as a compromise. Instead, they usually promote this practice as a standard procedure

We believe this situation is an example of how assimilation is taking place in the schools. Curriculum mapping is a good example of how the new is assimilated into the old without requiring a major change to the system's foundation. However, this is a kind of assimilation less severe than many other cases where the innovation is transformed entirely to keep every aspect of the traditional schooling the same. The schools have changed in many ways (i.e. long-term projects are possible), but some key aspects of traditional schooling are still kept the same. Thus, from a Papert's perspective, these schools are well in their developmental stages. It is essential, though, that they continue to evolve. Otherwise there is a danger of becoming too comfortable with the current practices that they may become stuck in an artificial stable state. For example, even though curriculum-mapping allows for project-based activities, project ideas often stem from the need to cover a certain topic in the curriculum more than the students' interests. All parties involved must work together to keep pushing things forward in a positive direction.

References

Cavallo, D. (2004). Models of growth: towards fundamental change in learning environments, *BT Technology Journal*, 22 (4), 96-112.
Papert, S. (1997). Why School Reform Is Impossible, The *Journal of the Learning Sciences*, 6(4), 417-427.
Papert, S. (2002). The turtle's long slow trip: Macro-educological perspectives on microworlds. *Journal of Educational Computing Research*, 27, 7-27.

Using a designed, online games based affinity space as a quasi-natural ethnographic context and experiment lab

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Abstract: This poster outlines an two-year ethnography of an informal after school lab for adolescent boys using the online game *World of Warcraft*. The purpose of the lab was to promote academic interests and practices to participants who were generally disengaged in traditional school settings. A variety of data was collected including chatlogs, multimedia fieldnotes, etc. The data was coded and analyzed, and general findings show that academic skills were used in a non-academic setting.

Introduction

For the past two years, we have hosted an informal after school lab called the GLS (Games, Learning, and Society) Casual Learning Lab on the University of Wisconsin-Madison campus for adolescent boys from local (mostly rural) areas using the online game *World of Warcraft* as a vehicle for the development of pro-academic practices and dispositions such as digital and print literacy, problem solving, and prosocial skills (Steinkuehler & King, 2009). Twenty-two local male youth ranging in age from 12-18, six undergraduate students, and six education researchers met regularly during the week for gaming sessions (as part of an in-game "guild") and monthly for face-to-face Saturday pizza parties on campus over the period of eight months (two years if we include the pilot). The pilot program ran from October 2007- May 2008, while the official program was from October 2008 – May 2009. The boys chosen for participation were described as "at risk" or chronically "disengaged". This population, adolescent boys, has been traditionally marginalized in studies and programs related to literacy (Newkirk, 2006), and have become increasingly disengaged in school (Steinkuehler & King, 2009). At the start of the program the graduate and undergraduate students provided mentoring and leadership for the guild; with the transfer of the leadership of the guild occurring as the study progressed.

The goal of this program was to use the natural tendencies of online gaming communities as a way to re-engage the academic interests of local youth who love gaming but hate school. Examples of skills that were promoted in the lab include distributed expertise and collective intelligence (Levy, 1999). At the same time, the lab functioned as both a quasi-naturalistic setting for ethnographic work and as a lab for conducting comparative studies of their academic practices, performances, and attitudes in the context of school (formal learning context) versus games (informal and unintentional learning context).

Data Collection

From this study we collected a variety of multimedia data, both in person and virtually. Data types included in-game chatlogs, multimedia fieldnotes including screenshots of game play, interviews, forum discussions, photos, videos and transcription, and school versus games studies data. The data because of its many faceted nature required strict organizational rules. A naming scheme was created, as well as a folder hierarchy, while the data was being collected for chatlogs, fieldnotes, video, photos, and study data. Proper naming conventions were essential to good data organization. Once the data were collected it was prepared for analysis. The fieldnotes, chatlogs, and photos were loaded into NVIVO, qualitative data analysis software. The videos themselves were kept separate due to their size and incompatible format with NVIVO. However, the videos and interviews were transcribed and these transcripts were included in NVIVO for analysis. The smaller school versus games studies were also kept separate from the main data set because they were intended to be analyzed individually. The data in NVIVO was analyzed through the use of a priori and emergent coding. The other studies were each analyzed with methods determined by their design.

Analytical Framework

The analytical framework developed for this data set included both a priori and emergent coding. The a priori coding set included a total of 11 themes. These themes included argument, problem solving, reading, information literacy, digital media literacy, design thinking, model-based reasoning, attitudes, sociocultural learning, cross cultural fluency, and work place literacy. With sub-themes there were a total of 48 codes that were used a priori during analysis. This framework of themes allowed us to trace the development of key practices, capacities, and dispositions longitudinally. Coding was undertaken in pairs with each code having two people coding to ensure inter-coder reliability, with an inter-coder reliability rate of 90% or higher deemed acceptable. Actual coder agreement was 98%.

School versus games studies

There were a series of five studies conducted within the larger ethnography that were all designed to examine each phenomena in a school versus games context. The five topics were chosen to target key domain areas. The studies conducted included a study on the participants' epistemological beliefs, an ethical decision making study, a reading study, an online reading comprehension study and a model-based reasoning study. A description of a sample of these studies is presented here. The ethics study conducted supplied the participants with two hypothetical scenarios, one being set in everyday life, the other in-game. These scenarios were designed to compare ethical decision making of the participants in life versus in the game. Another of the studies was a reading study that was designed to discover if the participants read at a higher level on a text that they read for interest as opposed to a standard school text, miscue analysis was used in the analysis of this study. Also an online reading comprehension study was conducted modeled on the study by Coiro and Dobler (2007). For this study, the participants were asked to answer a set of questions from a website about Tigers and one about Murlocs (small Non-Player Characters from *World of Warcraft*). The participants were asked to think aloud and were video recorded. The data was analyzed using the coding scheme developed by Coiro and Dobler (2007).

General Results

Figure 1 illustrates the data saturation of the aforementioned themes. Interesting patterns have been seen in overlap between codes such as the overlap that occurs between collaborative problem solving (which is a sub-theme of the theme sociocultural learning) and information literacy, which illustrates that information literacy is happening as a collaborative instead of an individual process in this virtual world. Another insight from the data was that practices of civic engagement (which is a sub-theme of the theme attitudes) are used by the participants to establish good practices within their guild.

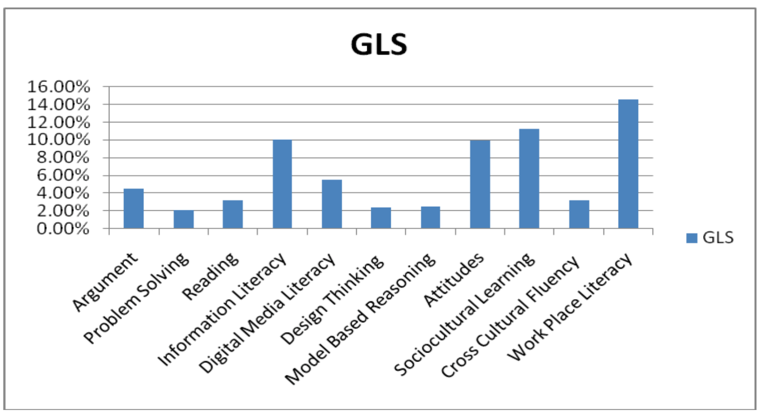

Figure 1: Coding Saturation for Themes

References

Coiro, J. & Dobler, E. (2007). Exploring the online reading comprehension used by sixth-grade skilled readers to search for and locate information on the Internet. *Reading Research Quarterly,42*(2), 214-257.

Levy, P. (1999). *Collective intelligence: Mankind's emerging world in cyberspace* (R. Bononno, Trans.). Cambridge, MA: Perseus Books.

Newkirk, T. (2006). *Misreading masculinity: Boys, literacy and popular culture*. Protsmouth, NH: Heinemann.

Steinkuehler, C. & King, B. (2009). Digital literacies for the disengaged: Creating after school contexts to support boys' game-based literacy skills. *On the Horizon, 17*(1), 47-59.

Facilitation of reform based teacher identity development in pre-service teachers using post-activity reflection debriefs

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Abstract: An exploratory case study approach was used to study twenty pre-service secondary science teachers to learn: What impact does post-activity reflection debriefs have on teacher identity development as a reform-minded science teacher? Analysis of debrief video and audio recordings revealed that debriefs provide opportunities for pre-service teachers to wrestle with issues related to practice and the struggle to enact the reform-based practices that they are learning about and believe they should implement.

Introduction

There is significant research on the benefits of reform-based practices specifically defined by the NRC as inquiry into authentic questions generated from student experiences (NRC,1996, pp. 32-33). Our reform-based teacher preparation program provides several field opportunities that are designed to afford pre-service teachers opportunities to take risks in a safe and nurturing environment, and learn from them through semi-structured reflection events. One of the instantiated reflection events is the post-activity reflection debrief. We argue that post-activity reflection debriefs can be an effective and integral part of a multi-pronged unified approach to identity repair (Gee, 2003) to facilitate an identity trajectory toward more reform-minded orientations.

There remains little evidence that reform-based practices occur in science classrooms today (Anderson, 2002). When we engage them in a reform-based teacher preparation program, the ensuing cognitive dissonance can be difficult to overcome. Post activity reflection debriefs are a vehicle to support the necessary changes in pre-service teacher identity toward reform-mindedness.

Literature Review and Theoretical Framework

Recent literature (Darling-Hammond & Bransford, 2005) has identified the complexity involved in adequately preparing novice teachers to reconcile a reform-based image of instruction with personal, prior beliefs (Kagan, 1992), position themselves within a larger community of practice (Windschitl, 2002), develop confidence and manage the emotional dimensions of personal development (Alsup, 2006), and integrate theory and practice (Feiman-Nemser, 1990). Program elements identified as successful include coherence between theory and practice, developmentally appropriate curriculum, and teacher learning situated in supportive, authentic contexts (Darling-Hammond & Bransford, 2005) We have much to learn about the unique challenges faced by beginning science teachers who are not only preparing to be expert practitioners but also agents of change.

Identity theory is a powerful lens for considering pre-service teachers trajectory in their professional development. Professional identity theory, addresses some of the unique challenges of the learning involved in becoming a reform-minded science teacher (Luehmann, 2007) and offers a lens in which one's experiences are considered in light of how they impact one's professional practices, values, and commitments. (Flores & Day, 2006). Professional identity development is the means by which one becomes a full participant in a community of practice (Lave & Wenger, 1991). We have argued elsewhere (Luehmann, 2007) that this framework offers the field of science teacher preparation two primary insights: 1) Trying on a new identity within a community of practice (especially when it is counter to the norm) involves assuming risks; and 2) Learning as identity work occurs in the interpretation, narration, and thus recognition of that participation (by self and others). Studying post-activity reflection debriefs affords an opportunity for understanding how recognition events afford greater access to identity resources so we can map trajectories of identity development.

Research Design

An exploratory case study approach was used where the unit of analysis was twenty pre-service secondary science teachers in a teacher preparation program that foregrounds reform-based science teaching and social justice. These pre-service teachers constitute the most recent cohort in this fifteen-month teacher preparation program. The two research questions we posed were: What impact does post-activity reflection debriefs have on teacher identity development as a reform-minded science teacher? What are the nature of the debriefs that contribute to meaningful change in teacher identity? Two core field experiences for these pre-service teachers completed thus far: 1) leading a summer science camp for urban middle school students; and 2) leading an after-school science club for urban middle school girls (Science STARS), have afforded us the opportunity to engage in debriefs with the pre-service teachers directly after a teaching event where semi-structured debriefs were employed as a routine. There were five days of the summer camp and ten days of Science STARS. The debriefs all use a "plusses and arrows" format whereby participants record plusses - elements of the lesson that went well

- and arrows - elements that can be improved or suggestions for improvement. These are generated in small group (including faculty) then shared with the large group.

The primary data sources for this study were video of summer camp debriefs and video and audio recordings of STARS debriefs. Secondary sources facilitated triangulation and included personal professional blogs that pre-service teachers keep for the entire fifteen-month program and semi-structured interviews targeting inquiry-based science teaching and social justice. Transcripts of debriefs were coded independently by two researchers with respect to: 1) the focus of the plusses and arrows; 2) the type of recognition; 3) statements of understanding of, appreciation for, commitment to, or confidence in using inquiry; 4) specialist language usage related to inquiry or reform-based science teaching or social justice. Blogs that correlated to these debriefs were analyzed for any carryover of these into public spaces and what shifts in perspective and stories or reporting occur. Due to this approach, two illustrative cases emerged and were explored in more detail.

Results

Our analyses revealed that the debriefs provide opportunities for pre-service teachers to wrestle with issues related to practice and the struggle to enact the reform-based practices that they are learning about and believe they should implement. The major issues raised in debriefs are: making learning engaging to students, moving away from teacher-centered lessons to student-centered lessons, scaffolding inquiry as a process to get students to design and carry out their own investigations. The activity structure of debriefs creates a bidirectionality between partner and group such that participants are not an island, can support each other in their quests for improvement as they articulate their struggles, tensions and dilemmas. Acknowledgement of things done well, recognition by self and others fosters a greater sense of commitment to a common purpose. The power of the debriefs in fostering safe exploration of reform-based identity is evident in the perceived failures that are coaxed into being true arrows and mechanisms for change; Reflection to move forward and continue desirable practices and change out-of-line practices into in-line practices within the tenets of reform-based science teaching that we, as a group, care about.

Discussion & Implications

Plusses and arrows facilitate recognition and enticement to change the pre-service teachers outlook and practice of what they do to purposefully become more reform-minded. Debriefs serve to establish an equilibrium toward greater congruency of who the pre-service science teachers are and who they want to be. These debriefs serve as a strong pathway to change teacher identity toward a more reform-minded path. Giving pre-service teachers access to a variety of supports for interpretation and recognition is essential to supporting professional teacher learning with reform-based teaching.

References

Alsup, J. (2006). Teacher identity discourses: Negotiating personal and professional spaces. Mahway, NJ, Lawrence Erlbaum Associates, Inc.

Anderson, R. D. (2002). "Reforming science teaching: What research says about inquiry." Journal of Science Teacher Education 13(1): 1-12.

Darling-Hammond, L. and K. Hammerness (2005). The design of teacher education programs. Preparing teachers for a changing world: What teachers should learn and be able to do. L. Darling-Hammond and J. Bransford. San Francisco, Jossey-Bass.

Feiman-Nemser, S. (1990). Teacher preparation: Structural and conceptual analysis. Handbook of research on teacher education. W. R. Houson, M. Haberman and J. P. Sikula. New York, Macmillan: 212-233.

Flores, M. A., & Day, C. (2006). "Contexts which shape and reshape new teachers' identities: A multi-perspective study." Teaching and Teacher Education 22: 219-232.

Gee, J.P., (2003). What video games have to teach us about learning and literacy. New York: Palgrave Macmillan

Kagan, D. (1992). "Professional growth among preservice and beginning teachers." Review of Educational Research 62(2): 129-169.

Lave, J. and E. Wenger (1991). Situated learning: Legitimate peripheral participation. Cambridge, UK, Cambridge University Press.

Luehmann (2007). Identity Development as a Lens to Science Teacher Preparation. *Science Education,* 91 (5), 822-839.

National Research Council (1996). National science education standards. Washington D.C., National Academy Press.

Windschitl, M. (2002). "Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural and political challenges facing teachers." Review of Educational Research 72(2): 131-175.

Structural validation of a feedback perceptions questionnaire

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Abstract: The efficiency of feedback content has received much attention in prior feedback research, but students' feedback perceptions have hardly been studied. A structural validation was conducted of a feedback perceptions questionnaire amongst 1535 secondary education students. The structural validity of the scales was confirmed: fairness (FA), usefulness (US) and acceptance (AC) constitute the joined component 'Perceived Adequacy of Feedback' (PAF), which in turn positively predicts willingness to improve (WI) and affect (AF).

Feedback content and perceptions

In instructional contexts the term "feedback" refers to all post-response information which informs the learners on their actual state of learning and/or performance (Narciss, 2008). Several recent reviews of research on feedback adopt a multidimensional view of feedback (Hattie & Timperley, 2007; Narciss, 2008; Shute, 2008). Widely investigated types of feedback are (a) simple feedback types providing outcome-related information, and (b) elaborated feedback types providing additional information besides outcome-related information (Narciss, 2008). The question of which feedback content is most efficient (i.e., which has the most beneficial effects on performance) has received much attention in prior feedback research. The issues of how learners perceive feedback content and how the perceptions relate to performance have not been addressed explicitly.

The perception of feedback – if measured – is commonly measured in terms of the single dimension 'usefulness', after the feedback has been applied and/or at the end of the task (Kwok, 2008). Yet, several authors have emphasised the 'mindful processing' of feedback as a critical factor for feedback efficiency (Kluger & DeNisi, 1996; Narciss, 2008). In instructional contexts there are at least five feedback sources, i.e. the teacher, peer, parents, book and/or computer-based environment, and the task (Hattie & Timperley, 2007). Depending on the source's characteristics, feedback content might be perceived as less useful or less credible, and affect task completion or learning differentially. Thus far the measurement of feedback perception has been neglected in feedback research. This study investigates the structural construct validation of a multidimensional feedback perceptions questionnaire.

Method

The sample consisted of 1535 pre-university and senior general secondary education students in the Netherlands from 130 schools. There were 817 female and 713 male students and their mean age was 15.75 (SD = 1.19). Participation to the study was based on informed consent. Students were presented with a scenario in which a fictional student received feedback by a fictional peer (in the context of the task of 'writing a business letter'). Feedback content was Concise General (CGF) or Elaborated Specific (ESF). CGF contained solely general remarks regarding the quality of the performance, whereas ESF provided the position and error type, as well as information on how to proceed. We used the Strijbos, Narciss and Dünnebier (in press) multidimensional 18-item feedback perceptions questionnaire. This questionnaire measures feedback perceptions in terms of fairness (FA), usefulness (US), acceptance (AC), willingness to improve (WI) and affect (AF). Questionnaire items were measured on a 10 cm bi-polar scale from 0 (fully disagree) to 10 (fully agree). Four scales consist of three items (FA, US, AC and WI). Affect was measured with three positive items and three negative items.

Confirmatory factor analysis

We conducted confirmatory factor analyses using Structural Equation Modelling (SEM) in EQS version 6.1. To interpret a model's fit, the following indicators were used: SRMR and RMSEA below 0.10 is considered adequate fit and below 0.05 an excellent fit, and CFI scores above 0.90 indicate adequate fit and above 0.95 excellent fit; and as the χ^2 statistic becomes increasingly unreliable in sample sizes > 250 it was not used as a criterion for model fit (Byrne, 2006).

SEM on all 18-items – with a common factor PAF for FA, US and AC items, and a common factor for all AF items – yielded a very weak fit, $\chi^2(127) = 2752.36$, CFI = .799; SRMR = .189; RMSEA = .116. We then conducted a separate analysis for the common factor PAF and a separate analysis for WI+AF. SEM was used to confirm the second-order factor structure of PAF (with correlated errors for negatively worded items AC2 and AC3). The proposed second-order factor structure fitted adequately, but a high RMSEA indicated poor fit,

$\chi^2(22) = 576.07$, CFI = .929, SRMR = .051, RMSEA = .128. Inspection of LM-multipliers suggested that item FA1 was more indicative of the US scale. This change resulted in a excellent model fit, $\chi^2(22) = 350.52$, CFI = .958, SRMR = .039, RMSEA = .098. We then tested the proposed correlated first-order structure of WI+AF. The initial correlated factor model fitted poorly, $\chi^2(26) = 1390.903$, CFI = .612, SRMR = .143, RMSEA = .185. Inspection of the LM-multipliers suggested a positive wording effect in the AF scale due to both negatively and positively worded items. Correlating errors for the positively worded AF items yielded an excellent fit, $\chi^2(23) = 278.26$, CFI = .927, SRMR = .070, RMSEA = .085). Tests for measurement invariance for type of feedback (CGF vs. ESF) and gender (Male vs. Female) revealed strong factorial invariance. Finally, to test the theoretical relationship between PAF, WI and AF, a path analysis was conducted using SEM (Figure 1). Modelling PAF as a predictor of WI and AF yielded a good fit, $\chi^2(122) = 1636.07$, CFI = .884, SRMR = .074, RMSEA = .090.

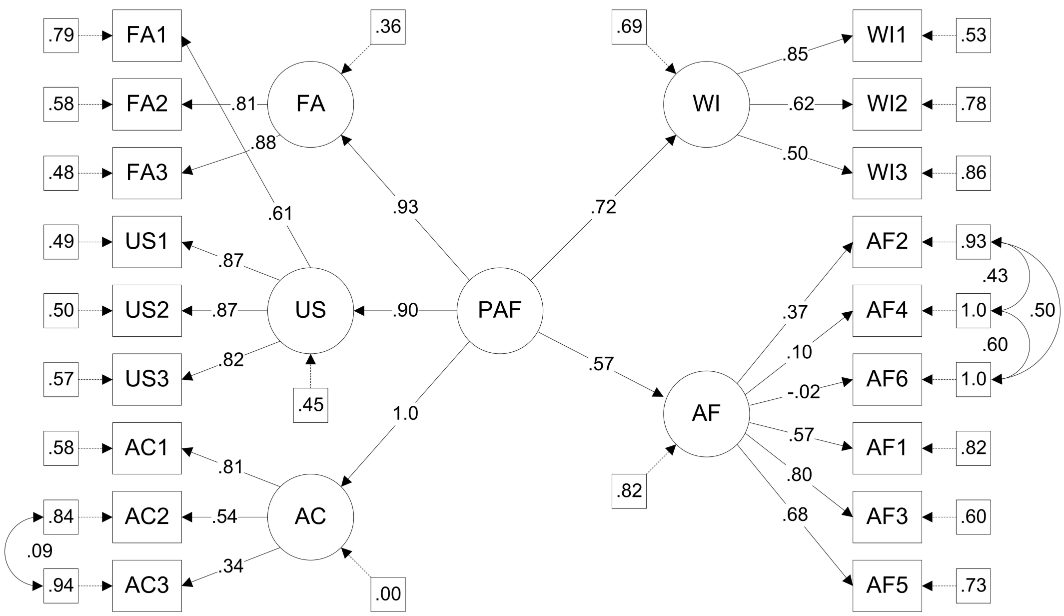

Figure 1. Path estimates and first and second order loadings [FA = fairness; US = usefulness; AC = acceptance; PAF = perceived adequacy of feedback; WI = willingness to improve; AF = affect].

Discussion

The results clearly reveal that students' feedback perception – in terms PAF, WI and AF – can be adequately captured. In addition, WI and AF were correlated – yet distinct measures. PAF was confirmed as a predictor of WI and AF. Both the PAF and WI+AF part of the questionnaire were invariant across both types of feedback as well as gender. Given the increased recent interest for feedback practices (between peers or by a teacher) in view of formative purposes of assessment, students' perception of feedback they receive could be a crucial determinant of how they treat the feedback and possibly help to uncover why elaborated feedback types are not always more efficient. With this questionnaire researchers can now reliably and validly investigate possible relations between feedback perceptions, subsequent performance and feedback efficiency.

References

Byrne, B. M. (2006). *Structural equation modelling with EQS*. Mahwah, NJ: Erlbaum.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*, 81-112.

Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin*, *119*, 254-284.

Kwok, L. (2008). Students' perception of peer evaluation and teachers' role in seminar discussions. *Electronic Journal of Foreign Language Teaching*, *5*, 89-97.

Narciss, S. (2008). Feedback strategies for interactive learning tasks. In J. M. Spector, M. D. Merrill, J. J. G. Van Merriënboer, & M. P. Driscoll (Eds.), *Handbook of research on educational communications and technology* (3rd ed., pp. 125-143). Mahwah, NJ: Erlbaum.

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, *78*, 153-189.

Strijbos, J. W., Narciss, S., & Dünnebier, K. (in press). Peer feedback content and sender's competence level in academic writing revision tasks: Are they critical for feedback perceptions and efficiency? *Learning and Instruction*.

Designing Environments to Encourage Collaborative Creativity: Two Case Studies in Higher Education

Abstract: Collaborative creativity often is lacking in university learning, despite its relevance to the 21st Century workplace. We describe two case studies of designed environments to teach collaborative creativity, along with the successes and challenges that we found in each approach. Overall, we found both environments, though different, to foster collaborative creativity, while there are still areas for improved instruction.

Teaching Collaborative Creativity to University Students

There is a modern emphasis on creativity—evidenced in part by a 68.3% increase in the level of patent applications from 1996-2001—that has led our emerging society to be called the "creative economy" (Banahan & Playfoot, 2004) where creative skills are critical to job and business success (Ogunleye, 2006). There is an additional emphasis on collaboration in the creative process, as this is the “secret to breakthrough creativity” and “group genius” (Sawyer, 2008, p. 3). Some researchers have found that collaborative creativity can be effectively taught in higher education. For example, Hokanson (2006) found that students who received creativity instruction improved their creative thinking. Ginamarie, Leritz, and Mumford (2004) reported in their meta-analysis that well-designed creativity programs produced performance gains. Driver (2001) argued that creativity education could be effectively integrated into business education. Finally, Cole, Sugioka, and Yamagata-Lynch (1999) found that supportive classroom environments promoted more creativity in higher education. However, higher education systems still often lack quality instruction in collaborative creativity. Ramocki (1994) argued, “we must be concerned with how creativity operates within groups” (p. 17) but lamented that marketing education has neglected the teaching of essential group creative skills.

Research Questions and Methods

The purpose of this research agenda was to analyze two examples of how collaborative creativity might be taught in higher education. Specifically, the research questions for this study were:

1. How well did each instructional experience assist students in learning to develop collaborative creativity?
2. What shared principles might be extracted from both contexts to inform the effective teaching of collaborative creativity in higher education?

Research Design and Participants

This study compared two case studies from two different settings. The first setting was a Design Studio for graduate-level instructional designers, occurring winter semester 2009. This Studio consisted of three courses with high levels of student collaboration within and between the different courses. Students were directly taught creativity principles during one class period, and then implicitly encouraged to be creative through faculty mentoring and the open and shared nature of the Studio community and class assignments. Four participants were selected as representative case studies from the Studio setting. The second research setting was an Innovation Boot Camp for technology and engineering undergraduate students. The Boot Camp was an intensive one-week experience where students from different departments were explicitly taught group problem finding, brainstorming, convergent thinking, prototyping, and other activities key to group innovation as they developed solutions to problems they identified in their community. This camp was repeated once a month over two semesters with 10-30 new students each time.

Data Collection

A combination of methods were used to explore the nature of the collaborative creativity process within the Studio community. In studying the Studio, we followed Seidman’s (2006) strategy for phenomenological interviewing, except for one modification. In Seidman’s process, the first interview is designed to understand the participant’s background relevant to the experience at hand; the second interview asks for specific details about the experience itself, and in the third interview the participant and researcher co-interpret the significance and meaning of the experience. We conducted the first and third interviews, and in lieu of Seidman’s second interview, we collected weekly 5-10 minute voice memos from the four participants. This provided more specific details of how their ideas developed through weekly group collaboration. This information was triangulated with an analysis of the students’ weekly design journals and through first-hand observation.

In studying the Boot Camp, we observed and video-recorded several of the groups in each iteration. We also collected pre- and post-participation survey data about their learning outcomes and the emergence of creativity and community-related elements in their groups. Survey items related to creativity were drawn from the literature and an innovation process developed by the instructors. Items related to the emergence of community were drawn from Rovai's (2002) Sense of Community scale and Anderson and West's (1996) innovation climate instrument.

Data Analysis Methods and Rigor Guidelines

Qualitative data were analyzed using constant comparison coding techniques for forming categories and theories derived from categories. Trustworthiness was developed through member checking case study reports with the participants, asking independent coders to analyze uncoded portions of the data to confirm emerging themes, peer review of the theoretical and methodological frameworks, and the use of multiple data sources.

Findings

Several positive outcomes were found in the design of the Studio. Students reported a high sense of community (50 comments), and collaboration (173 coded comments). The students also reported that a high percentage of their creative ideas coming through interactions with other people (78% of total new ideas identified). Interestingly, the students reported learning not only from being critiqued by their peers but in giving critiques and assistance as well. While this data indicated some success in fostering collaborative creativity, challenges from the Studio setting included an overt focus on task completion and grades rather than creativity, a lack of time and prerequisite skills for developing and implementing ideas, and superficial collaboration in the community at large (outside of a tight peer group).

From the surveys about the Boot Camp, we discovered several positive outcomes. These surveys were reported on a 7-point rating scale, with 7 representing the strongest level of agreement. Students reported high levels of community within their groups (5.5 average), innovation team climate (5.6) and a perception that the Boot Camp successfully taught them principles of creative thinking (5.8). We are currently analyzing the video and observational data to understand why these trends existed in the survey data, as well as to better understand the process of idea generation and development within the groups of the Boot Camp.

Implications for Creativity Instruction in Higher Education

As Greeno (1997) said, we need to understand "which combinations and sequences of learning activities will prepare students best for the kinds of participation in social practices that we value most" (p. 9). Because collaborative creativity is crucial to our students' success in the workforce, understanding how collaborative creativity can be successfully fostered in successful higher education experiences is critical.

References

Anderson, N., & West, M. A. (1996). The Team Climate Inventory: Development of the TCI and its Applications in Teambuilding for Innovativeness. *European Journal of Work & Organizational Psychology, 5*(1), 53.

Banahan, E., & Playfoot, J. (2004). Socio-organisational challenges in the creative economy. In L. M. Camarinha-Matos & H. Afsarmanesh (Eds.), *Collaborative networked organizations: A research agenda for emerging business models*. Boston: Kluwer Academic Publishers.

Cole, D. G., Sugioka, H. L., and Yamagata-Lynch, L. C. (1999). Supportive Classroom Environments for Creativity in Higher Education. *Journal of Creative Behavior, 33*(4): 277-93.

Driver, M. (2001). Fostering creativity in business education: developing creative classroom environments to provide students with critical workplace competencies. *Journal of Education for Business, 77*(1), 28-33.

Ginamarie, S., Leritz, L. E., & Mumford, M. D. (2004). The effectiveness of creativity training: A quantitative review. *Creativity Research Journal, 16*(4), 361–388.

Greeno, J. G. (1997). Response: On claims that answer the wrong questions. *Educational Researcher, 26*(1), 5-17.

Hokanson, B. (2006). Creativity in the design curriculum. *Journal of Visual Literacy, 26*(1), 41-52.

Ogunleye, J. (2006). A review and analysis of assessment objectives of academic and vocational qualifications in English further education, with particular reference to creativity. *Journal of Education & Work*, 19(1), 95-104.

Ramocki, S. P. (1994). *It is time to teach creativity throughout the Marketing Curriculum. Journal of Marketing Education, 16*(2), 15-25.

Rovai, A. P. (2002). Development of an instrument to measure classroom community. *Internet & Higher Education, 5*(3), 197.

Sawyer, R. K. (2008). *Group genius: The creative power of collaboration*. Cambridge: Perseus Books Group.

Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences* (3rd ed., p. 162). New York: Teachers College Press.

Teachers' Understanding of Partitioning When Modeling Fraction Arithmetic

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Abstract: We analyze how middle grades teachers in a professional development program reasoned about fraction arithmetic using length and area models. We discovered that teachers' abilities to partition length and area quantities were critical. In particular, we focus on ways that teachers' used multiplication factor/product relationships, distributive reasoning, and levels of units. Our findings contribute to the learning sciences' growing understanding of what teachers must know in order to use drawn representations effectively in instruction.

Theoretical Issue & Significance

External representations are important for organizing, recording, and communicating relationships in both mathematics (NCTM, 2000) and science (National Research Council, 1996). Given this importance, it is natural that representations would hold an important place in discussion of teacher knowledge. When introducing the construct of pedagogical content knowledge, Shulman (1986) emphasized knowledge of students' thinking about particular topics, typical difficulties that students have, and *representations* that make mathematical ideas accessible to students. More recently, Ball and colleagues (e.g., Ball, Thames, & Phelps, 2008) have developed the notion of mathematical knowledge for teaching (MKT) that refines Shulman's categories. MKT emphasizes the mathematics that teachers use to accomplish tasks central to their practice—for instance, using curricular materials judiciously, *choosing and using representations*, skillfully interpreting and responding to students' work, and designing assessments. Clearly, using representations is important for teachers.

Despite scholars' acceptance of the importance of PCK and the inclusion of external representations in theoretical perspectives on teacher knowledge, educational researchers do not know much about what teachers can do with drawn representations of problem situations and what they need to learn in order to use drawn representations effectively in instruction. The present study examines the knowledge that teachers need for reasoning about fraction arithmetic with drawn models. Fractions are an essential foundation for the study of algebra and functions that are used widely in mathematics and the sciences.

Research on teachers' knowledge of fractions for teaching has concentrated on fraction division. One finding that cuts across studies is that teachers can confuse situations that call for dividing by a fraction with ones that call for dividing by a whole number or multiplying by a fraction (e.g., Ball, 1990; Ma, 1999). Ma not only reported such constraints but also began to unpack PCK by indentifying *knowledge packages* that consist of numerous subtopics that are connected to one another and that support the teaching of a larger topic. To illustrate with the example most relevant to the present study, Ma described a knowledge package for fraction division in terms of the meanings of addition, multiplication, and division with whole numbers; the concepts of inverse operation, fraction, and unit; and the meaning of multiplication with fractions (p. 77). Other researchers (e.g., Behr, Khoury, Harel, Post, & Lesh, 1997; Izsák, 2008) have focused on the conceptual units that teachers form when using drawn models and manipulatives to reason about fraction arithmetic. This requires a more fine-grained perspective on knowledge than the subtopics Ma used to describe knowledge packages. In the present study, we extend this more fine-grained work by considering the knowledge teachers need to partition (e.g., subdivide) quantities when reasoning about fraction arithmetic. Understanding the fine-grained knowledge required to use drawn representations in instruction can inform more effective learning experiences for teachers.

Methodological Approach

We collected data for this study during a 15-week professional development course on fractions, decimals, and proportions offered to 14 middle grades teachers. The course emphasized solving problems in small groups and comparing solutions during whole-class discussions. Using drawn representations (e.g., number line and area models) to solve fractions problems was a central theme for the course. Software that allowed flexible manipulative of area models was often used by the teachers to support their reasoning. The teachers came from one large, urban school district. The course met once a week, and each session lasted three hours. We videotaped all sessions using two video cameras, one to capture the participants and one to capture their inscriptions. We analyzed the videos to identify the key mathematical challenges that teachers encountered. Through this analysis we discovered that teachers often have trouble partitioning quantities in ways that lead to problem solutions.

Findings, Conclusions, & Implications

We found that teachers' abilities to partition quantities were critical to their success in reasoning with drawn representations of fraction arithmetic. Specifically, we identified three aspects of partitioning that mattered. First, teachers' ability to anticipate factor/product pairs was vital. Teachers who did not invoke this whole-number knowledge were unable to anticipate how they might use subdivisions on a number line or in an area model. To illustrate, if a number line was partitioned into thirds and teachers needed to find fourths, many teachers did not understand that partitioning into 12ths would show thirds and fourths at the same time.

Second, teachers varied in their abilities to think about partitions distributively. In one example, teachers were asked to share two candy bars evenly between five people. The teachers partitioned each candy bar into five pieces but struggled with the question of how much of one candy bar each person got. They determined that two people got 2/5 of one bar, two people got 2/5 of the second bar, and the fifth person got 1/5 from each bar. The teachers recognized that 2/5 and 1/5 + 1/5 were the same numerically, but about half the class was unable to reconcile that getting 2/5 of one bar or 1/5 from each bar were the same.

Third, we noted that the teachers often resisted thinking in terms of nested levels of units. Research on students' multiplicative reasoning (e.g., Steffe, 1994), which includes fractions, has indentified nested levels of units as essential and challenging for students. To illustrate, one teacher was trying to use drawings to demonstrate why $2/3 \div 1/4 = 8/3$. She drew a rectangle, partitioned it into thirds, and shaded two of the thirds. She then discarded one of the thirds and explained that the problem only asked about 2/3. She divided each of the remaining thirds into four pieces and said that these eight pieces corresponded to the numerator in the numerical answer and that the thirds gave the denominator in the answer. Her interpretation of fourths in this answer was incorrect, and a fundamental difficulty appeared to be that she did not maintain correct relationships among fourths, nested in thirds, nested in the whole. (A correct explanation would describe 8/3 and the number of fourths that are in 2/3.) More generally, teachers who simplified tasks by ignoring "missing" parts struggled to make sense of their answers because they had eliminated the units to which the answers referred.

Our findings suggest that teachers need to develop a set of understandings related to partitioning quantities if they are to reason with drawn representations of fraction arithmetic effectively. Furthermore, teachers must be able to reason with drawn representations for themselves before they can use similar drawings in instruction. More generally, although researchers have investigated teachers' understanding of fraction arithmetic, most studies have not examined teachers' knowledge at a sufficiently fine grain-size to specify with precision what teachers must know in order to use representations in instruction. By uncovering the knowledge teachers need to use to interpret and reason with representations and drawings, we will be better able to provide the professional learning opportunities necessary to support teachers.

References

Ball, D. L. (1990). Prospective elementary and secondary teachers' understanding of division. *Journal for Research in Mathematics Education, 21*(2), 132-144.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*(5), 389-407.

Behr, M., Khoury, H., Harel, G., Post, T., & Lesh, R. (1997). Conceptual units analysis of preservice elementary school teachers' strategies on a rational-number-as-operator task. *Journal for Research in Mathematics Education, 28*(1), 48-69.

Izsák, A. (2008). Mathematical knowledge for teaching fraction multiplication. C*ognition and Instruction, 26*, 95-143.

Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. Mahwah, NJ: Lawrence Erlbaum Associates.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

National Research Council (1996). *National science education standards*. Washington, DC: Author.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Steffe, L. (1994). Children's multiplying schemes. In G. Harel & J. Confrey (Eds.), *The development of multiplicative reasoning in the learning of mathematics* (pp. 3-39). Albany: State University of New York Press.

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Putting the pieces together: The challenge and value of synthesizing disparate graphs in inquiry-based science learning

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Abstract: A comparative synthesis of multiple graphs is a common practice in scientists' work as well as in everyday contexts. We refer to this process as graph meta-analysis. We present findings from a classroom enactment in which cultivating students' graph meta-analysis skills was one aspect of fostering scientific literacy through an inquiry-based unit on socio-scientific dilemmas. We highlight the challenges that learners and teachers encountered, and their implications for future instruction and design.

Scientists conducting a literature review or citizens searching the web often encounter the same conundrum: making sense of an abundance of sources, each of which provides only a partial answer to the search question. In many cases, these may even be contradictory answers. This creates a need to synthesize and compare the different sources. Research articles that deal with similar questions often test different variables, operationalize the same variables in different ways, use different experimental manipulations or sample different populations. A simple comparison or aggregation of the information can yield erroneous conclusions. Therefore, special meta-analytic steps need to be taken to juxtapose and synthesize the information, such as using effect size to normalize findings to a common scale. This can be a complex and demanding process.

We have chosen to address this issue in the context of graph comprehension (Bertin, 1983). Graphs are central communication devices in most empirical reports, especially in science. Not surprisingly, graph interpretation and production skills are emphasized in national science standards (NRC, 1996). However, several studies have shown that full competence in reading and producing graphs is not achieved even by college and university graduates (Bowen, Roth, & McGinn, 1999; Leinhardt, Zaslavsky, & Stein, 1990). Bowen and Roth (2005) found that pre-service teachers, most of whom had a BSc degree, lacked basic skills in graph interpretation, and reached the sad conclusion that "preservice teachers do not seem to be ready to teach data collection and analysis in the way suggested by reform documents." These findings highlighted the need for concerted instructional attention on graphic literacy skills (di Sessa et al., 1991; Shah & Hoeffner, 2002). If making sense of a single graph is a difficult task, then having to glean information from a comparative synthesis of multiple graphs is even more challenging. This activity, which we refer to as graph meta-analysis, is a common feature in the work of scientists (and other professionals) when they analyze their own data or when they review data published by others. A similar challenge is faced by citizens who encounter graphs when they make decisions about science-related issues based on information that they garner from news reports, web searches or other similar sources.

We examined the ways in which 10th grade students (N= 35) and their teacher (in a pilot study) tried to contend with a graph synthesis task. The students compared drug effectiveness studies for four pharmacological smoking cessation treatments in order to recommend the best treatment for a particular case. This activity was part of a broader research project ("CoReflect") that aims to cultivate scientific literacy among European youth by having them produce evidence-based decisions, explanations and recommendations on socio-scientific dilemmas. The project uses web-based inquiry environments, one of which was developed by the authors and concerns nicotine addiction.

The specific inquiry task on which we focus required the students, who worked in pairs, to extract data from two graphs (one bar graph and one line graph) in order to rank the 4 treatments by their success rate, defined as abstinence from smoking. The graphs were modified from recent published articles. Each graph contained data from a different clinical study, in which only 2 or 3 treatments were compared, in addition to a placebo control group, but none of the graphs contained data concerning all 4 treatments. This is typical of clinical studies (and applied science in general), because very few studies compare all available treatments and the overall ranking of treatments requires a process of meta-analysis, involving measures of effect size. Another feature of the meta-analytic process represented in this task is the need to handle variability in the operationalization of the same variable, mainly, one study defined abstinence as refraining from smoking since the inception of the study, while the other defined it as refraining from smoking over the past seven days. We recorded the responses of the students to these graphs in the form of computerized worksheets ("templates"). In addition, we used audio recordings to document discussions between the teacher and student pairs, as well as whole-class discussions. These recordings were consulted in combination with retrospective reflections of the teacher in order to identify points of impasse and progress on the part of the students.

Preliminary findings

Not surprisingly, the students found the overall investigation very challenging and even frustrating. Their science studies to date did not prepare them to deal with the demands of complex graph interpretation and synthesis. Some students were completely helpless, and did not make any progress prior to teacher intervention. Others seemed oblivious to the fact that the two studies used different operational definitions for abstinence. Therefore, they simply used raw data (percentages) in order to rank the treatments. . The teacher tried to raise students' awareness of these issues through discussions with individual groups while they were working on their investigation, and through the asynchronous feedback notes that attach to the students' workspace. These mediations were not enough, so the teacher also held an impromptu whole class discussion that delved deeper into these issues. Obviously, the challenge for students became a challenge for the teacher, who played a central role in providing guidance (Tabak, 2004) that was not provided by the computerized environment. This challenge is amplified in settings where students work in small groups, each of which faces different obstacles in different time points.

Some of the specific challenges faced by students include:

1. *Merging data from different graph types*. Similar data (independent variables: time, treatment type; dependent variable: abstinence rate) were presented using a bar graph and a line graph, making the synthesis even more difficult.

2. *Focusing on specific features of data in the line graph*. In this task, abstinence rates were plotted as a function of time using multiple lines of different colors. One of the challenges was to differentially focus on the latest time points depicted, in order to discern long-term abstinence. The second challenge had to do with noting and understanding that two lines crossing each other means that one treatment is superior in the short run and the other in the long run.

3. *Understanding the implication of different operationalizations for the same variable*. Students needed to realize that "raw" success rates could not be used to merge the findings from the two studies, because one used a much stricter criterion to consider a participant as abstaining from cigarette smoking.

4. *Understanding the need to consider effect size*. The data in the graph showed that one treatment was the best in both studies and therefore should be ranked first of the four. However, identifying the 2nd, 3rd and 4th treatments required students to estimate the effect size of each treatment, using the data from the control groups.

Conclusions and implications

We realized that answering inquiry questions through a synthesis of existing disparate sources of information, especially scientific research reports, relies on a better understanding of the nature of experimentation, and on specific synthesis strategies as we described above. This informed some redesign decisions that include: (a) replacing the bar graph with a second line graph, thus ameliorating the cognitive load on students (see point 1 above); (b) adding prompting questions and hints in the text that accompanies the graphs and adding "synthesis templates" in the students' computerized workspace. These additions focus students on key issues and structure the synthesis process, and are aimed to reduce the load on the teacher as an agent of scaffolding. In fact, the added text was based on stimulating questions asked by the teacher (in class or using the feedback notes); (c) adding an introductory class on placebo effects and control groups in clinical trials. This class introduced the importance of the use of control group data in order estimate effect size. The efficacy of this redesign is to be tested in a second enactment, conducted in the same school. Our hope is that this work will yield key instructional strategies for supporting the critical, but neglected skill of graph meta-analysis.

References

Bertin, J. (1983). In Berg, W. (trans.), Semiology of Graphics: Diagrams, Networks, Maps, The University of Wisconsin Press, Madison, WI.

Bowen, G. M., & Roth, W. M. (2005). Data and graph interpretation practices among preservice science teachers. *Journal of Research in Science Teaching, 42*, 1063-1088.

Bowen, G. M., Roth, W. M., & McGinn, M. K. (1999). Interpretations of graphs by university biology students and practicing scientists: Toward a social practice view of scientific representation practices. *Journal of Research in Science Teaching, 36*(9), 1020-1043.

diSessa, A.A., Hammer, D., Sherin, B., & Kolpakowski, T. (1991). Inventing graphing: Meta representational expertise in children. *Journal of Mathmatical Behaviour, 10*, 117-60.

Leinhardt, G., Zaslavsky, O., & Stein, M. K. (1990). Functions, graphs, and graphing: Tasks, learning, and teaching. *Review of Educational Research, 60*(1), 1-64.

NRC. (1996). *National science education standards*. Washington, DC: National Research Council.

Shah, P., & Hoeffner, J. (2002). Review of graph comprehension research: Implications for instruction. Educational Psychology Review, 14, 47-69.

Tabak, I. (2004). Synergy: A Complement to Emerging Patterns of Distributed Scaffolding. *Journal of the Learning Sciences, 13*(3), 305-335.

The Design and Evaluation of Educative Just-In-Time Teacher Supports in a Web-Based Environment

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Abstract: Researchers have advocated for the development of educative curriculum materials to support teachers as they engage in reform-oriented teaching. In this poster we report on the design and evaluation of a set of just-in-time, educative, teacher supports for an online project-based unit. Our design of the supports was informed by frameworks for educative materials (e.g. Davis & Krajcik, 2005), and we analyzed their use with 17 middle and high school teachers in a pilot study.

Introduction

Engaging students in inquiry practices is challenging and effective instructional materials need to support teachers as they learn and implement reform-based teaching (Varma, Husic, & Linn, 2008). Such materials have been termed "educative' by Davis and Krajcik (2005). While there is a growing body of research on the development of educative materials, most of it refers to paper-based curricula and much less is known about the ways in which online inquiry-based environments can be educative for teachers (Davis, Smithey, & Petish, 2004; Varma et al., 2008). Moreover, educative materials tend to present teachers with a large amount of information. These materials can seem overwhelming to teachers who often request, and need, just-in-time support as they enact the unit or lesson. In this poster we describe our efforts to develop and pilot test a set of just-in-time teacher supports embedded into an online project-based learning environment called the COOL Classroom. Specifically, we designed the supports to aid teachers in their implementation of a unit on the impacts of the Hudson River water on the ocean waters of the Hudson Bay. We conducted a pilot study with middle and high school teachers to ascertain the ways in which teachers used the set of supports. In our poster we will discuss our design of the teachers support, findings from the pilot study, and our current attempts to revise the design in ways that address the challenges identified in the pilot study.

The Instructional Design

The two-week unit, entitled *Hudson River Plume,* focuses on the impact of non-point pollution from watersheds on the Hudson Bay ecosystem, and begins with the driving question "How does your watershed impact the ocean?" The unit included both on-line and off line activities. In this unit students explore Satellite Surface Temperature data sets to study the interaction between river and ocean water, they learn about non-point source pollution in watersheds, and they investigate the process of eutrophication through an online simulation.

The teacher supports, a set of text-box tabs, are superimposed on the student interface and can be toggled on or off (supports are only visible when the teacher is logged in). There are four support categories that we developed based on existing frameworks for educative materials. Ball and Cohen (1996) argued that educative materials can foster teacher learning, and they provided general suggestions to facilitate the development of these materials, for example the need to help teachers understand and deal with student ideas. Davis and Krajcik (2005) built on the ideas of Ball and Cohen (1996) and proposed nine heuristics for pedagogical content knowledge for educative science curricula. The nine heuristics are organized in three strands: pedagogical content knowledge for science topics, pedagogical content knowledge for scientific inquiry, and developing teachers' subject matter knowledge. In reference to these frameworks we developed four supports: *in-class notes, related activities, student difficulties, and resources*. *In-class notes* provided just-in-time information about running the lesson segment associated with the specific interface (or sequence of interfaces) such as: stopping for discussion, questions to ask students, etc. The *related activities* category provided information and links to additional offline activities relevant to the content on the current interface. Under *student difficulties*, we provided information about common student alternative conceptions and potential misunderstandings. The latter three categories provided pedagogical content knowledge for science topics in terms of teaching strategies, relevant student ideas and difficulties. The final category, *resources*, provided teachers with additional background information about the scientific phenomenon to extend their subject matter knowledge. Text in these tabs was kept as succinct as possible and tabs only appeared if there was relevant information for that specific interface. Our design goal was to provide support to teachers, that they could use in a just-in-time manner, as they engaged students with specific activities on the specific interface.

Methods

To study teachers' use of the supports we conducted a pilot study with 17 middle and high school teachers. We collected three sources of data from the pilot teachers: (a) teacher journals in the form of an online survey that we asked teachers to complete on a daily basis whenever the unit was implemented; (b) videotape recordings of a focus group session in which the teachers discussed their positive and negative experiences using the unit; and (c) small group exit interviews focused on teachers' experience with the implementation of a handful of specific activities and in particular the teacher supports for those activity pages.

We analyzed the data in terms of the following questions: (a) when did teachers use the supports? (b) which supports were useful for the teachers, and which were not as useful? and (c) in what ways did teachers' implementation of the unit vary from the instructions provided in the supports and what was their reasoning for these deviations? We began by looking at the teacher journals to ascertain trends in teachers' evaluation of the utility of the supports. We then analyzed the focus group sessions and small group interviews to determine when and how teachers were using the supports, as well as to characterize the reasons for low fidelity implementations.

Results and Discussion

Our findings suggest that teachers varied in how they used the supports, specifically there were variations in the just-in-time use of the supports, as well as the chunking or lesson segmentation. The latter variations were often due to underdeveloped or underspecified supports, and the use of supports in a just-in-time manner. Some of the variations in lesson segmentation, such as finding it difficult to have class discussions at times designated in the in-class notes, were due to teachers' misinterpreting the lesson segmentation information provided, or disagreeing with the segmentation as defined in the online environment. A solution to this issue is to make salient, via the web interfaces, where activity sets begin and end. We intend to revise the environment to introduce a third view that will provide a simultaneous view of a segment as a set of thumbnail images of the interfaces included in that segment. This will allow the teachers to view the sequence of segments, and what is included in each segment. We found that sometimes the variation in implementation were due to a lack of information in the supports. This was due to one of two reasons: (a) we as the designers did not anticipate and address problems relating to certain aspects of an activity or students' engagement with it; (b) we as designers provided instructions for implementation but did not explain the reasoning behind these instructions. The solution to the first problem is to more fully develop these supports given new information about the implementation of each activity obtained in the pilot study. The underspecified supports problem was often due to our attempt to keep the text of the teacher supports simple and brief. In our redesign we will supplement the text of the supports to include the missing rational as well as provide additional information about the design in the *teacher lounge* section of the environment. While we designed the supports for just-in time use (to reduce the cognitive load placed on teachers as they implement), we did not find evidence that teachers used them in such a manner. Most teachers read the supports prior to teaching the day's lesson. It may be that just-in-time supports are not conducive for first-time implementations. A solution to this issue is to enable teachers to print out the teacher supports (with thumbnail images of the student interface) as one document that can help them see the unit in its entirety as well as the specific supports for every student page. In addition we may include an automated prompt to remind teachers to log in so that they can view the supports as they are teaching.

References

Ball, D.L., & Cohen, D.K. (1996). Reform by the book: What is or might be the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher, 25*(9), 6 -8, 14.

Bransford, J. D., & Schwartz, D. L. (1999). Rethinking transfer: A simple proposal with multiple implications. *Review of Research in Education, 24*(1), 61-100.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3-14.

Davis, E. A., Smithey, J., & Petish, D. (2004). Designing an online learning environment for new elementary science teachers: Supports for learning to teach. *Proceedings of the 6th International Conference on Learning Sciences,* 594-594.

Varma, K., Husic, F., & Linn, M. C. (2008). Targeted support for using technology-enhanced science inquiry modules. *Journal of Science Education and Technology, 17*(4), 341-356.

Students' Investigations with Physical Activity Data Devices

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Abstract: Through a design experiment, we explored the potential for a suite of commercial physical activity monitoring devices to be used as data collection tools. Two pairs of high-school students were asked to engage in a week-long set of data investigations of physical activity that culminated in the design and implementation of their own mini-studies. This poster reports on those mini-studies, the challenges associated with the technologies used, and the supports that needed to be introduced.

Introduction

There has been a great deal of interest in the Learning Sciences around the potentials for portable technologies to support engagement in authentic disciplinary practices (e.g., Aleahmad & Slotta, 2002). These potentials arise because such technologies allow students to model phenomena, record observations, test hypotheses, and gather data. The latter potential is of particular interest for the current work. We are exploring the use of a portable athletic technology as a data collection device that can be used to support student engagement with data modeling practices (Lehrer & Romberg, 1996). Specifically, we are exploring the use of portable heart rate monitors and accelerometers students can use to collect data about their physical activities. We began this work under the assumptions that (1) personal relevance can make data about one's self intrinsically interesting for students and (2) prior knowledge about one's body and activities can bootstrap understandings students must develop in order to analyze and make sense of personalized data.

Operating under those assumptions, we conducted a first-iteration design experiment (Brown, 1992) in which a week-long, out-of-school learning experience was designed and implemented. Over the course of five two-hour sessions, two pairs of high school students (ages 14-16) conducted four inquiries into bodily activity, two of which were researcher-designed and two were student-designed. We had multiple goals in conducting this design experiment. First, we wanted simply to determine the feasibility of repurposing commercial athletic devices as data collection instruments for students. Second, we wished to ascertain what supports might be necessary in order to engage students in data analysis practices when working with physical activity data. Third, we hoped to make some initial determinations regarding the quality of investigations students would design, with guidance, after having been introduced to these technologies.

Technological Devices and Software

For this design experiment, we obtained a Garmin ForeRunner 50 device set for each student. The ForeRunner 50 is a multi-instrument set consisting of a sport watch that wirelessly communicates with a heart rate monitor chest-strap and a "Footpod®" accelerometer secured to one's shoe. The chest strap, worn underneath one's shirt, calculates heart rate in beats per minute based on the natural electrical activity of the circulatory system. The Footpod® approximates speed and distance measurements based on specific changes in acceleration due to foot impact. Every five seconds, a reading from both devices is automatically stored on the watch's memory, producing a hundred data points within five minutes. These records can be immediately uploaded onto a Mac or PC via an included wireless USB antenna. Once uploaded, the data are stored in specialized, easily accessed .xml files. We developed a script to extract the data from these files and append them with additional metadata such as who wore the device and what activity was being monitored.

As a data exploration and modeling tool, we chose the TinkerPlots software (version 1.1) (Konold & Miller, 2005) as it allowed for rapid importation of our enhanced data files. Although recommended for grades 4-8, our initial exploration of the software and review of other interventions that used TinkerPlots led us to conclude it was powerful enough for our sample of students to use for their data analysis purposes.

The Learning Experience

As stated above, the students participated for five two-hour sessions facilitated by a single researcher during the students' summer break. On the first day, the four students were introduced to the devices, shown how to collect data, and given a tour of the athletic facilities they would be provided access to throughout the intervention. On day two, they explored the TinkerPlots software, collected heart rate data of themselves as they were sitting at their computers, and under the researcher's guidance, devised and executed a plan to collect data enabling them to compare heart rates and distances when playing the basketball game "H.O.R.S.E". against repeatedly tossing a flying disc (e.g., a Frisbee®). On day three, the students explored the previous day's data and worked in pairs to design a physical activity investigation of their own choosing. The student-designed investigations compared distances and heart rates in different running environments (tracks and treadmills) and compared heart rates when using two cardiovascular machines that involve fluid, cyclical motions (elliptical trainers and stationary bicycles). Data for these two student-designed investigations were collected by all participants on the fourth day, and then examined and analyzed by both pairs of students on the fifth and final day. Details of each investigation, such as the students' data collection plans and their results, will be presented on the poster.

Data Sources and Analysis

Video recordings of each pair's work with TinkerPlots on the computer and all group discussions of investigation planning were collected on days 1, 2, 3 and 5. Students completed short worksheets each day that served to help the researcher assess prior knowledge related to representing data, estimating heart rates, and students' perceptions of what constituted scientific and mathematical activity. Several of these worksheets were repeated at the end of day 5 in order to gauge any change in opinions, perceptions, or intuitions about mathematical and scientific practices and their bodies' reactions to physical activity. Finally, all ForeRunner-obtained data files and student-modified TinkerPlots files were collected.

Selected video clips of student pairs were transcribed and analyzed qualitatively. Codes were assigned based on the mathematical content being discussed (e.g., averages, distributions, rates of change), the students' understandings of what the data showed, and explicit references to personal knowledge of their bodies or the data collection experience (e.g., "that can't be right! I know I didn't work that hard then.") Design notes, video of group discussions, post-mortem review of the design process, and ad-hoc instructional modifications from the week were reviewed in order to generate design recommendations for future iterations.

Results

With respect to feasibility, our conclusion from the first design iteration is that these devices could be repurposed and used relatively easily by students for data collection. Students were generally successful in operating the devices, and at the end of the week, all reported the equipment was easy to wear and use "once you got the hang of it". All students reported that they often forgot they were wearing the equipment. During a closing discussion about the experience, all students expressed that the technologies provided interesting feedback about their bodily efforts and expressed interest in using them in their math or PE classes.

However, problems emerged in the preparation of the data. The students did not have the technical know-how to convert the data to the appropriate formats. Despite development of scripting tools, an effort on Day 1 to provide instruction on how to upload and convert data was unsuccessful. As a result, the lead researcher provided support by manually uploading, converting, and preparing the data in TinkerPlots between sessions. A refined software tool is currently in development to simplify data preparation and transfer.

Additional support was required to encourage student data analysis. On the first days of examining data in TinkerPlots, the students were quick to decide on an answer to an overarching question with only a cursory glance at the data displays. In response, the researcher added a set of open-ended data-related questions for students to answer on subsequent days. The written responses to these were generally poor, in that they were often sentence fragments and often did not answer the given question. However, the quality of discussions that took place with respect to the questions showed a great deal of sophistication and engagement with mathematical and statistical ideas, such as how to compare two populations or measures of center. Those observations were encouraging and validate some of our core assumptions about the utility of these devices.

During days 3-5, the students successfully devised and enacted data collection plans. However, despite having designed their own investigations, the level of engagement in the data analysis appeared much lower than in the researcher-planned investigations. This result was surprising, and we believe could be attributed in part to the predictability of the outcomes of the student-designed investigations; all students had easily predicted the outcome of their designed investigations. This suggests more actively steering student-designed investigations toward questions that produce ambiguous results may be more fruitful. We are hopeful that observation and other lessons learned through this first-iteration design experiment will support our planned classroom enactments to take place later this year.

References

Aleahmad, T., & Slotta, J. (2002, June, 2002). *Integrating handheld technology and web-based science activities: New educational opportunities.* Paper presented at the 14th World Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA 2002), Denver, CO.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the learning sciences, 2*(2), 141-178.

Konold, C., & Miller, C. (2005). *TinkerPlots. Dynamic Data Exploration. Statistics software for middle school curricula.* Emeryville, CA: Key Curriculum Press.

Lehrer, R., & Romberg, T. A. (1996). Exploring children's data modeling. *Cognition & Instruction, 14*(1), 69-108.

A dual-level approach for investigating design in online affinity spaces

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Abstract: In order to address "design talk" within online gaming fan spaces, content analyses were used first to classify the predominant forms of design talk, then to provide a principled segmentation of forum data to come under further Discourse analysis. Serial implementation of these two approaches affords researchers of informal learning the ability to (1) identify productive exchanges within gaming affinity spaces to come under further d/Discursive analysis and (2) combine analyses of learning using both *nomothetic* (content analysis) and *idiographic* (Discourse analysis) approaches.

Learning in Gaming Affinity Spaces

Recently, learning scientists have focused on the educational implications of productive, "in the wild" (Hutchins, 1995) communities that have arisen to discuss games online (e.g., Steinkuehler & Duncan, 2008) and, within which, participants can develop sophisticated peer instructional materials (e.g., Squire & Giovanetto, 2008), tools for others to interact with games, and environments in which participants can negotiate the meaning of their gaming experiences. In this light, both the designed and ad hoc communities of practice (Lave & Wenger, 1991) that have come to exist "around" games are increasingly relevant for researchers interested in moving beyond appropriating games for traditional learning models toward understanding the dynamics of learning with popular media.

A renewed focus on social affiliations, collaborative problem-solving, the development of projective identities (Gee, 2003), and concomitant other skills and dispositions associated with gaming has become an important new emphasis for games and learning research, leading to a shift in focus from the individual gamer to communities of learners that critique, modify, and further explore game play. Toward this end, I investigate Gee's (2004) concept of "affinity spaces," or fan sites, often instantiated online, with shifting memberships in which participants can develop and express an affinity for a like-minded group around a particular media artifact. Although it has been a productive concept for understanding engagement with digital media (see Black, 2008; Duncan, in press; Gee and Hayes, in press), important methodological questions abound, including how best to analyze textual interactions within affinity spaces, as well as how to relate different forms of analysis with one another.

In this poster, I argue for the use of both content analysis (Mayring, 2000) and Discourse analysis (Gee, 2006) as productive means to make sense of the learning practices present within these affinity spaces. Using examples from analyses of online discussion forum text in the affinity spaces around three different games, game series, or gaming distribution platforms (*World of Warcraft*, *The Legend of Zelda*, and *Kongregate*, respectively), I forward an explicitly *dual-level implementation* of these methodologies.

Content Analysis

By "content analysis," I refer to the principled means of applying a qualitative coding scheme to the text present within the online discussion forums that make up much of the asynchronous, distributed discussions present within gaming affinity spaces. Mayring's (2000) content analysis model has similarities to other approaches for assessing verbal data (e.g., Chi, 1997), and has seen parallels with attempts to understand other phenomena, such as informal scientific reasoning within online gaming forums (Steinkuehler & Duncan, 2008). By applying a fundamentally *nomothetic* — or attempting to discern a general "state of the world" — approach to online discussion forum text, we can highlight the prevalence of the learning practices being studied within a potentially representative sample, and make generalizations regarding the typicality of the learning practices within the case(s) being analyzed.

I have developed a coding scheme to capture elements of *design thinking* (the iterative collaborative and competitive construction of artifacts) within the online discussion forums around three gaming affinity spaces. Basing the coding scheme largely upon Donald Schön's (1983; 1988) theories of design, this coding scheme was developed to assess discursive practices, design practices, and content of each case's forum text. Applying the coding scheme to representative samples of each case (*World of Warcraft* n = 242 posts; *Zelda* n = 125 posts; *Kongregate* n = 130 posts) the applicability of Schön's scheme was found to be only partial, with some codes highly applied while others found to be a poor fit to the particulars of a case. And yet, these were only the first step in the analysis: Addressing the prevalence of the design codes was useful for determining their general applicability and the overall commonality of some design practices, but did little to help "unpack" the finer details of specific meaning-making exchanges within the forums.

Discourse Analysis

Across a wide range of domains, Gee's (2006) "big-D Discourse theory" has put an emphasis upon understanding language acts as situated within cultural and social frameworks. As a methodology, it has provided a great deal of utility for the investigation of meaning-making, learning, and the social construction of knowledge (see, for example, Steinkuehler's, 2006, analysis of in-game Discourses). In terms of online gaming affinity spaces, the methodology's key utility is in helping to make sense of specific interchanges between participants in an online affinity space, and identifying the ways that particular turns of phrase represent larger social and cultural concerns.

Thus, following the content analysis methodology presented above, I have conducted Discourse analyses on specific exchanges within each of these three affinity spaces (*World of Warcraft, The Legend of Zelda, and Kongregate*). Shifting focus from analyzing design practices within each space to isolating how a subset of debates within the forums formed and evolved, I argue that Discourse analysis provides an important *idiographic* — or characterization of unique and situated meaning-making — approach to understanding learning within these spaces. In the three affinity space cases, these led to the uncovering of common framing narratives regarding the design practices within each space (design as a "science," design as a "technical literacy" and design as "fan activity"). For, as Discourse analysis ideally helps to situate specific exchanges in social and cultural frameworks, the results of the analyses can be revealing regarding important phenomena (e.g., framing narratives) that could not be easily uncovered via a content analysis based on an *a priori* coding scheme (a la the one based upon Schön's 1983; 1988 work).

A Dual-Level Interpretation of Text

The staged, dual-level approach described here is beneficial for two key reasons. First, content analysis addresses the overall coding saturation of a particular interpretive scheme, but does so necessarily divorced from individuals' unique trajectories of meaning-making; by incorporating Discourse analysis, we are thus able to address the "gaps" in one method by the judicious use of another method on a subset of the same data. Second, Discourse analysis is necessarily fraught with issues of sampling, and the results of a previous content analysis can help to provide justification for *why* certain excerpts of data are chosen for subsequent Discourse analysis. By using the results of a content analysis to justify which segmentation of the data is most promising to further investigate using Discourse analysis, assessments of the text within online affinity spaces become multi-faceted. In understanding learning within these spaces, researchers need to both be able to address the overall prevalence of a given learning practice, while also developing a stronger basis for data selection when using qualitative methodologies such as Discourse analysis.

References

Black, R. (2008). *Adolescents and online fan fiction.* New York: Peter Lang.

Chi, M. (1997) Quantifying qualitative analyses of verbal data: A practical guide. *Journal of the Learning Sciences*, 6, 271-315.

Duncan, S. C. (in press). Gamers as designers: A framework for investigating design in gaming affinity spaces. Manuscript for *E-Learning and Digital Media*, upcoming special issue on game design literacy.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy.* New York: Palgrave Macmillan.

Gee, J. P. (2004). *Situated language and learning: A critique of traditional schooling.* London: Routledge.

Gee, J. P. (2006). *An introduction to Discourse analysis: Theory and method, 2nd. ed.* New York: Routledge.

Gee, J. P. and Hayes, E. R. (in press). *Women and gaming: The Sims and 21st century learning.* New York: Palgrave Macmillan.

Hutchins, E. (1995). *Cognition in the wild.* Cambridge, MA: MIT Press.

Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Mayring, P. (2000). Qualitative content analysis. *Forum: Qualitative Social Research, 1* (2). Retrieved from http://www.qualitativeresearch.net/index.php/fqs/article/view/1089/2385

Schön, D. A. (1983). *The reflective practitioner.* New York: Basic Books.

Schön, D. A. (1988). Designing: Rules, types, and worlds. *Design Studies*, 9(3), 181-190.

Squire, K. and Giovanetto, L. (2008). The higher education of gaming, *E-Learning*, 5(1), 2-28.

Steinkuehler, C. A. (2006). Massively multiplayer online videogaming as participation in a Discourse. *Mind, Culture, & Activity*, 13(1), 38-52.

Steinkuehler, C. A. & Duncan, S. C. (2008). Scientific habits of mind in virtual worlds. *Journal of Science Education and Technology 17* (6), pp. 530-543.

Designing for an Informal Learning Environment: Towards a Participatory Simulation Design Process for Public Policy Planning

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Abstract: Modern planning practices recruit stakeholders to add specialized expertise to the planning process, but this expertise often remains inert, leading to superficial and circular discussions. By encouraging stakeholders co-construct an external shared representation, more nuanced debates could emerge. This work reports on formative interviews that will inform the design of software that will allow stakeholders to articulate and share their knowledge, and to inspect the underlying assumptions of others and the outcomes of the system.

Introduction

Watershed planning brings together diverse representatives (e.g. local govts., advocacy groups, business, industry, and academia) to contribute *specialized* knowledge to water use policy, but devising effective recommendations requires a *comprehensive* understanding of outcomes emerging from interactions between natural processes and human actions (Zellner, 2008). This work's ultimate aim is to design a computer-based tool to encourage stakeholders to share knowledge, learn from one another, and develop a systemic perspective.

Study & Findings

We observed one public session to understand meeting dynamics, and conducted telephone interviews with four stakeholders representing business, municipality, county government, and academia/public interest to assess their perceptions regarding modeling tools. Our preliminary findings focus on the *means*, *content*, and *context* of presenting models to stakeholders.

Means – Tools & processes to support stakeholder participation

Unlike Decision Support Systems (DSS) which are designed for a specific case and thus have limited reusability and require extensive data and resources to build (Densham, 1991), we are interested in repurposable software that can leverage the knowledge of attending stakeholders. Existing attempts at creating stakeholder-accessible models (e.g., MetroQuest, http://www.metroquest.com) tend to mask the system complexity by only eliciting pre-defined inputs and presenting pre-defined outputs. Our interviews found that this restriction on decision makers' ability to modify the model caused some of the stakeholders to view them as an unreliable "black box" as evidenced by this remark: "I feel it [software] was biased… I looked at the results and said it's not worth something to look at. This was a conclusion that somebody had and they wrote a survey and study to come to that conclusion*."* Another stakeholder, whose ideology was more aligned with the outcome of the software, indicated complete confidence in the outcome. Both respondents seemed to be suffering from a confirmation bias (Lord, Ross, & Lepper, 1979). These black-box models thus do not allow for the skeptics to explore how the outcomes emerge and do not encourage the believers to question their assumptions.

One strategy to address the black box problem is to migrate to more transparent Agent Based Models (ABMs), which *allow stakeholders to inspect the system's rules* and potentially even *use their expertise to modify or create rules for agents.* Our goal is to maximize participation so that every stakeholder's ideas and viewpoints get reflected. We found that stakeholders are more likely to bring mobile devices than laptops, which suggests *an "audience response system"-style form factor,* seen in participatory simulations augmented with a shared display (Wilensky & Stroup, 2000). This has the added benefit of grounding the conversation in a shared artifact, allowing the stakeholders to learn from their peers and to build a more nuanced mental model of the policies and their effects. Some findings (e.g., Brignull & Rogers, 2003) suggest that anonymity improves participation in such contexts but we found that stakeholders strongly felt that ideas and actions needed to be attributed to the creators. Thus *a mechanism is needed for clearly identifying the originator of any changes to model settings*, as evidenced by this quote: "No I don't think [anonymous contributions are] a good idea. There are many groups represented by the planning group members and they bring up many viewpoints and it's important that those viewpoints be acknowledged as belonging to that particular group."

Content – What is to be simulated?

Some classroom-based implementations of ABMs required students to build entire systems so that they have an understanding of all the agents in the system (Wilensky & Reisman, 2006). However, it is impractical at best to ask each of the more than 35 stakeholders to build a model of an entire system when they often lack an understanding of or an interest in issues outside of those which affect them directly, as indicated by the following quote: "I never speak up during the meeting… [the local government] viewpoint is well represented and I don't think there are major issues for us as there are for the environment and business." The interviewee seems to believe that policies that concern business and environmental interest groups will not impact the local government. There is obviously a need for the gestalt understanding that one could get by virtue of building everything, but an alternate strategy may be to present the model content so as to *emphasize the inter-connectedness between model elements*, so that even when stakeholders do not fully understand the position of another interest group, they are at least aware of how their interests intersect.

Sometimes, though, disconnects result from the difficulty in understanding how actions compound over time: "[We] have maintained wetlands, even created wetlands [and] open space, have … water facilities that meet & exceed the EPA standards… [The cities don't] and yet we keep hearing [from them and environmentalists] that [we] need to have growth control, slow down or stop to avoid urban sprawl." The interviewee is justly upset over a perceived "do as I say, not as I do" argument originating from city officials, but neglects that over time, their community may begin to resemble the city. *Making the trajectory of the decision path evident* (i.e. when a decision was formalized, identifying what model elements informed the decision, identifying what elements are affected by that decision, and characterizing the effect on those dependent elements, etc.) might help in identifying and planning for "unintended" consequences of decisions.

Context – Where, how long, and how often.

Interviews revealed the stakeholders were willing to use a computer-based tool for the entire duration of the meeting if it did not distract them from interacting. For example: "If the software is a facilitation tool, it can be used to run the meeting," or, "[It] should not distract from meeting – interaction should be live and not dependent on software." However, most existing classroom-based ABM projects require extended interaction with the model over several weeks (e.g., Klopfer, Yoon, & Um, 2005). This kind of interaction is not feasible in our context, where stakeholders meet once every month for 3 hours. Consequently, we have to *consider facilitating participation and interactions between the stakeholders outside the meeting space*. We found that the stakeholders had internet access at home and were willing to use the model outside the meeting setting for about 10-20 hours every month. In order to support extended interaction, the ABM tool should provide multiple access points for the stakeholders so that they can access the model from any location. Also, while allowing multiple accesses, we have to ensure that all the content generated for the model is credited to their creators.

Conclusion

The design guidelines that emerged from these preliminary findings were italicized above, and are summarized here. With relation to the *means* of presenting models, we found that model-based tools for diverse adult users in an informal learning environment should allow for inspection (and alteration/creation) of the underlying model rules, suggesting the use of ABMs. With respect to the *content* of the models, we found that contributions to the models must be clearly credited, and the model should emphasize element interconnectedness and decision trajectories to help stakeholders adopt a more comprehensive perspective. With respect to the *context* of use, we found that stakeholders will need multiple points of access, even outside meetings. Future work will be focused on implementing and refining these recommendations.

References

Brignull, H., & Rogers, Y. (2003). Enticing people to interact with large public displays in public spaces. In *Proceedings of*, (p. 17). Ios Pr Inc.

Densham, P. (1991). Spatial decision support systems. *Geographical information systems: Principles and applications, 1*, 403-412.

Klopfer, E., Yoon, S., & Um, T. (2005). Young Adventurers- Modeling of Complex Dynamic Systems with Elementary & Middle School Students. *Journal of Computers in Math and Science Teaching, 24*(2), 157-178.

Lord, C., Ross, L., & Lepper, M. (1979). Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. *Journal of Personality and Social Psychology, 37*(11), 2098-2109.

Wilensky, U., & Reisman, K. (2006). Thinking Like a Wolf, a Sheep, or a Firefly: Learning Biology Through Constructing and Testing Computational Theoriesâ€"An Embodied Modeling Approach. *Cognition and Instruction, 24*(2), 171 - 209.

Wilensky, U., & Stroup, W. M. (2000). Networked Gridlock: Students Enacting Complex Dynamic Phenomena with the HubNet Architecture. In *Proceedings of Fourth International Conference of the Learning Sciences*, Ann Arbor, MI, USA, (pp. 282-289). Mahwah, NJ: Erlbaum.

Zellner, M. (2008). Embracing Complexity and Uncertainty: The Potential of Agent-Based Modeling for Environmental Planning and Policy. *Planning Theory and Practice, 9*(4), 437-457.

Online Science Classroom Collaborations: A Comparison of Domestic and International Learning Communities

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Abstract: Students' views of their online collaboration and samples of scientific writing were studied within a principal contrast of U.S. students in domestic or international class partnerships. Results show that U.S. students in international partnerships maintained a higher level of excitement about their partnership and wrote a larger number of accurate scientific claims using more evidence and certain discourse components. Findings from this study have implications for further research and classroom practice.

Introduction

Current science learning communities are often constrained within the physical walls of a classroom. In contrast, scientific communities expand beyond the physical confines of a laboratory or meeting room. Scientists often engage in ongoing discourse with colleagues from all over the world. They participate in and contribute to peer-reviewed journals, newsletters, list-serves, conferences, and web seminars. The science education community can make use of online communication tools, as scientists have, to help students and teachers venture out of their classroom and become involved in global learning communities (GLCs). Research and thinking in this area of learning communities has focused on the contexts of group work, single classrooms, or limited online interactions (e.g. Lave & Wenger, 1991; Kelly & Green, 1998). However, global science education is emerging as a new area of research that has the possibility to significantly impact student discourse and the structure of science education.

Context

This research is set in the context of the From Local to Extreme Environments (FLEXE) instructional unit on energy concepts. FLEXE is an Earth Systems Science Project funded by the U.S. National Science Foundation and developed in partnership with Global Learning through Observation to Benefit the Environment, a worldwide web-based science and environmental education program. In FLEXE, students and teachers from United States, Thailand, Australia, and Germany along with deep-sea scientists engaged in online discussions about scientific data. FLEXE (both classroom based and on-line) activities promote student discourse in comparisons of local and extreme environments.

Approximately 1400 students and 50 teachers were involved in the FLEXE program during the spring of 2009. Most students were in grades seven through nine in Earth Science, General Science, or a related course. Students worked locally in pairs to complete classroom activities and submit online responses. Students then communicated by way of asynchronous online communication in class profiles, peer reviews bioassay experiments, student-scientist forums, and a wrap-up deep-sea research cruise. Local environmental data provided by students were used in these and other online and in-class activities. A principal contrast of domestic U.S. and U.S. to international class partnerships was established to study online learning communities. For a thorough description of the design decisions considered during the construction of FLEXE online collaboration tools see Kerlin, Goehring, Carlsen, Larsen, & Fisher (2009).

Methodological Approaches

A mixed methods approach was used to study the GLC established in the FLEXE program. Embedded surveys called quick questions (QQs) were employed to gather students' reactions to their class partnerships. Qualitative argumentation analysis of students' written scientific arguments characterized how students used evidence from different sources to back their scientific claims. One QQ from each of two sets of questions was randomly given to students upon completion of each online activity. The first, a multiple-choice question, was from a set about science content and processes. The second question, a Likert scale question, was selected from a set of students' views of the nature of science, attitudes toward science, and views of their class partnership. At this point, the six Likert scale questions that characterized students' views of their class partnership have been analyzed and are available for discussion. The Likert scale responses from samples of students are treated as interval data. The treatment of the responses as such allows for the comparison of the responses using T-tests and univariate two-way ANOVAs to determine differences between the two partnerships.

Qualitative analysis of student writing samples was conducted to characterize U.S. students' scientific writing. A framework for analysis of students' arguments with different data sources was applied to a stratified random sample of two student arguments associated with each U.S. teacher from four activities within the unit.

A few additional randomly selected student arguments were added to the samples to equalize the number of samples from each partnership. The framework was iteratively refined throughout initial analysis but has its foundations in an earlier studies by Kerlin, McDonald, & Kelly (2009), Jimenez-Aleixandre, Rodriguez, & Duschl (2000), and Kelly, Regev, & Prothero (2005). This study also expands on earlier work by Kerlin et al. (2009) and Hug and McNeil (2008) to gain understanding of how students use various primary and secondary scientific data sources to justify scientific claims.

Findings

The trends from initial analysis of students' views of partnerships and student scientific writing all support the hypothesis that international partnerships lead to favorable educational outcomes The embedded QQ results for questions about student excitement of their partnership show that U.S. students in international class partnerships maintained a higher level of excitement, throughout the instructional unit, to learn about the environment of their partner school and the lives of students in that environment than U.S. students in domestic class partnerships.

Argumentative discourse analysis of samples of student writing from four different activities showed favorable trends for participation of U.S. students in international partnerships. U.S. students in international partnerships wrote a higher number and greater percentage of correct scientific claims than U.S. students in domestic U.S. partnerships in three out of four of the activities analyzed. Students in international partnerships used larger count, mean, and median bits of evidence to support their scientific claims. We also found that students in international partnerships had fewer incorrect or invalid bits of evidence. In addition, U.S. students in international class partnerships had greater use of contrast, experience, and causality evidentiary discourse components.

Conclusions

The results from this study provide insight into student use of a complex set of data sources and views about online class partnerships. Variation in environmental data provided by students in different online partnerships and unfamiliarity of perceived audiences may account for the results described above. For example, U.S. students in international class partnerships examined environmental data from their partners that had a greater chance of being dissimilar to their local environmental data than their counterparts in domestic partnerships. Students innately considered and used the disparate scientific data more carefully and more thoroughly because the data itself prompted them to think from different perspectives and reconsider scientific reasoning from a global stance. The second factor that may account for the results is a function of the perceived audience. Throughout the activities students wrote responses to their teacher, scientists, and/or other students. Students with international partners seemed to place more stock in the use of data to justify their written arguments.

The methodologies employed have implications for use in other research projects and instructional practice. The embedded QQ survey method may be particularly useful in other large-scale projects with on-line components. The use of the argumentation analytic is useful in other studies of how students use data to support their scientific arguments. The instructional implication from this study is that students should be provided with opportunities to communicate with peers and use data sources from outside their classroom. The findings show that science classrooms should begin to incorporate online communication tools and engage in GLCs.

References

Hug, B., McNeill, K. L. (2008). Use of first-hand and second-hand data in science: Does data type influence classroom conversations? *International Journal of Science Education, 30*(13), 1725-1751.

Jimenez-Aleixandre, M.P., Rodriguez, A. B., & Duschl, R. A. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education, 84*, 757-792.

Kelly, G. J., & Green, J. (1998). The social nature of knowing: Toward a sociocultural perspective on conceptual change and knowledge construction. In B. Guzzetti & C. Hynd (Eds.), *Perspectives on conceptual change: Multiple ways to understand knowing and learning in a complex world* (pp. 145-181). Mahwah, N.J.: Lawrence Erlbaum Associates.

Kelly, G. J., Regev, J., & Prothero, W. A. J. (2005, April 4-7). *Assessing lines of evidence with argumentation analysis.* Paper presented at the annual meeting of the *National Association for Research in Science Teaching*, Dallas, TX.

Kerlin, S., Goehring, E., Carlsen, W., Larsen, J., Fisher, C. (2009). Design of an online global learning community: International collaboration of grades 7-9 science students. *CSCL 2009 Proceedings Vol. 2.*

Kerlin, S., McDonald, S., Kelly, G. (2009). Complexity of secondary scientific data sources and students' argumentative discourse. *International Journal of Science Education, iFirst Article, 1-19.*

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Mathematics at Play

Abstract: Based on interviews with 21 families, we found that school-aged children and their families engage in rich forms of mathematical reasoning as they engage in play and leisure activities at home. We present examples of the wide variety of activities and kinds of math reported, as well as an in-depth look at a few cases. From our results, we draw design implications for linking formal and informal mathematics learning.

Introduction

Although addressed by important visionaries in education (Vygotsky, 1967; Piaget, 1932), play and leisure are largely perceived to be orthogonal to children's learning, especially once children reach school age (Okan, 2003). Research suggests that play activities may be valuable for learning (Rieber, 1996), particularly in the domain of mathematics (Guberman & Saxe, 2000; Siegler & Ramani, 2008). However, relatively little research relates play and mathematics learning in the context of the home setting. The aims of this project are three-fold: First, we seek to investigate how families encounter and engage in mathematical practices during play and leisure activities. Second, we aim to provide a broad, cross-family account of the kinds of math involved in these activities, as well as an in-depth analysis within case families. Third, we hope to develop design implications from our results that bridge the informal mathematics learning we see in families with the formal mathematics in schools.

Method

21 families, who represented the racial and economic diversity of the San Francisco Bay Area, participated in semi-structured interviews as part of a larger study (Goldman et. al, 2006; Pea et. al, forthcoming). The interviews occurred in the home, lasted approximately two hours each, and centered on contexts in family life previously shown to be fertile for mathematical problem solving. The current analysis draws on this data set to specifically consider the many instances in the interviews where play and leisure organically came into conversation as families discussed mathematics. To conduct the analysis, we revisited our previously cataloged database to look at all the instances in which families discussed a problem they believed to have involved math, looking for instances that involved play and leisure as defined by Rieber (1996).

We coded each instance, noting the family, the members of that family participating in the activity, an overall summary of the activity, and the kinds of math that were involved. The play/leisure activities were broken into three categories: hobbies and projects, games, and informal sports related activities (i.e., activities related to sports but that were not being officially organized by a coach at the time). See Table 1 for a small sample of the full table of play/leisure activities reported that involved mathematics.

Table 1: A short excerpt of our Play and Leisure Analysis; includes hobbies and projects as well as games

Family Name	Who was involved?	What was the event?	Kinds of Math
Echevarria	Daughter	Inventing make-believe businesses	Arithmetic, Comparing Magnitudes, Decimals, Optimization, Proportional Reasoning
Pulepule	Mom, Daughters, Relatives, and Friends	Making Tongan mats	Arithmetic, Estimation, Measurement, Proportional Reasoning
Walters	Daughter, Son, Grandfather, and Grandmother	Playing bridge	Arithmetic, Logic, Probability
Muntz	Daughter	Playing *Neopets* game online	Arithmetic, Comparing magnitudes, Data analysis, Interest Rates

Case Studies

In addition to the cross-family analysis, we examined several cases in more depth. Given the space limitations of this paper, we highlight two of our examples.

Playing Neopets

The Muntz family includes the father, Donald, the mother, Nancy, and a 6th grade daughter, Erin. Like another middle school girl in our sample, Erin's plays *Neopets*, an online game where players care for computer pets. In this environment, players can buy things with *Neopoints*, which they earn by playing games. Erin buys things at the *Neopoints* store, and then later sells them for a profit at an auction. The balance of *Neopoints* is kept in an online bank account, which earns interest. To earn *Neopoints*, Erin sends in the scores she received playing a game. She is only allowed to send in three scores per day, so if she gets a score of 100, she has to decide if later she is more likely get a higher or lower score, and whether to send it in. Erin says she thinks about her average score in making the decision. From this small excerpt from the data, we can start to link how Erin is using standard financial practices such as maximizing interest and profit to achieve her goals in the game.

Imaginary Businesses

In a second example, the entire family is involved in a play activity, supporting the middle school-aged daughter's mathematical activity. The Echevarria family is from Columbia. The mother has lived in the US for 14 years, the father for 19 years. Their two children—the younger 6th grade daughter Sabrina and the older 9th grade daughter Rebecca—were born in the USA. The dad noted how "Sabrina loves to set up businesses, here, at home," as she "goes off by herself" to create make-believe businesses. Sabrina described a recent example, a laundry business: "I have to set up everything, like a stand, and figure out what materials I will need, and make things on paper for it to work out. I have to figure out how much I have to have in my cash register, and to spend on things, for the business to work." When asked how she kept track of all of this, she replied: "I have different prices for different things to be washed - pants $3 and shirts like $2.99. And then from these prices I kind of figure out how much I'd need for washing machine costs. And how many people's things coming in I would need to make my business work." The family reviewed the list of businesses she had developed in this way: magic shows, laundry, bank, restaurant, grocery store, play house. Her father said: "She goes off all by herself until she invites us to the show or to buy things – she plays the lady who sells the tickets at the entrance and also plays the star of the show." These businesses have large socio-dramatic components: she dresses up, prices items, and requires her family to come and buy things.

Design implications

In this analysis we look specifically at play and leisure activities to understand how math is understood in the context of informal and fun activities. Family members discussed hobbies, projects, games, and sports. We found that these events involve various family members and a range of math, including 2D and 3D geometric reasoning, estimation, arithmetic, probability, and proportional reasoning. The diversity of math-related problem solving in these activities, their repetitive nature, and the co-participation of family members make them ripe contexts for math learning, especially since these play and leisure activities are a matter of pleasure for the family members. Activities such as these are mathematically engaging, and in some cases, have links to other STEM fields such as engineering, science and technology.

The analysis of play and leisure is helpful as we move into creating designs for tools that encourage mathematical identification, problem solving, and support. It is also instrumental for building our design and cross-setting research work in and between homes and schools. We see more profound opportunities to craft boundary-crossing supports for mathematizing experience and supporting mathematical alignment across home and school settings. Our upcoming work builds off of these results, providing tools for family members to identify and treat daily activities in math-rich ways, raising awareness of math in family life and encouraging family conversations and problem solving with mathematics. For schools, we will design resources for upper elementary and middle-school that help teachers recognize and utilize families as resources for mathematics learning and thinking.

References

Goldman, S., Martin, L., Pea, R., Booker, A., & Blair, K. P. (2006). Problem Emergence, Problem Solving, and Mathematics in Family Life. *Proceedings of the 7th International Conference of the Learning Sciences,* Bloomington, Indiana. 1088-1093.

Guberman, S. R., & Saxe, G. B. (2000). Mathematical Problems and Goals in Children's Play of an Educational Game. *Mind, Culture, and Activity*, 7(3), 201-216.

Okan, Z. (2003). Edutainment: is learning at risk? *British Journal of Educational Technology*, *34*(3), 255–264.

Pea, R., & Martin, L. (forthcoming). Values that occasion and guide mathematics in the family. In O'Connor, K., & Penuel, W.R. (Eds.), *Research on Learning as a Human Science.* New York: Teachers College.

Piaget, J. (1932). The Moral Judgment of the Child. Glencoe, Ill.: Free Press.

Rieber, L. P. (1996). Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. *Educational Technology Research and Development*, 44(2), 43-58.

Siegler, R. S., & Ramani, G. B. (2008). Playing linear numerical board games promotes low-income children's numerical development. *Developmental Science*, 11(5), 655-661.

Vygotsky, L. S. (1967). Play and its role in the mental development of the child. *Soviet Psychology*, *5*(3), 6–18.

Learning as mediated by a nodal ecology: Findings from studies of *Gamestar Mechanic* and Quest to Learn

Abstract: The authors present two research studies related to game-based learning environments designed to help middle and high school students develop systems thinking skills. Pre and post testing and mixed-methods (quantitative and qualitative) longitudinal collection methods were used. The two studies focus on: (a) *Gamestar Mechanic*, an online video game, and (b) Quest to Learn, a games-based school which recently opened in New York City. Both studies assessed middle school students' ability to develop system-thinking skills as result of participating in these educational interventions. Levels of change in the development of systems thinking will be described in the paper, but the authors' main focus concerns *how* these gains were attained by the students. What role did context play in the learning process? The authors argue that a "nodal ecology" of redundant and predictable learning experiences serve to explain changes in cognitive development.

This poster presentation presents two studies that assessed middle school participants' development of systems thinking after participating in games-based learning environments. Both learning environments were designed using a "nodal ecologies framework," and claims about cognitive development have therefore been analyzed to understand the efficacy of this framework. Conceptualization of learning contexts as *learning ecologies* was guided by research and theories pointing to meaning making, cognitive development, and identity formation as a process whereby individuals travel through sets of varied but inter-related learning spaces (Bronfenbrenner & Morris, 1998; Goldman-Segall, 1998; Lave & Wenger, 1991; White, 2008). The learning ecologies for both studies discussed in this paper have been framed around a set of interacting, interdependent learning nodes. Nodes in a particular ecology are defined as interconnected, but distinct physical or virtual spaces that house predictable and redundant instances of specialized content (e.g, systems-thinking, algebra, fashion, basketball), social activity, learning tools, and a discourse the defines certain ways of knowing and doing.

One study employed a game called *Gamestar Mechanic*, intended to help middle and high school students develop basic game design skills. Both game design, as well as systems thinking skills, were conceptualized as dialogic in nature. The overall study, designed using design-based research methods (Barab, 2006; Barab & Squire, 2004), focused on testing the viability of using *Gamestar Mechanic*—and the learning ecology it instantiated—to improve students' systems thinking skills. A principal research question that guided the study was: Does a learning ecology generated and mediated by the game design of *Gamestar Mechanic* improve participants' ability to engage in systems thinking?

The second study, which is currently underway and uses both qualitative and quantitative methods (Shute, 2009), similarly considers the nodal ecology of Quest to Learn, a new games-based school that opened in New York City in September 2009, in relation to middle school students' development of systems thinking skills. Similar to the *Gamestar* study, Quest to Learn has designed a learning environment framed around a nodal ecology of learning experiences. Enabling students to develop systems thinking is also a core goal of the school.

Brief overview of systems thinking

We are currently witnessing a foregrounding of complexity as one of the defining characteristics of our new century. Stephen Hawking (2000) has said that we are living in the era of complexity and that complexity itself will form the science of the 21st century. Similarly, Heinz Pagel (1988) has written that those who master this science will form the economic, political, and cultural superpowers of this new century (see also Rambihar & Rambihar, 2009). Systems thinking for both studies is defined as the ability to see and understand the "big picture." This requires learners to solve problems using a wholistic versus a reductive (e.g., considering discrete variables) approach (Shute, Masduki, Donmez, et al., in press; Torres, 2009a, 2009b). Specific systems thinking skills that both studies assessed include: dynamic thinking (i.e., the abilty to account for reciprocal interactivity between variables), closed-loop thinking (i.e., the ability to account for reinforcing and balancing feecback dynamics and time delays), and model transfering (the ability to see how similar system dynamics may be present in other seemingly dissimilar systems).

The crux: Implications and significance

While this presentation will offer an overview of systems thinking, along with quantitative learning gains students have made in their systems thinking development, the key issue concerns the research and design of learning environments. In most schools, students are given opportunities to learn in one primary node—the classroom context. Furthermore, in most instances they are learning *about* something instead of learning *to be* something, such as a chemist, historian, journalist, and so on. Seeing learning as intricately tied to identity development, both leaning interventions discussed here ask students to step into roles and specific identities (e.g., game designer, scientist, historian). The two studies we report on depart from a customary "learning about" approach to teaching and learning. Indeed, the notion of cognitive development resulting from social, physical, and mental activity through the passage of nodes offers a striking departure from the design of learning environments in schools today.

References

Barab, S. (2006). Design-based research: A methodological toolkit for the learning scientist. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences*. Cambridge, England: Cambridge University Press.

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground *The Journal of the Learning Sciences, 13*(1), 1-14.

Bronfenbrenner, U., & Morris, P. (1998). The ecology of developmental processes. In W. Damon & R. M. Lerner (Eds.), *in Handbook of Child Psychology*. New York: John Wiley & Sons.

Goldman-Segall, R. (1998). *Point of viewing children's thinking*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Hawking, S. (2000). Science in the next millennium Retrieved December 20, 2008, from http://clinton4.nara.gov/ Initiatives/Millennium/shawking.html

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Pagel, H. (1988). *The dreams of reason: The computer and the rise of the sciences of complexity*. New York: Simon and Schuster.

Rambihar, V. S., & Rambihar, V. (2009). Complexity science may help in defining health. *BMJ.* Retrieved on February 2, 2009, from http://www.bmj.com/cgi/content/extract/338/jan09_1/b32

Shute, V. (2009). Assessing Quest to Learn, MacArthur Funding Proposal, August 2009 to January 2011 (18 months).

Shute, V. J., Masduki, I., Donmez, O., Kim, Y. J., Dennen, V. P., Jeong, A. C., & Wang, C-Y. (in press). Assessing key competencies within game environments. To appear in D. Ifenthaler, P. Pirnay-Dummer, N. M. Seel (Eds.), Computer-based diagnostics and systematic analysis of knowledge, New York, NY: Springer-Verlag.

Torres, R. J. (2009a). *(Dissertation) Learning on a 21st century platform: Gamestar Mechanic as a means to game design and systems-thinking skills with a nodal ecology*. Ann Arbor: UMI ProQuest.

Torres, R. J. (2009b). *Learning on a 21st century platform: Gamestar Mechanic as a means to game design and systems thinking within a nodal ecology*. New York University: ProQuest Dissertations.

White, H. C. (2008). *Identity and control: How social formations emerge*. Princeton, NJ: Princeton University Press.

The Role of Student Agency and Sustained Inquiry on Collaboration and Learning of Science Practices

Abstract: We redesigned a traditional inquiry-based science unit, creating a unit that incorporates student agency and sustained inquiry during science inquiry experiences. Using a quasi-experimental design, the two units were compared. Fourteen teachers in 5th grade classrooms in one school district in the Pacific Northwest participated. Data collected include an embedded inquiry assessment and video-recordings of student discourse. Preliminary findings show that students in the redesigned unit saw gains in both collaboration skills and scientific practices.

Major Issues Addressed

At present, many schools employ hands-on science curricula to help students become proficient in aspects of science inquiry and knowledge. However, our analysis suggests that for the most part these curricula do not engage students in what might be considered *authentic* science practice in the sense that students do not conduct *sustained, original inquiry* nor have *agency* in determining the course of their inquiry.

Research suggests that students can develop and pursue--with teacher scaffolding--their own program of research related to a complex problem (Chinn & Malhotra, 2002; Metz, 2004). Building on this work, we conjecture that students, when provided with the opportunity and appropriately supported to engage in authentic science, will be motivated and more likely to engage in sense-making and knowledge-building in the context of their work, and hence, more likely to acquire a deep understanding of science concepts and inquiry processes.

To evaluate these ideas, we examined collaborative learning processes (Herrenkohl & Guerra, 1998) and learning outcomes in elementary classrooms using two different hands on science units—one (of our own design) that offered students greater agency and opportunities for sustained, original inquiry, and one that involved a series of discrete investigations directed by the classroom teacher.

Potential Significance of Work

This research has the potential to contribute to our understanding of how student-driven, authentic science inquiry influences student engagement, discourse, and learning of science concepts and processes. It also has the potential to contribute to our understanding of effective design principles for science curricula.

Theoretical and Methodological Approach

Taking Science to School (Duschl, Schweingruber & Shouse, 2007) suggests that teaching "science as practice" involves "engaging children in designing and conducting investigations and answering complex questions" (p. 256). In inquiry science classrooms, students are purposefully engaging in scientific practices, grappling with important science ideas, and building conceptual understanding through meaningful discourse and activity. In contrast to this idealized depiction, current classroom practice more often involves a teacher giving students the questions and procedures for a series of discrete science investigations, and students' scientific work involves conducting these investigations and interpreting the results. In these classrooms, students' work is largely procedural, and lacks personalization and consequence (other than a grade).

In the present study, we compared a "traditional" science inquiry unit to a unit reformulated to embody more authentic science inquiry practices. Both units addressed similar concepts and skills, involved student collaboration, and were "hands on." The cornerstones of the "authentic" unit were student-choice/agency and student-guided collaborative investigations related to an over-arching problem (Vye, Schwartz, Barron, Bransford, Zech & CTGV, 1998). Namely, small teams of students were challenged to design and conduct a series of investigations that would inform their design of a habitat for isopods. We hypothesized that students in the Isopod Habitat unit would participate more productively in inquiry practices—that is, show greater evidence of sense making and knowledge-building over time--and be relatively more proficient at science inquiry practices.

The study involves a quasi-experimental design. Demographically matched schools were randomly assigned to either a comparison (i.e., traditional unit) or intervention (i.e., isopod habitat unit) group. A total of fourteen 5th grade teachers in one school district in the Pacific Northwest participated for 12 weeks each. Eight teachers and 122 students participated in the Isopod Habitat unit; 6 teachers and 72 students participated in the Comparison unit.

Data sources presented in this paper will include: a) students' performance on an embedded inquiry assessment that was conducted during week 10 in both the Comparison and Isopod Habitat classes; and b) videos of students' designing two investigations (during the first and last quarters of the unit).

In the embedded inquiry assessment, students in both conditions were asked to generate their own research ideas including an investigative question, a prediction, and an explanation for their prediction. They conducted the study, interpreted their findings, and then were asked to decide upon and justify a good follow-up study. Two coders "blind" to treatment condition scored students' responses.

For the purposes of this paper, we have selected one group from each of 2 classes in both the Comparison and Isopod Habitat conditions (for a total of 4 student groups). For the Comparison classes we selected the 2 expert teachers who had provided students with an opportunity to design a study. Similarly for the Isopod Habitat classes, we selected 2 teachers whom we thought had implemented the unit with special fidelity. The groups were chosen based on the completeness of the video records.

For each of the 4 student groups, we selected videos of their design work early and late in the unit. This affords us the opportunity to examine the extent to which students' discourse changed over time as well as a comparative perspective on discourse processes under conditions of greater/lesser agency and sustained thinking. The video records were transcribed for discourse analysis.

Preliminary Findings, Conclusions and Implications

As illustrated in Figure 1, results from HLM analysis of items comprising the embedded inquiry assessment indicate that Isopod Habitat Challenge students performed significantly better than Comparison students in the following areas: generating a quality investigative *question* ($p < .0005$), *prediction* ($p < .1$) and, design for *follow-up study* ($p < .05$). This association cannot be considered causal, since the assignment procedure was not random. However, in these analyses, differences in baseline achievement are not a likely explanation for the estimated effects, since students' previous year's achievement scores on the Washington Assessment of Student Learning (WASL) standardized tests were used to control for prior achievement.

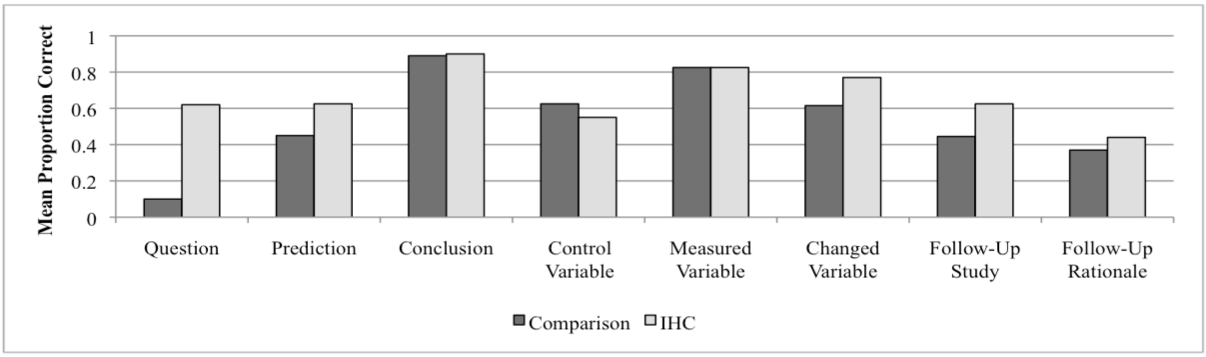

Figure 1. Performance on Embedded Inquiry Assessment

The discourse analyses are on-going; however, preliminary analysis indicates that Isopod Habitat students show greater evidence of knowledge-building over time. More students contributed during discussions, and there were more knowledge-building interactions between students. Lengths of exchanges were longer, and the Isopod Habitat students used greater precision in their language. In addition, engagement was markedly higher for the Isopod Habitat students. Preliminary findings indicate the value of building sustained inquiry and student agency into scientific inquiry experiences.

References

Chinn, C., & Malhotra, B. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, *86*, 175-218.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (Eds.). (2007). *Taking science to school: Learning and teaching science in Grades K-8.* Washington, DC: National Academy Press.

Herrenkohl, L., & Guerra, M. R. (1998). Participant structures, scientific discourse, and student engagement in fourth grade. *Cognition and Instruction, 16*(4), 431-473.

Metz, K. E. (2004). Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction*, *22*(2), 219-290.

Vye, N. J., Schwartz, D.L., Bransford, J.D., Barron, B.J., Zech, L.K., & Cognition and Technology Group at Vanderbilt (1998). SMART environments that support monitoring, reflection, and revision. In D. Hacker, J. Dunlosky & A. Graessar (Eds.), *Metacognition in educational theory and practice* (pp. 305-346). Mahwah, NJ: Erlbaum.

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Reviving Dewey's "Reflective Thinking" Framework for the Design of Problems in Virtual Learning Environment-based Assessments of Content and Inquiry

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Abstract: This poster presentation revives Dewey's "reflective thinking" framework to inform the design of problems for virtual environment-based assessments of content and inquiry. After describing "reflective thinking" and illuminating a conceptualization of what is a problem, we show how we are using the "reflective thinking" framework to inform the design of problems in our SAVE Science virtual environment assessment modules.

Virtual Learning Environments (VLEs)

Since digital media are increasingly becoming a part of students' lives in and out of school, VLEs and supporting technologies can be woven into the fabric of their everyday school science experiences to prompt reflective thinking. It has been shown that contemporary education using virtual methods of inquiry can play a significant role in substituting for physical experimentation in K-12, because they obviate the need for expensive equipment and minimize the impact of deficient training for teachers on how to implement inquiry (Ketelhut and Nelson, in press; Nelson & Ketelhut, 2007). Furthermore, it has also been shown that virtual environments have the advantage of giving students time to 'reflect' on their course of action (Schank & Cleary, 1995). But, what are the design heuristics necessary for prompting reflective thinking? In this paper, we propose a framework for designing problem-based VLEs to promote reflection based on Dewey's Reflective Thinking Framework (1910). We discuss how this framework was used to design modular assessments in an NSF-funded project, called Situated Assessment in Virtual Environment for Science Content and Inquiry (SAVE Science).

Reflective Thinking

"Reflective thinking," according to Dewey (1910), is "[a]ctive, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends" (p. 6). Reflective thinking is part of the critical thinking process of analyzing and making judgments about what has occurred or what problem has been posed. Reflective thinking ranges from simple acceptance of a judgment to deep inquiry into posed problems.

Dewey developed and articulated the four steps required for reflective thinking, or problem solving. The four steps are: 1) identify or define the problem; 2) suggest solution; 3) collect evidence; and 4) conclude. Although the steps are enumerated, reflective thinking (problem solving) does not necessarily occur in that order or in a linear fashion. One does not have to complete the first step in order to proceed to the second. The formal steps involved in reflective thinking are less important than a sequence that results in the solution to the specific problem. Furthermore, during reflective thinking the problem solver goes back and forth through general stages before settling on a solution.

Reflective Thinking Problem Design

Problems that arise from experiences can be arrayed on a continuum with simple problems (easy task) to complex problems (hard task) as extremities. Simple problems are those that typically appear in classroom science and mathematics and can be solved easily. The simplest of all problems would be solved progressing through each of Dewey's four reflective thinking stages only once before a conclusion is made. However, problems in life are never this easy. Complex problems can be difficult social problems, like hunger and poverty, and are hard to solve. As problems become increasingly more complex, the problem solving pathway through the reflective thinking stages can occur multiple times before a conclusion is drawn.

According to Dewey (1910), experiences are imbued with rich sources of problems. He believed that a problem causes a "state of perplexity, hesitation, [or] doubt" (p. 9) creates a tension mental unrest (disequilibrium) and suspense. This imbalance was a precondition for inquiry and reflective thinking. Indeed, the perception of a disturbance "would lead to an act of search or investigation directed toward bringing to light further facts which serve to corroborate or to nullify the suggested belief" (p. 9). Dewey assumed that this tension was often vague and not clearly focused. In fact, his first state of reflective thinking was a search performed within the environment for information that would clarify the problem.

What are the characteristics of a good problem that creates this mental unrest? Drawing on Dewey's notion of genuine problems (1910), Polanyi (1957) suggests that good problems should: 1) hint that there is a known but hidden solution; 2) result in the amount of effort matching the reward of finding that solution; and 3) have clues that hint at or are part of the solution. Dewey (1910) further recommended that the problem should be based in a story, and should have interest for the solver. Foreshadowing Csikszentmihalyi's concept of flow years later (1990), Polanyi (1957) cautions that the "logical gap" (the difference between what is known and what is needed to be known to solve the problem) is a major factor to be considered in designing the problem.

Applying Reflecting Thinking Problem Design to SAVE Science

The SAVE Science project is designing and implementing a series of virtual environment-based assessment adventures (or quests) used for assessing both science content and inquiry in middle grades. To do this, we are creating assessment quests for students to solve using knowledge they have gained in their middle school science classroom. We are using the above framework to guide our design of our assessment quests. "Sheep trouble" is the first quest that we designed to assess student understanding of concepts of adaptation and structure/function. First, to create a problem with a knowable but hidden solution, we have students greeted bya medieval farmer who asks them to help him find a scientific solution for why his new sheep are dying. His brother and many of the townsfolk think that there is no findable solution, but he is convinced that there is and that the student-scientist can help him find it. Second, we are supporting student effort as they progress through the problem by foregrounding relevant elements and events in the virtual environment. We are doing this by highlighting computer agents and other interactive items. Third, students are provided clues to the solution through posters, computer agents, and the design of the actual world. For example, a poster shows that the new sheep come from a very different locale (flat, snowy island) from the current farm (hilly, rocky, and dry). By exploring, students also discover that to find the best grass to eat, the sheep need to climb the hill. Finally, the problem is firmly based in a narrative that includes helping the farmer save his sheep from the town executioner who is under orders to destroy them unless proof that they are not 'bad magic' is found.

SAVE Science Pilot

A pilot was conducted in May 2009 in a mid-Atlantic school. Twenty students participated in the sheep trouble module. While this was primarily a usability implementation, we were also evaluating our problem design framework. Using students' own words (see table 1), we discovered that our problem narrative was interesting. All students felt that the solution was discoverable as witnessed by their engagement with the project. Students used the provided clues to solve the problem and when questioned, pointed to those clues in their rationale. Finally, students indicated that our 'logical gap' might have been too small as many students asked for more complexity or difficulty in future modules.

Table 1. Example student comments on the four aspects of our design framework (n=20).

Solution availability	Effort-benefit ratio	Clues to problem	Narrative interest
it was fun with the evidence that you had to find on the two kinds of sheep	It was really fun because you got to go around and explore why the new sheep were sick	I liked how you could interact with the different people	its really fun
the game was very intriguing. It was a brain puzzle but still lots of fun	it was sort of a challenge.	Give a second hint about what the problem is	its real enough looking that I can really get into it.
I think this a great way for students to test their skills	I think the barriers of the game was too small.	I need more stuff to interact with	But the story will get old and it would probably be better if there were different challenges
You get to figure out what's wrong	It was fairly easy	(need) more clues or hints	It seemed like a real-life question
the most interesting part was trying to find out what was wrong with sheep.	Make a bit harder and longer		It was fun and realistic. It didn't feel like we were just taking a test on a blank screen.

References

Csikszentmihalyi, M. (1990). *Flow: The psychology of optical experience.* New York: Harper Perennial.

Dewey, J. (1910). *How we think.* Boston: Heath.

Ketelhut, D.J., and Nelson, B. (in press). Designing for real-world scientific inquiry in virtual environments. *Educational Research.*

Nelson, B., and Ketelhut, D. J. (2007). Scientific inquiry in multi-user virtual environments. *Educational Psychology Review 19*(3), p. 265-283.

Polanyi, M. (1957). Problem solving. *British Journal for the Philosophy of Science, 8*(30), 89-103.

Schank, R. and Cleary, C. (1995). *Engines for education.* Hove, UK: Lawrence Erlbaum Associates.

Developing an iMVT Pedagogy for Science Learning

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Abstract: We summarize an emerging pedagogical approach to learning science subjects as iMVT (Modeling and Visualization Technology Integrated Inquiry-based Learning) based on our school-based research and the literature of technology for science education. The authors use evidence in their chemistry, biology, and physics studies to show the potential of using iMVT as a uniformed theoretical framework for designing effective learning environments to support science learning.

1. The iMVT Innovative Pedagogy

We summarize an innovative pedagogy that applies to chemistry, biology, physics, and perhaps other subject learning as iMVT (Modeling and Visualization Technology integrated inquiry-based learning). It is a collaborative **i**nquiry-based pedagogy to address student science learning difficulties. A **M**odeling approach allows students to represent and construct understanding of science phenomena as complex systems by elaborating on variables, relationships, and the interaction among the components of the systems. **V**isualization is to simulate abstract and invisible interactions (e.g. particle level interaction during chemistry reactions) through visible manipulative. This usually involves the use of **T**echnologies. Figure 1 provides a process model of the iMVT pedagogy according to a chemistry study of our project *Enhancing Inquiry-based Science Learning through Modeling and Visualization Technologies*. Students started from asking questions like 'what affects the speed of chemical reaction'. Next they made their hypotheses, designed and carried out lab investigations, collected data to analyze how different variables (e.g. temperature and concentration) affect the speed of chemical reaction, and then derived the conclusions. Based on their observations in real lab, they further explored what might happen at particle level that affected their data by drawing paper models to explain the micro-level interaction like the example shown in Figure 2. However, this was not as efficient and effective as running computer models such as NetLogo chemistry models as shown in Figure 1. Also in Figure 1, we can see that students actually worked in pairs collaboratively and their teacher served as a facilitator to guide their model-based inquiry process. The elaboration of this iMVT approach used data from the project mentioned above. The process model is similar to a modeling-based inquiry process described in a paper by Hay and his colleagues (Hay, Kim, & Roy, 2004). Although learning sciences through the i, M, V. T described above is not uncommon, to put them together to form an iMVT framework can be a new paradigm to reshape the science learning pedagogy when using technology. The core idea is that student modeling and visualization practices were not "add-ons" to teacher-centered instruction but an integrated part of student-centered inquiry processes.

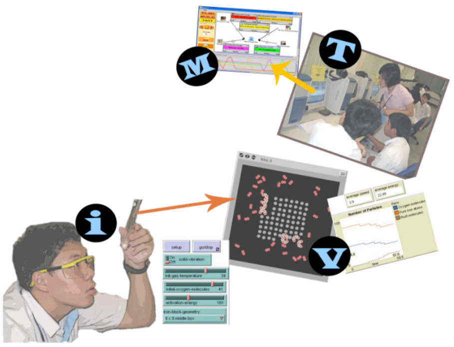

Figure 1. The iMVT pedagogy

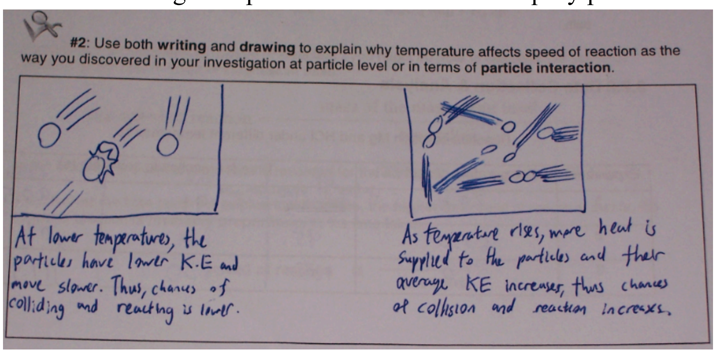

Figure 2. Paper model: How temperature affect the speed of reaction

2. Subject Characteristics

Chemistry is a science that systematically studies the composition, properties, and reactivity of matter at the atomic and molecular level. Johnstone (1982) indicated three worlds of chemistry: the macroscopic, the microscopic, and the symbolic world. The symbolic or representational world is used by scientists to reason and represent the dynamic interactions in the micro world and how the visible phenomena appear to our senses. Modeling is central to chemists' work to describe, explain, and even predict the behaviors of chemical phenomena using chemistry representations. When the micro-level phenomena are visualized using models, it is easier to understand and learn (Gilbert & Treagust, 2009). *Physics* is concerned with the observation, understanding and prediction of natural phenomena and the behavior of man-made systems. In order to create quantitative predictions, physics uses mathematical models of experimental observations, the equations for the model are generated and the model formed related back to what is observed experimentally (Quality Assurance

Agency for Higher Education, 2008). *Biology* is the subject of life and living organisms. Biologists answer questions about diversity and about the common characteristics of living organisms through their investigation (Quality Assurance Agency for Higher Education, 2008). Models take up the intermediate position between the observed reality of phenomena and the theory explaining it (France, 2000). Biological models are used in biology to represent the empirical systems such as DNA double-helical structure and biologists often describe models as having three components – parameters, variables, and laws, while laws are the relationships between parameters and variables (Otto & Day, 2007). Modeling process is utilized by biologist to express this relationship and make sense of life. The iMVT approach is in essence central to chemistry, physics and biology; students should also benefit from iMVT when learning natural and probably social phenomena as systems.

3. Empirical Findings

In our project, there were three studies on chemistry, biology, and physics, respectively. Each had one learning sciences research agenda. The studies were carried out in two Singapore secondary schools to explore the ideal conditions for using iMVT to facilitate student learning. The *chemistry* study compared two different modeling software in supporting students to learn the same chemistry topic. We studied how equation-based modeling tool (Model-It) and agent-based modeling tool (NetLogo) facilitated student learning the Speed of chemical reaction as described at the beginning of this paper. The results showed that students in both classes improved their content understanding significantly measured by pre- and post-tests (Zhang, Deng, Jacobson, & Kim, 2008). The *physics* study went beyond using algebraic models for teaching the physics of electricity, which was supported by real laboratory experiments that verify Ohm's law, formulae for resistance of series and parallel circuit. With NetLogo models, we enabled students to visualize the electricity phenomenon at microscopic level, such as the behavior of electrons under varying voltage and resistances; the software also allowed for relating voltage to velocity, current to number of electrons and resistance to the time taken for electrons to travel from one point to another. The number of electrons and time are concrete concepts as compared to current and resistance that are more abstract in nature. Students overcame many misconceptions and learning difficulties. Analysis of pre-tests and post-tests showed large improvements in understanding (Pathak, Jacobson, Kim, Zhang, & Deng, 2008). The *biology* study compared different conditions in applying visualization software called Biologica to facilitate secondary four students in learning genetics. Results showed the open-inquiry environment with manipulative in general improved student understanding significantly measured by pre- and post tests (Zhang et al., 2008). All the three studies collected both process (e.g. video recordings of student computer screen activities and conversation when using modeling and visualization tools) and outcome data (e.g. student understanding of modeling measure by survey questionnaires). Preliminary analysis results showed a combination of i, M, V, T had great potential in engaging students in representing, simulating, and testing their ideas about how things were related in natural phenomena to gain conceptual understanding of science.

4. Conclusions and Discussion

In this short paper, we analyzed subject characteristics of chemistry, biology, and physics to argue that iMVT can be a pedagogy that applies to all the three and perhaps more subjects. We present results from our project to show the efficacy of the iMVT pedagogy. Adapting scientific models and visualization tools in education has been the focus of important research not only for physical models (Lehrer & Schauble, 2000) but also for computer models (Loh et al., 2001). Edelson, Gordin, and Pea (1999) suggest that technology support (e.g., computer modeling and visualization) is an important principle for implementing inquiry-based learning. Our iMVT pedagogy is aligned with the above proposals. The empirical results have proved that the iMVT combination is more powerful in facilitating student learning difficult science concepts such as the speed of chemical reaction, genetics, and the physics of electricity. The well-designed tools have software–realized scaffolding in addition to human face to face scaffolding as a way of thinking about and exploring disciplines (Guzdial, 1995). We hope to invite more research to explore how iMVT combination might have changed the way science is represented and learned by students to argue for the novelty of the iMVT pedagogy.

5. Selected References

Pathak, S. A., Jacobson, M. J., Kim, B., Zhang, B. H., & Deng, F. (2008). *Learning the physics of electricity with agent-based models: The paradox of productive failure.* Paper presented at the 16th International Conference on Computers in Education.

Zhang, B. H., Deng, F., Jacobson, M., & Kim, B. (2008). *Exploring the representational affordances of two types of modeling tools.* Paper presented at the Annual meeting of the American Education Research Association.

Zhang, B. H., Jacobson, M., Kim, B., Deng, F., Lin, X., & Pathak, S. (2008). *Exploring modeling and visualization technology (MVT) enhanced biology teaching and learning in Singapore* Paper presented at the The International Conference for the Learning Sciences (ICLS), Utrecht, the Netherlands.

Units of length: A notational system for conceptual understanding of size and scale

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Abstract: A cross-sectional study (101 grade 6-14 students) and teaching experiment (24 grade 6-8 students) suggest measurement units are important in conceptual understanding of size and scale. Students were significantly better at absolute size than relative size estimation after the teaching experiment. Students appear to off-load the requirement for fractions or decimals onto the notational system of measurement units. A planned cross-cultural study will indicate likely improvements if US students had greater schooling in metric units.

Introduction

The concepts of size and scale are important both in science and for science learning. Size is a characteristic of every object, and is the magnitude or extent of the object. The size of an object is established by comparing it to a standard, which functions as a scale. Scales are "the spatial, temporal, quantitative, or analytical dimensions used by scientists to measure and study objects and processes" (Gibson et al. 2000, p. 219). Tools that allow the exploration of new size regimes have opened entire scientific fields, e.g., the invention of the optical microscope led to microbiology and the development of atomic force microscopes to the nanotechnology revolution. Scale is a "common theme" that pervades science, and can be used to unify student learning (AAAS, 1993).

Theoretical Background

Vygotsky (1978, 1985) pointed out the importance of cultural tools to thinking and learning. More recently, Pea (1988) noted that "intelligence is often distributed by off-loading what could be elaborate and error-prone mental reasoning processes as action constraints of either the physical or symbolic environments." (p. 48), including "notational systems such as algebra equations" (p. 54). Research revealed that experts and gifted seniors in high school use units as a notational system on which to distribute intelligence, by visualizing small units (e.g., the nm) "as a new unit (rather than as a fraction of a meter)", with this unitizing possibly underlying conceptual understanding of spatial scales (Tretter et al., 2006, p. 1063). The research reported in this poster studies whether and how typical middle school students use units to construct understanding of size and scale.

Methods

The data used in this poster were obtained from a cross-sectional study with 101 students in grades 6-14 (Delgado, 2009), and a teaching experiment involving 24 students who had finished 6th through 8th grades at a diverse, low SES public school district in a small Midwestern city, during a summer camp (Delgado, Short, & Krajcik, 2009). The curriculum for the teaching experiment was built following a construct-centered design (CCD) approach (Pellegrino et al., 2008) and incorporating findings from the cross-sectional study. The instructional activities (Delgado et al., 2009) were designed to build conceptual understanding of size and scale by having students explore four aspects of size (ordering by size, grouping by size, relative scale or how many times bigger one object is than another, and absolute size) and the connections among the aspects. An engaging driving question – *How can nanotechnology keep me from getting sick?* – provided the context for the 12-hour curriculum. Participants were audiotaped while being individually interviewed; in the case of the teaching experiment, one week before camp, and after completion of the curriculum on size and scale. The interview includes questions about the smallest known unit of length, estimating the relative scale of atom, red blood cell, human, and Earth (relative to a 1-mm pinhead), and estimating the absolute size of the same four objects. The author coded the interviews according to a rubric; a second rater coded 10% of the interviews with inter-rater reliability above 90%. Paired-sample t-tests or McNemar tests (depending on the type of variable) were used to test for changes in the means of student performance pre- and post- instruction, as well as independent-sample t-tests or McNemar tests to compare groups or variables at a given point in time.

Findings

In the absence of the teaching experiment curriculum, next to no pre-university students knew of units of length smaller than the millimeter, yet students often felt a need for these. While any length can be expressed using any unit, many students asked what unit was smaller than a millimeter when prompted to estimate the absolute size of a red blood cell or atom. In the cross-sectional study, around 41% of students mentioned units larger than a millimeter (e.g., centimeter or inch) for the smallest unit they knew. Half of these students did not use the millimeter even after this unit had been provided to them in subsequent interview tasks. Students who continued to use the centimeter or inch scored significantly lower than those who did not initially respond with the millimeter but later used it ($p < 0.01$ for t-test, and effect sizes above 1 [calculated using pooled standard deviation]). Additionally, students became significantly more accurate at absolute size estimation compared to relative scale estimation at the end of the teaching experiment ($p < 0.01$), while there was no statistically significant difference at the beginning of the teaching experiment. This is noteworthy because previous research focusing on perception has shown that relative size is more accessible than absolute size (e.g., Vasilyeva et al., 2004), and research focusing on size estimation has found no consistent difference (Tretter et al., 2006).

Discussion and Implications

The power of units may reside in their allowing students to work with more familiar numbers. Many students struggled to find fractions, decimals, or powers of 10 to express the size of the cell or atom in millimeters, centimeters, or inches. Units may be allowing students to off-load the requirement for fractions or decimals onto the notational system (Pea, 1988) of measurement units. Despite having introduced students to micrometers and nanometers as fractions of a millimeter, most students resorted to micrometers and nanometers when expressing the size of a cell or an atom in the post-teaching experiment assessment, rather than using fractions of a millimeter. The few students who *did* use fractions of a millimeter mainly estimated grossly inaccurate sizes.

While scientists around the world near-universally employ the SI system, the United States still employs English units like the foot and mile for everyday use. Most other countries have long employed the metric system or are further along than the US in their transition from English to metric. Non-US students may be enjoying an advantage in their learning about size and scale by virtue of being more familiar with the metric system of units compared to US students. Finding better ways to help students construct their understanding of "common themes" (AAAS, 1993), including scale, through better curriculum and instruction may be a powerful way of improving US science education. A planned cross-cultural study will shed light on what kinds of improvements, if any, we might expect if US science and mathematics education included earlier and more extensive instructional experiences with the metric system, with the intention of supporting greater student learning and understanding of the common theme of scale. The data collection phase of this new study is scheduled to be completed shortly before ICLS 2010; preliminary findings will be included in the poster.

References

American Association for the Advancement of Science [AAAS]. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Delgado, C. (2009). *Development of a research-based learning progression for middle school through undergraduate students' conceptual understanding of size and scale*. Unpublished doctoral dissertation, University of Michigan, Ann Arbor.

Delgado, C., Short, H., & Krajcik, J. (2009, April). *Design, implementation, and evaluation of the effectiveness of a 12-hour middle school instructional unit for size and scale.* Paper presented at National Association of Research in Science Teaching (NARST) Annual Conference, Garden Grove, CA.

Gibson, C., Ostrom, E., & Ahn, T.-K. (2000). The concept of scale and the human dimensions of global change: a survey. *Ecological Economics, 32* (2), 217-239.

Pea, R. D. (1988). Practices of distributed intelligence and designs for education. In Salomon, G. (Ed), *Distributed cognitions: Psychological and educational considerations.* Cambridge & New York: Cambridge University Press, pp. 47-87.

Pellegrino, J., Krajcik, J., Stevens, S., Swarat, S., Shin, N, Delgado, C., et al. (2008). Using Construct-Centered Design to align curriculum, instruction, and assessment development in emerging science. In G. Kanselaar, V. Jonker, P.A. Kirschner, & F. Prins, (Eds.). Proceedings from ICLS '08: *International perspectives in the Learning Sciences: Creating a learning world* (vol. 3, pp. 314-21). Utrecht, the Netherlands: International Society of the Learning Sciences.

Tretter, T.R., Jones, M.G., & Minogue, J. (2006). Accuracy of scale conceptions in science: Mental maneuverings across many orders of spatial magnitude. *Journal of Research in Science Teaching, 43*(10), 1061-1085.

Vasilyeva, M., & Huttenlocher, J. (2004). Early development of scaling ability. *Developmental Psychology, 40,* (5), 682-690.

Vygotsky, L. S. (1978) *Mind in society: The development of higher psychological processes*. London, England: Cambridge University Press.

Vygotsky, L. S. (1985). *Thought and language*. Cambridge, MA: M.I.T. Press.

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Using a Comparison Task to Support Prospective Educators' Interpersonal Skill Development

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Abstract: Despite family involvement's importance in children's education, teacher preparation programs often fail to help educators develop the communication skills they will need to engage effectively with families. This exploratory study used comparison of two simulated parent-teacher conferences to assess and enhance prospective educators' interpersonal skills, knowledge and dispositions for family involvement. Its purposes were to: validate the cases' contents; pilot them as teaching tools; and develop rubrics for evaluating student responses.

Framework

Interpersonal skills are essential to success in a variety of professions yet they are difficult to quantify and teach. Medical education addresses this challenge via a simulated learning paradigm--the Standardized Patient Protocol –which immerses prospective doctors in authentic, no-fault clinical interactions with "standardized" patients (Barrows, 1993). Recently, Dotger and colleagues have adapted this paradigm to the context of teacher education, immersing teacher candidates in a series of simulated teacher-parent conference scenarios called a "Standardized Parent" (SP) protocol (Dotger & Smith, 2009; Dotger, Harris & Hansel, 2008).

The present study repurposed videos of these simulated parent-teacher conferences with an eye toward testing their utility as tools for learning through vicarious experience. Grounded in cognitive science research demonstrating that comparison of different approaches to the same problem improves learning (e.g., Namy & Gentner, 2002; Rittle-Johnson & Star, in press; Gentner, Loewenstein & Thompson, 2003), we asked teacher candidates to compare two 15-minute videotapes captured in the SP paradigm. Each video involved the same parent (an actress) and challenge, but two different teachers (both female teacher candidates); thus the task showed how two different teachers approached the same situation. The actress was trained to present both teachers with the same conversational "triggers" and attitudes; however, she was also instructed to change her behaviors (e.g., body language, provision of information) in accordance with the teacher's interpersonal stance. According to a panel of evaluators who independently viewed the contrasting videos, the teacher in simulation 1 was highly structured but unresponsive (gave many suggestions but did not listen well); the teacher in simulation 2 was highly responsive but unstructured (empathized and gained more information but failed to suggest follow-up steps or problem-solving strategies).

Methods

Participants were 47 students enrolled in an educational psychology courses taught by the first author (11 graduate students [8 female; 1 African-American, 7 White]; 36 undergraduates [25 female; 1 African-American, 1 Hispanic American, 23 White]). Four participants were parents who had attended parent-teacher conferences; no participants had conducted a parent-teacher conference. Participants received a written overview of the task in class and were given the chance to ask questions about the assignment. Later, they received an e-mail containing a user name and password that allowed them to log on to a secure online system where they would complete the task. Participants were instructed that there were no right and wrong answers and that the task would be graded as pass-fail. The task involved three stages:

Stage 1: Participants rated their self-efficacy for communicating with families using a 15-item survey (items rated on a 5-point scale, 1 = not at all confident to 5 = very confident; $\alpha = .90$; sample item "I am able to actively listen to parents' responses"). Then they read a challenge describing how one student's academic performance and behavior prompted a teacher-initiated parent-teacher conference (i.e., "*Chris Burton is one of 25 students in your 6th grade class. During the first ten days of the new semester, you have assigned and collected four classroom assignments, three of which Chris did not turn in at all.")* They responded to two questions about the challenge: (1) If you were the teacher in this situation, what questions would you have? and (2) If you were the teacher, what strategies would you use to make this conference successful?

Stage 2: Participants watched and evaluated the two videos using a checklist that focused their attention on important communication sequences and skills (adapted from Makoul, 2001).

Stage 3: Participants chose which teacher did the better job and justified their choice in a paragraph, using specific examples to support their decision.

Analyses and Results

Stage 1. Participants' efficacy ratings were high, despite their limited experience (M = 4.07, SD = .21). Responses to the question, "What strategies would you use to make this conference successful?" were coded for seven categories adapted from the Macy model of doctor-patient communication (Makoul, 2001). The most frequently used strategies were asking questions (96%), sharing information (79%), maintaining a positive relationship (79%) and establishing an action plan (77%). Few participants focused on establishing a positive opening to the meeting (13%), accepting the parent's emotions (6%) or managing the flow of the meeting (2%). Analyses of responses to the question, "If you were the teacher, what else would you like to know?" revealed frequent requests for basic information (85%), but few student-centered questions (e.g., "Is he engaged in any after school activities?"; 15%) or partnership-oriented questions aimed at leveraging the parent's expertise ("How do you keep him focused and attentive?"; 11%).

Stage 2. Students' perceptions of each teacher's strengths and weaknesses aligned with our panel's evaluations.

Stage 3. Most students chose Teacher 2 (undergraduates = 64% [n = 23], graduates = 45% [n = 5], X^2 = .54, p < .66). Analysis of their rationales suggest this choice stemmed from the belief that responsiveness was more important than having an action plan, "*If you have a very harsh personality and are not welcoming then I don't think the parent would be likely to come back to you or keep in touch for any reason*." Those who chose Teacher 1 felt differently"*...to make sure that you do not waste your time and the time of the parent you must have a template of what will be discussed…you must have a plan for student improvement*." Other comments suggest the task helped students appreciate the complexity of parent-teacher interactions and their own dispositions and skills. For example, one student wrote, "*I see myself as being the friend type teacher to the parent. But I see that I should not get too friendly because then nothing would get solved or accomplished. Teachers need a balance with being the friend but also being in charge*."

Significance

The present study used carefully selected contrasting videos of simulated parent-teacher conferences as a tool for teaching pre-service educators about two essential dimensions of interpersonal communication: responsiveness and structure. There were three major findings: (1) video contents can be reliably coded according to a model of professional communication, (2) videos made two important dimensions of communication 'visible' to students in relatively short order, and (3) completing the task prompted insights about professional boundaries and identity.

References

Barrows, H. (1993). An overview of the uses of standardized patients for teaching and evaluating clinical skills. *Academic Medicine, 68*(6), 443-453.

Dotger, B. & Smith, M (2009). 'Where's the line?' – Negotiating simulated experiences to define teacher identity. *The New Educator*, *5*(2), 161-180.

Dotger, B. H., Harris, S., & Hansel, A. (2008). Emerging authenticity: The crafting of simulated parent-teacher candidate conferences. *Teaching Education, 19(4),* 337–349.

Namy, L. L., & Gentner, D. (2002). Making a silk purse out of two sow's ears: Young children's use of comparison in category learning. *Journal of Experimental Psychology: General, 131,* 5-15.

Rittle-Johnson, B. J., & Star, J. (in press). Compared with what? The effects of different comparisons on conceptual knowledge and procedural flexibility for equation solving. *Journal of Educational Psychology.*

Gentner, D. Loewenstein, J., & Thompson, L. (2003). Learning and transfer: A general role for analogical encoding. *Journal of Educational Psychology, 95,* 393-405.

Makoul, G. (2001). Essential elements of communication in medical encounters: The Kalamazoo consensus statement. *Academic Medicine, 76(4)*, 390-393.

Argumentation at the table-talk level of middle school students participating in scientific cafés

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Abstract: "Scientific café" refers to the public discussion of socially pertinent questions which have scientific content in an informal setting, typically a bar. This scheme has been adapted to middle and high school class settings. This paper presents an experimental organizational scheme which uses electronic voting. The scheme is evaluated with respect to student engagement and participation, as well as the relationship between the preliminary, private discussion in the small groups and students' public space interventions.

Current practice

Beginning in 1997, scientific cafés have been developed as a means of engaging the general public in discussion and debate of scientific research. Stated goals of the organizers include not only the advancement of general scientific literacy with regards to current trends in research and technology, but also the reunion of individuals having widely different experiences and attitudes to discuss the social consequences of recent advances in technology. Stated otherwise, the scientific café has the objective of forming better informed, more engaged citizens by proving a context for rational discussion and debate of science related social issues. French curriculum standards echo this objective: starting at the middle school level an accent is placed on pluridisciplinary approaches (including social sciences) to the examination of complex issues such as global warming, genetically modified organisms in agriculture or sustainable development. Indeed, argumentation in class has been widely studied as a practice for building students' ability to make explicit their representation of facts and phenomena, validate common representations and articulate them to everyday experience. (For reviews of the study of argumentation in school setting facilitate a variety of teaching goals, see von Andriessen 2006 and Aufschnaiter 2008) For this reason, the format has been transposed to middle and high school settings with varying results ("café junior").

Under the classical organizational scheme of a junior scientific café, the organizer will invite two or three experts who answer questions which have been prepared by some of the students. Most often, an attempt is made to reproduce the café setting, and so the students are often arranged in a disordered fashion, in groups of 4-6 around tables, and they may actually be served refreshments. The basic interactional scheme of the scientific café is maintained: there is a public debate/discussion which is organized by a neutral leader who gives the floor in turn to experts and students and guides the advancement of the subject. There is however a second level of discussion in the scientific café, that is the small discussions held sotto voce around the tables. It is assumed that this private discussion space should enrich the public discourse.

Research-based development

The authors have been leading an action research project in collaboration with several nonprofit associations which aims at the adaptation of the scientific café format so as to better engender the engagement of the students in discussion and facilitate their participation in the public debate. A preliminary observation of current practice in café junior organization based on the scheme described above found a general lack of engagement on the part of the students in the subject. In short, the interaction was often reduced to simple question-response between confident students and the experts. This fell short of the organizers' ambitions (and the teachers' objectives) for the café format. We found that the presence of identified experts under this scheme was a major factor limiting student participation. We also observed the tendency of the students to discuss among themselves, and the tension that exists between the desire to foster discussion with the need for classroom order in order to have the public debate.

We proposed and developed a novel organizational scheme designed to relieve some of these obstacles. In the experimental, the scientific café revolves around the results of real-time polling of the students rather than interactions with experts. One subject has been fully developed and has been deployed (in six 8^{th} grade classes, two hours of café each) using this organizational scheme. The title question of this café is "Why do people drink bottled water?" and the café is organized around four thematic phases: water on earth, water in your body, water in the city, water pollution. The café is run by a discussion leader who has some expertise in the subject of the café (but is not announced as an expert) who poses a series of multiple choice questions to the students using the presentation software included in the ActiVote (1) public response system. After reading each question, the leader explicitly allows time for small group discussion around the table before calling for a vote on the question. The collective results of the vote are immediately displayed. The discussion leader incites discussion, particularly for opinion questions (see below), by asking for justification for both majority and minority responses.

Depending on the nature of the question, a public discussion of the result may ensue. After a question for which a single valid response is possible (e.g. “What percentage of your body weight is water?”), discussion is limited to resolving any misunderstanding on the part of students. In a typical thematic phase, four such knowledge questions will be followed by an opinion question, for which there is no single valid response (e.g. “In your opinion, which of these waste water sources is the most polluting.” – “bath water”, “toilet”, “car washing”, “dish washing”, “cleaning the floors”, “watering crops”). The students are given more time for private discussion before voting these opinion questions, and the public discussion of the results of the opinion polls represents nearly half of the time spent in the café junior.

Methodology

The scientific café corpus analyzed consists of three major elements: the questionnaire together with the individual responses of each student to each question as recorded by the ActivStudio software; the public debate as recorded by minimally guided video camera placed behind the students; and a sample of private space student discussion, recorded by unmanned hidden cameras and body microphones on each student at two tables. Primary analysis of the audiovisual corpus focused on identifying each phase of the event, notably the private space interactions. Independent schemes are used to code group leader and student verbalizations, each of which are evaluated quantitatively as indicators for the evaluation of the efficiency of the new debate organizational format (see below). Systematic transcription is limited to the short private space discussions. Cross analysis identifies relationships between most notable between private space utterances with not only the student’s anonymous electronic vote, but also with his eventual public space interventions.

Results and perspectives

As stated, the action research goal for this study is stated as greater student engagement and participation. We have developed criteria for the evaluation of these aspects. Engagement is evaluated by measuring the time that the students’ stay “on topic” during private space discussion versus time spent talking about extraneous subjects. Student participation is evaluated in terms of public space discussion: organizational schemes are thus compared through the actions of the discussion leaders (for example, how often must the leader solicit student interventions to keep the discussion moving) and through the nature of student public utterances (does the student make a statement, ask for information, refute another statement, ask for clarification, etc.). Early results indicate that the experimental café organizational scheme performs better than the classical café scheme as judged by these criteria.

The broader research subject considers finer aspects of students’ interactions during the event and the articulation between the informal, private space discussion and the more ordered public space discussion. Early analysis on the corpus (twelve hours of private space discussions) has identified episodes where individual students put forward first in the private, table-talk space tentative positions before intervening in the public debate. Of particular interest will be the incidence of group co-construction of arguments and the eventual role of peer validation as a factor leading to public space intervention. In an extension of our previous studies, (Buty, 2009) attention will also be given to the position adapted by the student with respect to his own responses: does he intervene publicly to justify or explain his own response or, rather, does he comment on positions he does not support? Does he identify with his true position, as recorded in the electronic vote?

Endnotes

(1) http://www.prometheanworld.com/server.php?show=nav.15999

References

Andriessen, J. (2006). Arguing to Learn. In: K. Sawyer (Ed.) Handbook of the Learning Sciences (pp.443-459). Cambridge: Cambridge University press.

Buty, C., & Plantin, C. (2009). Variété des modes de validation des arguments en classe de sciences. In C. Buty & C. Plantin (Eds.), *Argumenter en classe de sciences ; du débat à l'apprentissage* (pp. 235-280). Lyon: INRP.

von Aufschnaiter, C., Erduran, S., Osborne, J., & Simon, S. (2008). Arguing to learn and learning to argue: Case studies of how students’ argumentation relates to their scientific knowledge. *Journal of Research in Science Teaching*, 45(1), 101-131.

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Effects of Case-Based Professional Development on Teacher Technological Pedagogical Content Knowledge

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Abstract: This study investigated the efficacy of case-based professional development in helping teachers build capacity for technology integration. Specifically, it examined the ways in which case discussion and case development helped teachers deepen their understanding of the relationship between technology, content, and pedagogy. Data sources included content analysis of case discussions, examination of written cases, and teacher questionnaires. Findings indicated that the use of cases enhanced teacher understanding of the inter-relations between technology, content, and pedagogy.

Introduction

In recent years, researchers emphasized that some of the most powerful professional development opportunities available for teachers are grounded in the systematic study and analysis of classroom practice (Ball & Cohen, 1999). A specific pedagogical approach that engages teachers in a form of practice-based PD is the use of case methods, such as *case analysis* and *case development*. During case analysis, teachers engage in critical assessment of practice and exploration of complex pedagogical issues by discussing cases developed by *other teachers* (Merseth, 1996). During case development, teachers turn their classrooms into a site of inquiry and critically examine their *own* practice in order to develop cases from which other teachers can learn from (J. Shulman, 2002). Despite the potential of the case approach, little is still known about the impact of case methods on teacher knowledge and practice, as well as the specific features and instructional interactions that make cases most effective (Merseth, 1996).

This paper has three inter-related objectives. First, it investigates the ways in which teachers assessed, interpreted and made sense of teaching with technology when they read and analyzed cases developed by *other* teachers. Second, it looks at how they integrated different facets of knowledge as they discussed and analyzed the cases under study. Third, it examines the ways in which teachers connected knowledge to practice as they designed, enacted and reflected on their *own* technology enhanced activities in the context of case development.

Theoretical Framework: Defining Teacher Knowledge of Technology Integration

Research has recently conceptualized a new form of teacher knowledge required for effective application of technology in teaching called *Technological Pedagogical Content Knowledge* (TPACK; Mishra & Koehler, 2006). Building upon L. Shulman's work (1986), TPACK consists of three primary bodies of knowledge: Technological Knowledge (TK), Content Knowledge (CK), and Pedagogical Knowledge (PK). TK refers to computer literacy and the ability to apply technological tools for everyday tasks. CK is concerned with the knowledge of the subject matter to be taught. PK involves knowledge of general teaching and learning methods, knowledge of learners, and knowledge of assessment and classroom management strategies. More importantly, TPACK emphasizes the links and relationships that exist *between* these bodies of knowledge. The relationship between technology and content, for example, results in Technological Content Knowledge (TCK), which focuses on the manner in which technology and content are reciprocally related. Similarly, the relationship between content and pedagogy results in Pedagogical Content Knowledge (PCK), which involves knowledge for teaching within a specific discipline (Shulman, 1986). Finally, the relationship between technology and pedagogy results in Technological Pedagogical Knowledge (TPK). TPK includes the ability to identify specific pedagogical techniques and the ways in which they can be applied to the use of technology. Together, these bodies of knowledge represent TPACK, the ability to integrate TK with CK and PK to enhance student learning.

Methods

The study was conducted in the context of graduate level course offered at a Mid-Atlantic University, titled *Cognition and Technology,* taught by the author over a period of 14 weeks. The course focused on learning sciences theories and their role in the design and use of educational technology in real-world settings. In addition to reading relevant materials, participants explored a range of computer-based learning environments developed within a learning sciences framework. As a culminating activity, students were required to complete a project that centered on case development. The course used a hybrid design whereby students met every other week for three hours. When not meeting face-to-face, all students engaged in asynchronous online interactions where they discussed course readings and analyzed cases developed by other K-12 teachers. To facilitate communication and interaction a course management system available at the university was used.

Participants
A total of 12 students participated in the course. All participants engaged in case discussion and analysis. Of those 12 participants, 8 held K-12 teaching positions and completed the case development project. Three of those teachers taught at the elementary level. The other five taught mathematics, science, social studies, language arts or foreign languages at the middle and high school level. Six teachers were in their first 5 years of teaching. One teacher had 5-10 years of experience while the other one was seasoned with more than 10 years of experience. With the exception of one teacher, all others taught at public schools.

Use and Pedagogy of Case Methods in this Study
The use of case methods in this study was divided in two phases. In *Phase 1* (Weeks 2-9), participants discussed and analyzed a set of three cases developed by other K-12 teachers who had previously engaged in a case development project. Each case provided a detailed account of a real teaching experience that focused on the design and implementation of a technology enriched curriculum unit consistent with state standards. All cases were built around the same format and included both a narrative and a reflective section. Teachers discussed the cases online using the communication features of the course management system. A set of open ended questions was provided to scaffold case discussions and analysis.

In *Phase 2* (Weeks 4-14), 8 participants engaged in a case development project. The process of case development was divided in four stages. In *stage 1*, teachers identified a current pedagogical problem from their classrooms (e.g., helping students see the application of mathematics in real-world) and considered ways in which technology can offer solutions to this problem. In *stage 2*, teachers developed a technology integration plan to address the identified problem. In *stage 3*, teachers enacted their technology integration plans in their classrooms and collected relevant artifacts. In *stage 4*, teachers wrote a narrative case based on the cycle of preparation, enactment, and reflection of the technology integration plan in their classroom. To facilitate case development participants followed a template, which incorporated a series of *writing* and *reflection* prompts.

Data Collection and Analysis
Data were collected from three sources: online case discussions, examination of written cases, and written questionnaires on the value of case analysis and case development. These data were first analyzed qualitatively to identify emerging patterns. Subsequently, verbal analysis (Chi, 1997) was employed to count and represent facets of knowledge evident in participants' discussions and cases, using an a priori coding scheme.

Findings
Findings indicated that case analysis provided an engaging context for discussing technology integration where multiple perspectives were generated and theoretical principles were illuminated through practice. Further, both case analysis and case development helped teachers strengthen their knowledge by helping them build or link connections among the different facets of TPACK. What is most promising is the fact that issues related to technology did not dominate case discussions or case narratives, as is typical in traditional professional development opportunities on the use of technology. Rather, issues related to pedagogy such as learners, instruction and assessment, both independently and in relation to technology were emphasized. In addition, teachers did not only strengthen their knowledge of technology integration, but they also had an opportunity to connect their knowledge to the daily work of the classroom.

References

Ball, D.L., & Cohen, D.K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In L. Darling-Hammond, & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice.* (pp.3-32). San Francisco: Jossey-Bass.

Chi, M.T. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *The Journal of the Learning Sciences, 6*(3), 271-315.

Merseth, K. (1996). Cases and the case method in teacher education. In J. Sikula (Ed.), *Handbook of research on teacher education* (pp. 722-746). New York, NY: Simon & Schuster/Macmillan.

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.

Shulman, J. H. (2002, April). *Happy accidents: Cases as opportunities for learning*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Learning in mathematics: Effects of procedural and conceptual instruction on the quality of student interaction

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Abstract: Quantitative analyses from our previous research indicated that collaboration is more effective when learning with conceptual instruction than when learning with procedural instruction. To explain this differential effect, we analyzed student interaction during instruction. First analyses show that the conceptual instruction elicited more fruitful interaction behavior than the procedural instruction. Furthermore, in the procedural condition, students more often split potential learning opportunities between each other, yielding decreased practice opportunities.

Introduction

While research has generally shown that collaboration may facilitate student learning in mathematics, such positive effects are not always found (Lou et al., 1996). Quantitative analyses from our previous research indicated that the impact of collaboration may depend on the type of knowledge students are expected to acquire during the interaction (Diziol, Rummel, & Spada, 2010). The study compared the effect of four conditions on student learning in mathematics. In two procedural conditions, students learned the execution of computational procedures that are necessary to solve equations; in two conceptual conditions, students learned to translate between verbal and algebraic representations of basic mathematical concepts. During instruction, students worked either individually or collaboratively. Post-test results indicated a differential impact of collaboration on the individual learning outcome: When learning with procedural instruction, collaboration impeded student procedural knowledge acquisition compared to individual learning; when learning with conceptual instruction, collaboration improved students' conceptual understanding. Furthermore, collaboration had a different influence on student learning behavior during instruction depending on the type of tasks they solved. As indicators for student learning processes, we assessed the time students spent prior to problem-solving steps and the time after errors. While collaboration reduced the time prior to steps for procedural instruction, it increased the time prior to steps and after errors for conceptual instruction. How can this differential impact of collaboration be explained? Following the interaction paradigm introduced by Dillenbourg, Baker, Blaye, and O'Malley (1996), we argue that the different task types that students worked on during instruction elicited different types of interactions, and that the elicited interactions were not equally effective to promote student learning. To evaluate the influence of the instruction material on student interaction, we analyzed student learning processes during instruction. The results of these process analyses can help to increase our understanding of when and why collaboration is helpful.

Evaluation of students' learning processes

Seventy-nine high-school students were randomly assigned to four conditions: individual vs. collaborative learning with procedural instruction, and individual vs. collaborative learning with conceptual instruction. During instruction, students worked in a computer-supported learning environment on linear algebra problems. The instruction alternated between worked examples and tutored problem-solving. During tutored problem-solving, the learning environment provided immediate feedback to student actions: Errors were marked in red, and correct answers were marked in green. To ensure that students would not get stuck, the learning environment automatically launched a hint after the third incorrect student attempt which told students the correct solution to the problem-solving step. The procedural and conceptual instruction differed in the following way: In the procedural conditions, students learned to solve linear equations. In the conceptual conditions, students derived linear equations from story problems. To enable the comparison of learning processes of individual students and collaborating dyads, half of the students in both the procedural individual and the conceptual individual condition received additional instruction to think aloud during problem-solving, and we recorded both audio and video data and students' problem-solving actions (log data).

To compare students' learning processes during instruction, we developed a coding scheme that evaluates student behavior after making errors and receiving hints. Earlier studies have shown that errors and hints are important learning opportunities in tutoring environments; however, students do not always take advantage of these opportunities. Two ineffective learning strategies are trial and error, and hint abuse (i.e. students merely copy the correct answer from the hint). In contrast, it is more fruitful for learning if students elaborate on how to correct an error or if they try to understand the solution step proposed by a hint, and particularly the mutual elaboration with a learning partner can promote students' knowledge acquisition. For student behavior following errors, we classified for each error whether students were able to correct the error, whether they engaged in the ineffective trial and error strategy, or whether they elaborated on the error (*learning processes dimension*; for an overview of the categories, see Table 1). For student behavior following hints, we classified for each hint whether students engaged in hint abuse, whether they elaborated on the hint, and whether they were able to understand it. In the collaborative conditions, we furthermore analyzed if both students capitalized on the learning opportunity (*interaction dimension*): Did they collaborate to correct the error or to understand the hint, was only one student responsible for the action following the error or hint, or did they not discuss the error or hint at all? We expected that students particularly benefit from collaboration if they interact with each other, while they may not benefit from the learning opportunity if they are not both engaged in problem-solving. We implemented the coding scheme with Activity Lens (Avouris, Fiotakis, Kahrimanis, Margaritis, & Komis, 2007). By combining log data from the learning environment and video recordings, Activity Lens enabled us to navigate to the relevant sequences of the video for the process analysis.

So far, we concentrated our analysis on the collaborative conditions. Analyses of students thinking aloud are in progress, and results will be presented at the conference. The comparison of the two collaborative conditions suggests that the conceptual instruction elicited more fruitful learning behavior than the procedural instruction (learning processes dimension, Table 1). Dyads in the conceptual condition showed higher elaboration following errors. In contrast, dyads in the procedural condition engaged more often in ineffective learning behavior: After nearly half of the errors that were not immediately corrected, students showed trial and error behavior, and a fifth of the hints were merely copied by students. Furthermore, in the procedural condition, the learning opportunities after errors and hints were more often split between learning partners (interaction dimension): Mostly one dyad partner was responsible for the subsequent solution step (after 49 % of errors and 40 % of hints), while mutual interaction was rare (32 % of the errors and 20 % of the hints). Frequently, dyads even did not talk about the following step at all (after 19 % of errors and 40 % of hints). The consequential decrease of practice in the procedural collaborative condition can explain why these students did not profit from the interaction with a partner. In contrast, in the conceptual collaborative condition, all hints were verbally addressed by at least one student of the dyad, and in 74 % of the errors and in 62 % of the hints, students worked together to decide on the next action. Our next steps will be to statistically compare the learning processes in the four conditions and to evaluate the impact of the different learning processes on students' learning outcome. These analyses can further increase our understanding of the influence of the instruction material on the quality of student interaction and reveal when and why collaboration is helpful. At the conference, we will present the results of these analyses and discuss implications of our research for practice.

Table 1: Percentage of student behavior following errors and hints (learning processes dimension).

		procedural	conceptual
error: next step incorrect	trial and error: immediately next error	44 %	15 %
	reflection on error, without verbal elaboration	6 %	15 %
	reflection on error, with verbal elaboration	50 %	70 %
error: next step correct	immediate correction	60 %	32 %
	reflection on error, without verbal elaboration	10 %	0 %
	reflection on error, with verbal elaboration	30 %	68 %
hint	hint abuse: copying the correct step	20 %	0 %
	reflection on hint, without verbal elaboration	40 %	19 %
	verbal elaboration on hint, but step is not understood	20 %	24 %
	reflection on hint, with verbal elaboration	20 %	57 %

References

Avouris, N., Fiotakis, G., Kahrimanis, G., Margaritis, M., & Komis, V. (2007). Beyond logging of fingertip actions: analysis of collaborative learning using multiple sources of data. *Journal of Interactive Learning Research JILR*, *18*(2), 231-250.

Dillenbourg, P., Baker, M., Blaye, A. & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds) *Learning in Humans and Machine: Towards an interdisciplinary learning science* (pp. 189-211). Oxford: Elsevier.

Diziol, D., Rummel, N., & Spada, H. (2010). *Are two heads always better than one? Taking a closer look at collaborative learning in mathematics.* Manuscript submitted for publication.

Lou, Y., Abrami, P. C., Spence, J. C., Poulsen, C., Chambers, B., & d'Apollonia, S. (1996). Within-class grouping: A meta-analysis. *Review of Educational Research, 66*(4), 423-458.

Beyond epistemological deficits: Incorporating flexible epistemological views into fine-grained cognitive dynamics

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Abstract: Researchers have argued against deficit-based explanations of students' troubles with mathematical sense-making, pointing instead to factors such as epistemology: students' beliefs about knowledge and learning can hinder them from activating and integrating productive knowledge they have. But such explanations run the risk of substituting an epistemological deficit for a concepts/skills deficit. Our analysis of an undergraduate engineering major avoids this "deficit trap" by incorporating multiple, context-dependent epistemological stances into his cognitive dynamics. (Support: NSF 08-335880).

Introduction

Engineering students often have trouble learning and using mathematics effectively (Redish & Smith, 2008), and epistemologies play a major role in explaining these difficulties (Hammer, 1994; Schoenfeld, 1988; Schommer, Crouse, & Rhodes, 1992). Our case study of a student who gets stuck while solving a problem during a clinical interview adds to this literature in two ways. First, we provide a fine-grained account of *how* Jim's epistemology affects his mathematical problem-solving in the moment. This complements large-*N* studies showing that epistemological beliefs correlate with approaches to learning and using mathematics and with performance (reviewed by Muis, 2004). Second, we show that Jim's "problematic" epistemological stance is nuanced and flexible in response to conceptual cues, and we provide a toy model that can explain his subtle shift between epistemological stances. In this way, we avoid attributing to Jim an epistemological deficit, i.e., an absence of productive epistemological resources. Our analysis also has instructional implications: instead of needing to confront and replace "mis-epistemologies" such as the one Jim initially appears to hold, instructors can create instructional environments that tend to trigger more favorable epistemological stances.

Methods and theoretical framework

We videotaped clinical interviews of Jim and six other engineering majors taking a first-semester physics course, probing their approaches to using mathematics in physics. Subjects were asked to explain both a familiar and an unfamiliar equation to themselves and to others, and to solve problems while thinking aloud. Jim solved one problem easily, but got stuck on another despite his fluidity with mathematical manipulation and his understanding of the relevant physical ideas. We thought that understanding why Jim got stuck — and then, why a particular conceptual cue helped him get past the impasse — could shed light on the cognitive dynamics by which epistemological stances and conceptual ideas interact during mathematical problem-solving.

Our analysis began with close scrutiny of the episode where Jim gets stuck and later unstuck, borrowing tools from discourse analysis (Gee, 1999) and framing analysis (Tannen, 1993) to interpret gestures, word choice, and the contextualized substance of his utterances, taking into account that social expectations and power dynamics play a role in interviews. We formed explanations for his behavior and looked for confirmatory or disconfirmatory evidence elsewhere in the interview (Miles & Huberman, 1984). Working from a knowledge-in-pieces perspective (diSessa, 1993; Minsky, 1986), we did not attribute patterns of behavior to globally robust (mis)conceptions and epistemological beliefs; we continually considered how contextual cues might trigger different local coherences in his thinking (Hammer, Elby, Scherr, & Redish, 2005).

Data and analysis: Brief synopsis

The interviewer asks whether the pressure 7 meters beneath the surface of a lake is greater than or less than pressure 5 meters beneath the surface. Jim uses the equation $p = p_{at\ top} + \rho gh$, to which he had just been introduced (p, ρ, and g denote, pressure, density of water, and acceleration due to gravity, and h denotes the distance beneath the surface. Jim thinks h must be negative (i.e., 5 meters beneath the surface corresponds to $h = -5$ m), and concludes that the p is greater at a depth of 5 meters. The interviewer tries to correct the sign error:

Interviewer: Suppose I told you that *h* is positive.
Jim: Always positive?
Int.: Yes, ... Would that help you?
Jim: I mean, that would just make 7 greater than 5.
Int.: Okay. Does that bother you?
Jim: I mean... What I keep thinking is that you are going *down* (gestures down) so 7 cannot be greater than 5 and negative. That's why I keep coming back to that.

> Meaning, if you do say it's positive then ... I guess it doesn't bother me. (sighs) 7 is greater than 5 in positive-land.

Jim is skeptical about *h* being is positive, given that its direction is *down* from the surface. Jim sighs as he tries to accept that idea and perhaps tries to distance himself from it by saying it's true in "positive-land," which he says with a hint of sarcasm. In the conversation that follows, Jim reverts to thinking of *h* as negative.

The interviewer then asks Jim how a friend who doesn't know physics would answer this question. Jim says that, based on personal experiences, the friend would say the pressure is higher at greater depths. Jim acknowledges the conflict between the common-sense answer and the mathematical answer, but thinks the mathematical answer is more trustworthy partly because perceptions can be misleading:

> For an equation to be given to you it has to be like theory and it has to be fact-bearing. So, fact applies for everything. It is like a law. It applies to every single situation you could be in. But, like, your experience at times or perception is just different - or you don't have the knowledge of that course or anything. So, I will go with the people who have done the law and it has worked time after time after time.

He doesn't try to reconcile "perceptions" with math, though he has the tools to do so, as shown below.

At first glance, we might think Jim's behavior stems from the robust conception that downward always corresponds to negative. But solving an earlier problem, Jim took downward as positive. We can also rule out conceptual or skill deficits, using data we lack space to present here. The reason he gets and stays stuck, we argue, is that his perception of how difficult it would be to reconcile common sense and the formal result (while he's "on the spot" in the interview!) stabilizes his epistemological stance that mathematical formalism and common-sense ideas need not speak to each other, and that mathematical formalism expresses confirmed truths.

This stance is more nuanced and flexible than a globally-robust "belief" that mathematical formalism is disconnected from everyday thinking or the real world. When the interviewer asks about the sign of *g*, Jim immediately reconciles the mathematics with common sense: with *g* and *h* both taken as negative, ρgh is positive and hence the pressure is greater 7 meters beneath the surface. Upon reaching this conclusion, Jim displays relief in his physical posture and his vocal pitch while noting that this makes more sense and agrees with the physical experience of pressure. We argue that his epistemological stance has shifted in this moment (not necessarily permanently!), towards a greater expectation that mathematical formalism should mesh with everyday experience. And this shift is actually quite subtle: even before the reconciliation, in response to the interviewer's query about whether the mathematical formalism relates to real-life experiences under water, he adds, "I think there is some way that just completely links the two together, but it's not obvious what that relation is." So, Jim always thought reconciliation was possible, but he thought achieving it would be prohibitively difficult until the interviewer pointed him toward a path. In our poster, we will model Jim's stances before and after the reconciliation as networks of finer-grained knowledge elements, and the subtle *epistemological* shift as a cascade resulting from a *conceptual* cue.

References

diSessa, A. A. (1993). Towards an epistemology of physics. *Cognition and Instruction*, *10*(2-3), 105-225.

Gee, J. B. (1999). *An introduction to discourse analysis: Theory and method*. London: Routledge.

Hammer, D. M. (1994). Epistemological beliefs in introductory physics. *Cognition and Instruction*, *12*(2), 151-183.

Hammer, D. M., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. In J. Mestre (Ed.), *Transfer of learning from a modern multidisciplinary perspective* (pp. 89-120). Greenwich, CT: Information Age Publishing.

Miles, M. M., & Huberman, A. M. (1984). *Qualitative data analysis: A sourcebook of new methods*. Newbury Park, CA: Sage.

Minsky, M. L. (1986). *Society of Mind*. New York: Simon and Schuster.

Muis, K. R. (2004). Personal Epistemology and Mathematics: A Critical Review and Synthesis of Research. *Review of Educational Research*, *74*(3), 317-377.

Redish, E. F., & Smith, K. A. (2008). Looking Beyond Content: Skill Development for Engineers. *Journal of Engineering Education*, *97*, 295-307.

Schoenfeld, A. (1988). When good teaching leads to bad results: Disasters of well taught mathematics classes. In T. P. Carpenter & P. L. Peterson (Eds.), *Learning mathematics from instruction* (Vol. 23, pp. 145).

Schommer, M., Crouse, A., & Rhodes, N. (1992). Epistemological Beliefs and Mathematical Text Comprehension: Believing it is simple does not make it so. *Journal of Educational Psychology*, *84*, 435-443.

Tannen, D. (1993). *Framing in discourse*. New York: Oxford University Press.

NetLogo HotLink Replay: A Tool for Exploring, Analyzing and Interpreting Mathematical Change in Complex Systems

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Abstract: Some of the most important patterns of change that we encounter in our everyday world – global warming, fluctuations in the unemployment rate, voter trends – are produced by the interactions and accumulation of many different individuals and events. This interactive poster will demonstrate NetLogo HotLink Replay, a computational tool designed to provide students a context to reconcile large-scale patterns of mathematical change with the interactions and events that contribute to and are reflected by that change.

Introduction

One of the primary goals of education should be to equip students with the tools to make sense of and act within an increasingly interconnected and changing world. Whether reading a newspaper report about increasing global temperatures due to individual consumption and feedback cycles, or learning about the dynamics of a predator-prey system (Wilensky & Reisman, 2006), the mathematical patterns we observe in the world are often reflective of *complex systems* – systems that are comprised of a number of individual *agents* (such as consumers, employees and employers, or voters) that interact with one another and their environment to produce large-scale outcomes. In this sense, mathematical change is not produced by a single entity or phenomenon, but by the interactions and accumulations of many. *NetLogo HotLink Replay* is an environment designed to help students link the behavior of complex systems to the mathematical trends they generate.

Background

The *NetLogo HotLink Replay* software environment leverages findings about the kinds of experiences that help students to make sense of both *mathematical change over time* and *complex systems*. For example, although the mathematics of change is often considered a difficult topic (Leinhardt, Zaslavsky, & Stein, 1990), research has shown that educators can leverage students' real-world experiences to address these difficulties – primarily in the context of motion (Nemirovsky, Tierney, & Wright, 1998; Roschelle, Kaput, & Stroup, 2000). From this literature we know that students can benefit especially from activities such as *controlling* a phenomenon that produces change over time (Kaput, 1994; Wilhelm & Confrey, 2003); interacting with time-series *plots* and other representations of a value its rate of change (Confrey, Maloney, & Castro-Filho, 1997); and making linkages between *intervals* and *shapes* of plots and the events they represent (Yerushalmy, 1997).

At the same time, complex systems are becoming increasingly important in education (Jacobson & Wilensky, 2006). One way to provide students a context within which to think and learn about complex systems from the perspective of embodied experience is with *agent-based modeling* environments such as NetLogo (Wilensky, 1999). An agent-based model is built by defining the *agents* or individual entities of a system (such as voters), and the *behaviors* and *interactions* of those agents that make that system work (such as the ways that friends may influence on another's vote). By interacting with and building agent-based models, students can reconcile behavior and outcomes on multiple levels of a system (Wilensky & Resnick, 1999), and develop generative and deep understandings of complex systems in a number of domains (Wilensky & Reisman, 2006).

The NetLogo HotLink Replay Environment

NetLogo HotLink Replay is designed to leverage the strengths of agent-based modeling, which provides students a means to connect large-scale complex systems to more personal, individual actions; as well as the strengths of dynamic, controllable mathematics environments, while providing opportunity and context for student *interpretation and meaning-making* through modification and annotation. NetLogo HotLink Replay includes a number of features intended to foster a deeper understanding of the mathematics of complex systems:

Dynamically Linked Representations. The two primary representations included in the environment are visuospatial agent-based models and time-series plots. These two representations are dynamically linked, such that students can click on critical features of a plot and observe that corresponding point in time in the simulation, or play the simulation over time as a cursor indicates the corresponding area on the plot.

Annotation Tools. Students are able to identify any intervals on a plot, and annotate that interval with respect to the aggregate (whole-system) or agent-based (individual actors) behavior that it reflects.

Numerical Approximation Tools. In addition to plots and visuospatial representations, the environment also calculates a user-defined piecewise linear approximation of change on any area of a featured model plot.

Recording Function. Students can opt to run a model in the NetLogo modeling environment, modifying parameters (for example, infection or illness mortality probabilities in the model featured in Figure 1) and observing the outcomes. These interactions can be captured and replayed, so that students can then reflect on their own modifications to the system and the resulting mathematical patterns.

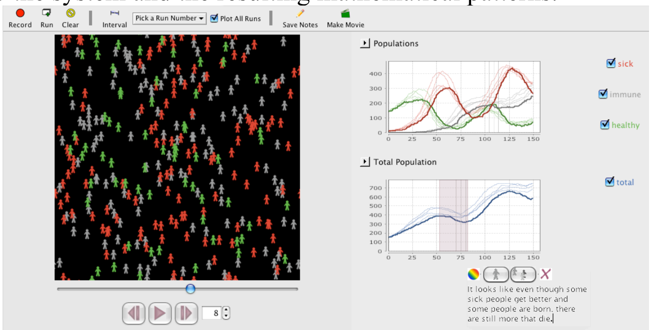

Figure 1. *NetLogo HotLink Replay*, featuring an annotated set of "runs" of an agent-based model of virus spread in a population

Pilot and Future Work

The design of the HotLink environment is informed by preliminary interviews with 12, 10th and 11th grade students enrolled in a precalculus course at a high-performing, urban public school. In one-on-one interviews, they were asked to interact with a simple NetLogo model of exponential population growth and describe their understanding of rate of change and accumulation in terms of results of the model, as well as their understanding of the individual behaviors and their implications for the system. They were then asked these same questions as they constructed their own models by including different behavior patterns of interest. Each interview was analyzed along a number of dimensions: to determine which representations students leveraged (and, at times, coordinated) to think about different properties of systemic change; to identify when students "slipped between levels" (Wilensky & Resnick, 1999) and how those conflicts were resolved; and to explore how students' conceptualizations of notions of rate and accumulation changed during those activities.

We found that by noticing and attempting to resolve differences between conventional (aggregate trends and smooth graphs) and computational (individual behaviors and noisy graphs) representations of population growth, students began to consider how factors such as randomness, heterogeneity, and feedback effect systems and how they might or might not manifest in different representations, as well as how mathematical notions such as "rate of change" could include or reveal information about some real world events, such as a catastrophic event or shift in the behavior of individuals. We hope that the *NetLogo HotLink Replay* environment will leverage these findings, to provide students a more integrated way to interpret and connect the events and mathematical patterns that characterize complex systems across representations.

References

Confrey, J., Maloney, A., & Castro-Filho, J. (1997). *Interacting diagrams: A new learning tool.* Paper presented at PME-NA 19, Columbus, OH.

Jacobson, M., & Wilensky, U. (2006). Complex systems in education: Scientific and educational importance and implications for the learning sciences. *Journal of the Learning Sciences, 15*(1), 24.

Kaput, J. (1994). Democratizing access to calculus: New routes to old roots. In A. Schoenfeld (Ed.), *Mathematical thinking and problem solving* (pp. 77-156). Hillsdale: Erlbaum.

Leinhardt, G., Zaslavsky, O., & Stein, M. (1990). Functions, graphs, and graphing: Tasks, learning, and teaching. *Review of Educational Research, 60*(1), 1-64.

Nemirovsky, R., Tierney, C., & Wright, T. (1998). Body motion and graphing. *Cognition and Instruction, 16*(2), 119-172.

Roschelle, J., Kaput, J., & Stroup, W. (2000). Simcalc: Accelerating students' engagement with the mathematics of change. In M. Jacobson & R. B. Kozma (Eds.), *Research, design, and implementing advanced technology learning environments.* Hillsdale, NJ: Erlbaum.

Wilensky, U. (1999). NetLogo: http://ccl.northwestern.edu/netlogo.

Wilensky, U., & Reisman, K. (2006). Thinking like a wolf, a sheep or a firefly: Learning biology through constructing and testing computational theories - An embodied modeling approach. *Cognition and Instruction, 24*(2), 171-209.

Wilensky, U., & Resnick, M. (1999). Thinking in Levels: A dynamic systems perspective to making sense of the world. *Journal of Science Education and Technology, 8*(1).

Wilhelm, J. A., & Confrey, J. (2003). Projecting rate of change in the context of motion onto the context of money. *International Journal of Mathematical Education in Science and Technology, 34*(6), 887-904.

Yerushalmy, M. (1997). Mathematizing verbal descriptions of situations: A language to support modeling. *Cognition and Instruction, 15*(2), 207-264.

The Impact of Using Video Games and/or Virtual Environments in Pre-service Elementary Teacher Science Education

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Abstract: The purpose of this work is to share findings in using video games and/or virtual environments to facilitate the understanding of basic science concepts with pre-service elementary teachers. We explored the impact of using a game called *Supercharged!* on pre-service teachers' understanding of electromagnetic concepts compared to students who conducted more traditional inquiry oriented investigations. Additionally, we looked at how students responded to learning about water quality through their participation in the virtual environment known as *Quest Atlantis.*

The Major Issue

Many scientific domains deal with abstract and multi-dimensional phenomena that students have difficulty with both in comprehension and application. Mastery of abstract scientific concepts requires that students build flexible and testable mental models (Barnett, Keating, Barab & Hay, 2000; Redish, 1993). Digital technologies can immerse the learner in worlds that not only represent scientific phenomena, but also behave according to the rules of physics and other scientific phenomenon. By representing the simulation through digital gaming conventions, educators can potentially increase engagement while also fostering deeper learning, as learners engage in critical and recursive game play, whereby they generate hypotheses about the game system, develop plans and strategies, observe their results and adjust their hypotheses about the game system (Annetta, 2008; Gee, 2003; Mayo, 2009; Squire, 2008). Supporting future elementary teachers in learning basic science concepts has proven to be challenging (e.g. McDermott & Shaffer 2000; Schoon & Boone, 1998). In fact, many science educators have recognized that elementary teachers struggle teaching science topics conceptually (Forbus, 1997; diSessa, 2000). Elementary teachers have particular difficulty in comprehending physics concepts, such as the basics of electrostatics, which have very few real-life referents and incorporate invisible factors, forces operating at a distance, complex abstractions (Chi, et al., 1991). We believe that educators might use gaming structures such as fantasy, challenges, cooperation, or competition to create even more powerful learning tools, coupling the intrinsically rewarding aspects of games with the pedagogical power of simulations in order to teach complex conceptual science topics (e.g. Cordova & Lepper, 1996).

Context, Methods, and Analysis

This study examined the pedagogical potential of *Supercharged!* and pre-service teachers engagement with *Quest Atlantis*. We first examined the classroom practices that emerged when *Supercharged!* was used to teach an electrostatics unit in an undergraduate content course designed for future elementary teachers. The control group (n=65) participated in a series of scientific investigations that were designed to help them learn the same concepts as their experimental group (n=71) peers. These investigations included understanding the force of a magnetic field on a charged particle, the relationship between force on a test charge and distance, and the impact of electric fields on charges. The experimental group was expected to complete five levels of the *Supercharged!* game where at each level there was increased difficulty or the introduction of a new concept. The quantitative data was analyzed using ANOVA and ANCOVA analysis. The qualitative data was analyzed using naturalistic methods (Lincoln & Guba, 1985) to examine how learning unfolded during game play. Using the constant-comparative method (Glaser & Strauss, 1967), researchers generated assertions from the data, consulting video tapes and field notes to search for supporting and disconfirming evidence.

The second part of this study examined how pre-service elementary education teachers perceived and interacted with an immersive, 3D virtual world – *Quest Atlantis.* Students in a elementary science methods course engaged with *Quest Atlantis* using the *Taiga* unit on water quality. The students (n=75) participated in the water quality activities while, learning the science content as well as the pedagogical tool. This qualitative data was analyzed using naturalistic methods (Lincoln & Guba, 1985) to understand students' perceptions of how these environments could be used in the classroom setting. Researchers generated assertions from the data, consulting field notes in order to search for supporting and disconfirming evidence.

Results

In general the experimental group outperformed the control group on the conceptual assessment questions.

Table 1: Pre-Post Assessment Results.

Group	N	N_M	N_F	Pre-Test	Std. Dev	Post-Test	Std. Dev	Change
Experimental	71	30	41	6.2	1.70	9.4	1.20	3.2
Control	65	20	45	5.9	1.72	8.3	1.27	2.8

A two-way ANOVA was also calculated with post-test scores as the dependent variable. Intervention (Experimental or Control) and Gender (Male or Female) were between-subjects variables. There was a significant difference between the experimental and control groups, $F(2,134) = 4.8$, $p < 0.05$, $\eta 2=0.59$. The qualitative data supported the idea that the students in the experimental group began to see themselves as the charge experiencing forces which influenced their understanding of how magnetic fields effect charged particles. Additionally it was shown that the game play supported student conversations on "force vs. distance" and the trajectory of moving charges and superposition of forces. Finally, despite the positive learning gains, students in the experimental group disliked the playing of the game versus traditional instruction.

In the *Quest Atlantis* experience, students engaged in the 3D water quality environment. The qualitative data exposed the notion that the students were concerned about "the role of the teacher." They had difficulty understanding the paradigm shift in their role from being the "distributer" to the "facilitator of inquiry." Additionally, students became concerned about student play versus what they perceived to be learning in the environment. While content was presented on topics of water quality (dissolved oxygen, pH, turbidity, etc) and ecosystems, this educational value appeared to be lost on these students. Students had very traditional ideas about what constituted classroom learning.

Conclusions

Our findings suggest that video game designers should embed meta-cognitive activities such as reflective opportunities into educational video games to provide scaffolds for students and to reinforce that they are engaged in an educational learning experience. For example, most educational video games that are being used in classrooms have an implicit assumption that learning and skill development, such as scientific argumentation practices, will unfold organically. Steinkuhler and Duncan (2008) found that game-related forums were rich sites for social knowledge construction where "discursive practices include argument, counter-argument and the use of evidence to warrant one's claims"(p.541) was prevalent and where "the predominant epistemological disposition exhibited in the forum posts was 'evaluative' and therefore appropriate to science" (p. 541). This study supports these notions purported by Steinkuhler and Duncan (2008), but we include the caveat that learning would be supported if appropriate scaffolds are purposively built into video games.

Additionally, in the *Supercharged!* study, we were concerned that the experimental group of students did not find playing the game to be a learning experience. This perspective was also demonstrated with the *Quest Atlantis* pre-service teachers. There are several reasons for these viewpoints. First, *Supercharged!* has a relatively unpolished graphical interface compared to what students may experience in game consoles (3D), television (HD), or movies. Another reason could be that the game-based lab was vastly different from their expectations and experiences of a typical lab resulting in the students being disconnected from the learning aspect of the game, instead judging it solely on "entertainment" value. However, the students' writing and comments suggested that their discomfort with the video game and virtual world was due to the fact that neither group perceived that video games or virtual worlds could have educational value. This perspective is potentially problematic; if pre-service teachers do not see video games and virtual environments as a learning tools during their teacher education years, then it is unlikely that they will experiment with games or use them as a part of their own practice once they have their own classroom (e.g. Russell, Bebell, O'Dwyer, & O'Connor, 2003).

References

Annetta, L. (2008). Video games in education: Why they should be used and how are they being used? *Theory into Practice,* 47: 229-239.

Barnet, M., Keating, T., Barab, S.A., & Hay, K. (2000). Conceptual change through building three-dimensional models. In B. J. Fishman & S. F. O'Connor (Eds.), *Proceedings of the International Conference of the Learning Sciences* (pp. 134-142). Hillsdale, NJ: Erlbaum.

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1991). Categorization and representation of physics problems by experts and novices. *Cogntive Sciences, 5*.

Cordova, D. I., & Lepper, M. R. (1996). Intrinsic motivation and the process of learning: Beneficial effects of contextualization, personalization, and choice. *Journal of Educational Psychology, 88*, 715-730.

diSessa. A. (2000). *Changing minds*. Cambridge: MIT Press.

Forbus, K. (1997). Using qualitative physics to create articulate educational software. *IEEE Expert*, May/June, 32-41.

Gee, J.P. (2003). *What videogames have to teach us about learning and literacy*. New York: Palgrave Macmillan.

Glaser, B.G. & Strauss, A.L. (1967). *The discovery of grounded theory.* Chicago, IL:Aldine Publishing.

Lincoln, Y.S. & Guba, E.G. (1985). *Naturalistic Inquiry.* Newbury Park, CA: Sage.

Mayo, M.J. (2009). Video games: A route to large-scale STEM education? *Science,*323, pp. 79-82.

McDermott, L.C., Shaffer, P.S., & Constantinou, C.P. (2000). Preparing teachers to teach physics and physical science by inquiry. *Physics Education,* 35.

Russell, M., Bebell, D., O'Dwyer, L., & O'Connor, K. (2003). Examining teacher technology use: Implications for pre-service and in-service teacher preparation. *Journal of Teacher Education,* V. 54: 297.

Schoon, K. & Boone, W.J. (1998). Self-efficacy and alternative conceptions of science of pre-service elementary teachers. *Science Education,* 82(5),

Steinkuhler, C. & Duncan, S. (2008). Scientific habits of mind. *Journal of Science Education and Technology.*17:530-543.

Squire, K. (2008). Video game-based learning: An emerging paradigm for instruction. *Performance Improvement Quarterly,* V. 21, No. 7.

The identity formation of youth with disabilities across academic disciplines and social contexts

Abstract: The learning identities of high school students are shaped by their participation within institutional and social contexts. In school settings, however, disability labels do not reflect the context-specific nature of "ability" and "potential". By documenting daily experiences of 14 high school students with diagnosed disabilities across regular classrooms, project-based programs, and everyday life, this study investigates the complex nature of youth identity and what shapes their motivation and positioning within social communities.

Major Issues and Research Questions

This study is centrally concerned with how positioning dynamics influence learning identity formation for students with disabilities across social interactions. For many of these students, daily lived experiences in school are not associated with a positive sense of identity or self-worth (Burden, 2008), while nonacademic accomplishments help them experience a sense of pride (Murtaugh, 1988). Thus, if "learning disability" serves more as a category based on institutional arrangements as opposed to a fixed condition (McDermott, Goldman, & Varenne, 2006), it is important to understand their experiences across a variety of social contexts. These experiences help shape their identities as learners, as they participate in sociocultural contexts and move between "socially generated, culturally figured worlds" (Holland, Lachicotte, Skinner, & Cain, 1998). How individuals are positioned by others and by themselves as they move between these worlds influences how they participate and what opportunities shape their future goals and pursuits. By following youth in traditional high school classrooms, project-based programs in a variety of disciplines, after-school activities, and everyday life, this project aims to answer the following research questions:

How do positioning dynamics influence learning identity formation for students with disabilities across social interactions? How does the social context and important relationships shape their opportunities to participate and subsequent perceptions of their abilities?

Potential Significance of the Work

This study has the potential to inform how we think about special education services, since it looks at youth with disabilities across contexts, rather than only using the classroom lens to determine whether a student is meeting academic standards. This also contributes to special education literature by making the social processes of participation and learning more concrete and visible to educators, particularly in the context of "disability".

Additionally, this research adds to both the study of identity development as well as the field of anthropology, because it is grounded in a sociocultural framework which engages questions about how the social and institutional contexts of learning shape individual identities. In particular, this study focuses primarily on the youth perspective as a way to understand how different experiences shape their identity around ability, as well as their developing identities as scientists, artists, or debaters. The focus on "disability" offers a clear context in which social and institutional processes often become most visible.

Theoretical Approaches

Current special education literature focused on students with disabilities in out-of-school settings tends to look at rates of student involvement rather than examining their actual lived experiences in a variety of contexts (e.g. Wagner, et al, 2002; Simeonsson, et al, 2001). Instead, I argue it is important to look how youth with disabilities participate, with attention to interpersonal relationships built within communities (Cousin, Diaz, Flores, Hernandez, 1995). In accordance with Dreier's (2002) framework, I conceptualize this participation to be continuous interaction in social practice, which can be shaped by perceptions of others, available opportunities, past experiences, and personal agency. How an individual participates in a range of social experiences has the potential to influence their future trajectories or "cultural learning pathways" (Bell, et al, 2006).

This cultural learning pathway model accounts for how a series of situated actions are discursively accomplished (Ochs, 2002) through actions and social positions (Harré, 2008) that influence the developing interests, practices, and identities of learners. In particular, disability labels can influence people's perceptions of where these youth are "able" to participate as well as the opportunities made available for them to demonstrate expertise (Vygotsky, 1993). Being limited in their opportunities to participate also restricts the types of experiences they are permitted to have (Dreier, 2002), which not only shape future trajectories of participation, but also their own self-understandings about potential and what it means to be "able" or "expert".

Study Procedures and Methods

In this two-year team ethnography, we collected video and audio-recorded observations and interviews of 14 students with diagnosed disabilities across a variety of contexts, including regular academic classes, project-based program environments, and home life. This poster focuses on three of these students, who represent the three project-based program environments (debate, music, and outdoor environmental science). We began our observations in the programs, in hopes of observing settings that emphasized student strengths, and then briefly observed these students in all of their regular academic classes (before finally deciding which of these classes to focus our attention). In March of Year 1, we began our monthly home visits to the focal students' homes, to interview their families and understand their everyday lives. Data collection is currently ongoing.

Using social interaction/video analysis, we attempted to understand how students interacted with one another, as well as how and whether their disability label played a role in how they participated in school. We played particular attention to how teachers interacted with these students, and interviewed both the teachers and students about how they perceived the students' performance. In the out-of-school informal settings (i.e. debate tournaments, music performances, science symposiums), we also recorded how the focal students participated in activities with their peers, and whether they felt like a valued member of a community.

Preliminary Findings

At this point in the analysis, we find that the space for social participation is restricted or expanded through social positioning and that identities can vary dramatically across formal and informal settings and evolve over time. These results suggest that disabilities are not fixed and may be influenced by institutional processes involving stereotypes and the marginalization of minority youth, which in turn influence their domain-related interests and learning. On the other hand, participation can be protected when expert reputations are reinforced by a trusted member of the community (such as when the focal student is seen as an "expert" by other "advanced" or "expert" students in that community).

Interactions and relationships with adults in the different learning environments also shape participation, and thus, students' disability labels appear to manifest themselves differently (at times, not at all) depending on the context. At this point in the study, how students are perceived and positioned by themselves and by others shapes the opportunities and situations in which they are invited to participate and consequently whether they feel like a member of the learning community. The notion that participation both shapes and is shaped by social perceptions implies that the inclusion of students with disabilities must address more than just whether these students attend or are involved in classes with their non-disabled peers.

References

Bell, P., Bricker, L. A., Lee, T. R., Reeve, S., & Zimmerman, H. T. (2006). Understanding the cultural foundations of children's biological knowledge: Insights from everyday cognition research. In S. A. Barab, K. E., K. E. Hay & D. Hickey (Eds.), *Proceedings of the Seventh International Conference of Learning Sciences (ICLS)*(pp. 1029-1035). Mahwah: LEA.

Burden, R. (2008). Is Dyslexia Necessarily Associated with Negative Feelings of Self-Worth? A Review and Implications for Future Research. *Dyslexia, 14*(3), 188-196.

Cousin, P. T., Diaz, E., Flores, B., & Hernandez, J. (1995). Looking forward: Using a sociocultural perspective to reframe the study of LD. *Journal of Learning Disabilities, 28*(10), 656-663.

Dreier, O. (2002). Personal trajectories of participation across contexts of social practice. *Outlines: Critical Social Studies, 1,* 5-32.

Harré, R. (1984). *Personal Being: A theory for individual psychology.* Cambridge, MA: Harvard University Press.

Holland, D., Lachicotte, Jr., W., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press.

McDermott, R., Goldman, S., & Varenne, H. (2006). The cultural work of learning disabilities. *Educational Researcher, 35*(6), 12-17.

Murtaugh, M. (1988). Achievement outside the classroom: The role of nonacademic activities in the lives of high school students. *Anthropology and Education Quarterly, 19*(4), 382-395.

Ochs, E. (2002). Becoming a speaker of culture. In C. Kramsch (Ed.), *Language acquisition and language socialization: Ecological Perspectives* (pp. 99-120). New York, NY: Continuum Press.

Simeonsson, R. J., Carlson, D., Huntington, G. S., McMillen, J. S., & Brent, J. L. (2001). Students with disabilities: a national survey of participation in school activities. *Disability and Rehabilitation, 23*(2), 49-63.

Vygotsky, L. S. (1993). *The collected works of L. S. Vygotsky Volume 2: The fundamentals of defectology.* New York, NY: Springer.

Wagner, M., Cadwallader, T. W., Newman, L., Garza, N., & Blackorby, J. (2002). *The other 80% of their time: the experiences of elementary and middle school students with disabilities in their nonschool hours.* Menlo Park, CA: SRI International.

The Role of Definition in Supporting Mathematical Activity

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Abstract: Definition is a form of mathematical activity that is fundamental to the profession's emphasis on conjecture, theorem and proof, yet is often treated in school as rote memory. We describe an alternative approach in which sixth-graders invented and revised definitions during investigations of space and geometry. Defining led to contest about taken-for-granted intuitions. A mathematical system emerged as relations among defined objects were constructed and extended, first by conjecture and later by theorem and proof.

Introduction

Often, in mathematics classrooms, definitions are learned by mere naming and memorizing. Not only is this practice problematic for students' conceptual development (Vinner, 1991), but it also denies students opportunities for mathematically richer work. Here, we describe an alternative approach, in which sixth-grade students (ages 11,12) created and refined mathematical definitions of objects featured in their school's curriculum. We conjectured that the activity of definition would encourage analysis of important qualities of these mathematical objects and would afford opportunities for developing *relations* among multiple objects. Reasoning about relations constitutes a mathematical system, and a focus on system is the departure point for other forms of important mathematical work, such as questioning, conjecturing, and proving.

The sixth grade class's work with definition was conducted within a curriculum unit on polygons (Connected Mathematics Project). Our emphasis on space and geometry stemmed from the prospects afforded by spatial reasoning for a general mathematics education: "Geometry, broadly conceived, can help students connect with mathematics, and geometry can be an ideal vehicle for building what we call a 'habits-of-mind perspective' (Goldenberg, Cuoco, & Mark, 1998, p. 3)." Goldenberg et al. (1998) stress that a habit-of-mind entails a close coupling between a specific form of mathematical practice and the grounds for knowing. For example, proofs should explain even as they secure the foundations of a particular conjecture. Hence, a habit-of-mind reflects epistemic disposition as well as a particular form of activity.

Our design for instruction capitalized on students' everyday experiences and conceptions of space, especially bodily motion, and on everyday forms of argument, especially propensities to categorize and classify. For example, we anchored students' learning about polygons to paths that they walked (Abelson & diSessa, 1980; Lehrer, Randle, & Sancilio, 1989) and related familiar properties of polygons, such as "straight" sides to experiences of unchanging direction while walking. Working from these embodied forms of activity, we cultivated students' dispositions toward posing questions and making conjectures. We privileged forms of explanation that were oriented toward the general and that appealed to mathematical system.

Given this support for reasoning about the mathematics of space, we aimed to support student authority to create their own definitions as a mathematical community. Here we trace initial mathematical explorations that emerged as students pursued one deceptively simple question: "What is a polygon?" The teacher asked this question to get a sense of what students had learned about polygons from a week of previous activity with their classroom teacher. We illustrate how the dynamic of definition unsettled what students took for granted (e.g., straight) and supported the development of a mathematical system. We then illustrate how the initial work of defining supported later forms of mathematical activity, as we describe how students elevated a conjecture about the number of diagonals in a polygon to the status of a theorem.

Method

Participants (n =18, 10 male, 11-12 years of age) attended an urban school serving primarily underrepresented youth in the southeastern region of the United States, where 60 to 80-percent of the school qualifies for free or reduced lunch each year. One of us served as the primary classroom instructor for mathematics during the school year. Mathematics class was conducted for 1.5 hours twice each week. Each lesson was videotaped and digitally rendered. Field notes were taken of whole group interactions in order to contextualize the video recordings and serve as a platform for reflection to inform the next day's instruction. Although our choice of mathematical topics was informed by the school's grade-level standards for mathematics, the conduct of any particular class was informed by our interpretations of students' questions and by our judgments of their current levels of understanding. The latter were informed by classroom interaction, by the results of periodic assessments and by summaries written in the students' journals of their understandings and experiences.

The analysis was informed by our history as participant observers and as designers to focus on themes that emerged during the course of our year-long involvement with the class. We employed comparative methods of interpretation to guide our analysis of the unfolding of student thinking, as suggested by the field notes and episodes of video. We watched video of lessons and generated preliminary ideas about what we noticed about the class's developing definitions. We then followed up on selected classroom lessons to refine or refute our conjectures about the emergence and history of use of particular definitions, focusing on episodes at the start of the year and several months later. We traced the development of definitions through the first six lessons by parsing whole class activity into segments of "definitional activity," which included instances where a mathematical object (e.g., polygon) was being defined or its definition contested in some form (e.g., is an circle a polygon?). We then identified links between one definitional activity and another, that is, where discussion about one mathematical object spurred discussion of another. For example, when defining polygon as "sides and angles and closed," a question arose of what constitutes a "side." We used these references in classroom conversation to generate an image of the mathematical system developed within the span of these initial lessons.

Results

Definition was an avenue for developing mathematical qualities of space, especially fundamental notions such as straight, angle, side and closure. Definitions began with contested claims about an aspect of space. Embodied activity served as a starting point and definition as means for resolving these contested claims about aspects such "straight" and "bent." Definitions were made increasingly public via practices of representation. For example, rotating his body different amounts (e.g. 90-degrees, 120-degrees), the teacher asked the students to describe the turns on paper, using words and/or drawings. Students were selected to present their representations while others were asked to describe, compare and contrast them. The discussion highlighted differences in how the drawings showed relative amounts of turn and ultimately supported a conception of angle as rotation. As definitions of these qualities of space were refined and elaborated, they were increasingly interconnected and related.

Explorations of central concepts in Euclidean space began by pursuing the definition of a polygon. Students' initial definitions of polygon introduced new mathematical objects: side, angle and regular polygon, all of which were contested. Students increasingly became more central participants in discussions about definitions. For instance, during the third class, when a student posed a football-shaped object as a possible polygon (in response to the teacher's question of whether a polygon can have two sides), another group of students responded with the question, "What's a side, people?" During the first six lessons analyzed, students constructed systems of relations among defined qualities. For instance, straight participated in subsequent definition of vertex. Moreover, all of these were considered from multiple perspectives: as dynamic paths created by motion (a local view), and as structures emerging from this dynamic activity (a global view). Hence, definitions increasingly reflected these multiple perspectives on shape and form.

These central concepts served as building blocks for other important forms of mathematical activity. For instance, later in the year the definition of diagonal set the stage for the development of a theorem relating the number of sides of a polygon to the number of diagonals. The theorem, that the number of diagonals of a polygon is a function of the number of sides [$(n^2 - 3n)/2$, where n represents the number of sides], originated in small-group investigations where students first noticed and described empirical patterns. The students' justifications of the pattern were supported by one student's introduction of the diagonal as a *path* in which the direction of connection did not matter. This embodied definition helped students conceptualize the number of vertices that could be "reached" from a single vertex as (n-3). Because there were n vertices, they reasoned that the number of "reachable" vertices was n x (n-3). But, as the student had earlier pointed out, reaching via a diagonal was a special kind of path, one that did not preserve direction. Hence, the expression *must be* $n(n-3)/2$. This expression of generalization was built from the particular, but its structure relied on embodied perspectives of a polygon's diagonal, sides, and vertices. It also was an argument of necessity, an important mathematical habit-of-mind. Although humble, definition and classification has traditionally resulted in fruitful mathematical pursuit (Senechal, 1990), and this historic trend was evident in the mathematical activity of the classroom too.

References

Abelson, H., & diSessa, A. (1980). *Turtle geometry: The computer as a medium for exploring mathematics.* Cambridge, MA: MIT Press.

Goldenberg, E. P., Cuoco, A. A. & Mark, J. (1998). In R. Lehrer & D. Chazan (Eds.), *Designing learning environments for developing understanding of geometry and space* (pp. 3-44). Mahwah, NJ: Erlbaum.

Lehrer, R., Randle, L., & Sancilio, L. (1989). Learning pre-proof geometry with Logo. *Cognition and Instruction, 6*, 159-184.

Senechal, M. (1990). Shape. In L. A. Steen (Ed.), *On the shoulders of giants. New approaches to numeracy.* (pp. 139-181). Washington, D.C.: National Academy Press.

Vinner, S. (1991). The role of definitions in the teaching and learning of mathematics. In Tall, D. (Ed). *Advanced Mathematical Thinking*. Dordrecht: Kluwer

Designing an online environment for *all* teachers: Supporting teachers in learning to learn online

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Abstract: Online collaborative environments have the potential to transform how teachers are supported in their professional learning and work. Yet, many teachers fail to fully or productively participate in these opportunities. To address this challenge, *A Learning Community of Teachers (ALCOT),* an online professional collaboration environment, was designed to support mentors and leaders in providing guidance to novices as they learn to develop and share ideas online.

Introduction

Web-based communication tools can provide teachers the opportunity to share ideas and interact with experts in ways otherwise not possible. To encourage professional growth, however, online environments need to encourage thoughtful collaborations around real issues in science and mathematics teaching and learning. In addition, developing professional identity appears to be particularly important for professional growth. We have some evidence that online conversational tools can be helpful. For example, blogs have been shown to support teachers' developing identities as professionals (Luehmann, 2008). But not all teachers take advantage of these new opportunities for support. Only 15 percent of teachers have participated in a professionally-oriented online community or social networking site and only 28 percent have read or written a blog about teaching (Berry, 2009). To be effective online environments need to engage *all* teachers in opportunities to develop as professionals.

A Learning Community of Teachers (ALCOT) is an online environment designed to support teacher learning and community at each phase of the professional continuum. The idea is to explicitly support productive and professional relationships for all teachers. Guided by ideas about how teachers learn to teach and become active members of professional community, this web-based environment is centered on the individual, facilitates one-to-one and group guidance, and encourages continuing participation. ALCOT is specifically designed to support mentors and leaders in providing guidance to novices as they learn to develop and share ideas online. The goal of this study is to describe the challenges and leverage points for teachers new to online collaboration when they are supported by specific communication features – such as electronic journals, blogs, or public dialogue – and instructional guidance – such as individual mentoring, prompting, and feedback – as they learn to use web-based communication to learn and participate in a professional community.

E-learning for teachers' professional learning and work

To be effective, online environments need to facilitate collaborations in ways that match teachers' needs for learning and support. Based on ideas about how expertise develops, I propose that science and mathematics teachers' learning and participation can be supported by learning the practices and discourse of reform-oriented teachers and teacher educators. Participating in the discourse of a community can help teachers develop their identity as a member and encourage their continued and increasingly competent participation (Beijaard, Meijer, & Verloop, 2004). Identity in particular appears to be important in explaining how teachers engage students with content and participate in guiding new teachers (Beijaard, et al., 2004). Teachers will, however, need guidance – including guidance from within the community – to productively participate in these dialogues. Creating such active and interactive environments will require rethinking how we support teachers' learning and community online.

The community of inquiry model (Garrison & Anderson, 2003) proposes that in an e-learning environment, educational experiences are at the intersection of cognitive, social, and teaching presences. Consistent with this model, *A Learning Community of Teachers (ALCOT)*, an online environment, is designed to encourage professional conversations, projects, and identities that integrate cognitive, social, and guidance aspects for teachers. ALCOT centers assets and conversations on individuals, facilitates one-to-one and group guidance from leaders and peers, and has ongoing or durable assets and groups to encourage continued and increasing participation. Although other researchers have explored strategies for supporting teachers online (e.g., see: Davis, Smithey, & Petish, 2004; Farooq, Schank, Harris, Fusco, & Schlager, 2007; Fishman, et al., 2001; Moore, 2002; Schlager, Farooq, Fusco, Schank, & Dwyer, in press), and have illustrated the power of online communities and teacher-to-teacher interactions, these efforts struggle to encourage all teachers to participate in meaningful ways. Through ALCOT design and research, I am exploring strategies to explicitly support teachers, including those who might be most hesitant, in learning how to learn and teach in innovative online environments.

Methods

To begin putting the ALCOT model into practice, the tools to support conversations, projects, and identities were piloted during the 2008-2009 academic year. These features were used by 20 experienced teachers (4-12 grade) participating in a graduate course for new mentor teachers hosting a preservice candidate and by 18 initial licensure teachers (4-12 grade) participating in a graduate course just prior to or during their first two year of teaching. In this pilot, the mentor role was filled by the faculty instructor of the graduate courses. Thus, experienced teachers learning about mentoring were themselves mentored by the instructor. Participating online was a component of the course grade but no set number, frequency, or timing of posts was required. This was to encourage authentic use and explore the value of the supports. Feedback was collected through interviews and recording of verbal comments throughout the semester. In addition, records of online conversations and identities were collected to determine how, when, and for what purpose teachers used ALCOT features.

Outcomes

One leverage point for developing conversations was the one-to-one conversations supported by the mentor-mentee journal. Here the course instructor/mentor provided direct questions for the teachers' response. In this way, teachers were first encouraged to post online. Over the course of the semester, teachers first posted simple responses to direct questions, then responses to follow-up questions (which they did not do initially), then began to post their questions, then information such as thoughts on class activities. The questions that prompted the most descriptive answers for experienced teachers were related to their classroom events. For initial licensure teachers, prompts regarding their course paper resulted in more detail and many follow-up questions from the teachers. One request was for the ability to post audio rather than text only so that the mentors or mentees could "talk" to each other. Both groups quickly used comments to post ideas in response to the leader's blog.

The leverage point for developing identity online was the group leader blog. In this blog, the group leader modeled blogging and took a lead in sharing ideas. Teachers were quick to post comments to the blog entries including thoughtful comments based on the ideas posed. Teachers reported and showed evidence in their posts of reading these entries regularly. Personal blogs, on the other hand were more challenging. Teachers did not know what a blog was and were unsure how or why to blog. Sometimes they posted random questions to their mentor on the blog rather than using the journal. They also did not necessarily understand they could post a blog without it being an instructor guided task. This challenge indicates that learning to blog, as a form of presenting yourself, will take more time than other types of online posts.

References

Beijaard, D., Meijer, P. C., & Verloop, N. (2004). Reconsidering research on teachers' professional identity. *Teaching and Teacher Education, 20*, 107-128.

Berry, B. (2009). *The teachers of 2030: Creating a student-centered profession for the 21st century*: Center for Teaching Quality.

Davis, E. A., Smithey, J., & Petish, D. (2004). *Designing an online learning environment for new elementary science teachers.* Paper presented at International Conference on the Learning Sciences, Santa Monica, CA.

Farooq, U., Schank, P., Harris, A., Fusco, J., & Schlager, M. (2007). Sustaining a community computing infrastructure for online teacher professional development: A case study of designing Tapped In. *Journal of Computer Supported Cooperative Work, 16*(4-5), 397-429.

Fishman, B., Marx, R., Bobrowsky, W., Warren, D., Marrill, W., & Best, S. (2001). *Knowledge networks on the web: An on-line professional development resource to support the scaling up of curriculum enactment*. Paper presented at the American Educational Research Association.

Garrison, G. D., & Anderson, T. (2003). *E-learning in the 21st century*. London: Routledge.

Luehmann, A. L. (2008). Using blogging in support of teacher professinal identity development. *Journal of the Learning Sciences, 17*, 287-337.

Moore, J. (2002). *The inquiry learning forum: Online professional development with a community orientation.* Paper presented at the Society for Information Technology and Teacher Education, Chesapeake, VA.

Schlager, M., Farooq, U., Fusco, J., Schank, P., & Dwyer, N. (in press). Analyzing online social networking in professional learning communities. *Journal of Technology Education.*

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SURGE: Integrating Vygotsky's Spontaneous and Instructed Concepts in a Digital Game?

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In Thought and Language, Vygotsky discusses the potential for leveraging intuitive understandings from everyday experience ("spontaneous concepts") with "instructed" scientific concepts to build robust understandings. The question remains whether or not the intuitive spontaneous concepts players develop in through computer games can be successfully leveraged into robust instructed concepts in a manner that transfers to academic assessments and across domains recognized as central by the scientific disciplines themselves. This poster presents data from early studies with the SURGE video game, where students demonstrated significant learning across multiple items of a posttest based on the Force Concept Inventory, suggesting that the sequence and structure of the models and representations designed in the SURGE game are effective in changing how students think about the formal instructed concepts. However, care must be taken to ensure that the ideas that students take away from the game are the ones intended.

Research Goals and Theoretical Framework

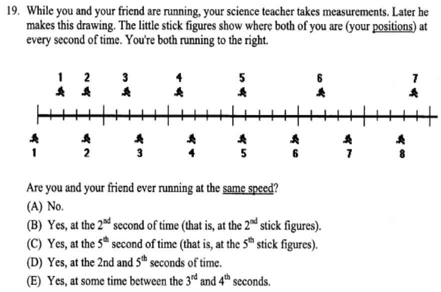
School science, with its focus on explicit formalized knowledge structures, seldom connects with students' tacit intuitive understandings. Interestingly, many commercial video games focus on physics, ecology, engineering, and other critical STEM concepts at their core. Furthermore, commercial video games are exceptionally successful at helping learners build accurate intuitive understandings of the concepts and processes embedded in the games due to the situated and enacted nature of good game design (Gee, 2003, 2004, 2007). As SURGE advisor James Gee explains, good game design is inherently about problem solving. According to Gee, however, these games fall short because they do not help students articulate and connect their evolving tacit intuitive understandings into larger explicit formalized structures allowing knowledge transfer and application across broader contexts. In Thought and Language, Vygotsky (1986) discusses the potential for leveraging intuitive understandings from everyday experience ("spontaneous concepts") with instructed scientific concepts to build robust understandings. The question remains whether or not the intuitive spontaneous concepts developed in games can actually be successfully leveraged into robust instructed concepts in the format and terminology of academic assessment and across domains recognized as central by the scientific disciplines.

Game Context and Data

SURGE (Scaffolding Understanding by Redesigning Games for Understanding) investigates design principles for connecting students' intuitive "spontaneous concepts" about kinematics and Newtonian mechanics into formalized "instructed concepts." SURGE integrates research on conceptual change, cognitive processing-based design, and socio-cognitive scripting with design principles and mechanics of popular commercial video games such as Mario Galaxy, Switchball, Orbz, and Portal to support students' articulation and connection of their evolving tacit intuitive understandings into larger explicit formalized structures allowing knowledge transfer and application across broader contexts relevant to Newtonian mechanics. SURGE incorporates the game play designs of these games in levels alternating between marble "travel" and marble "launching" in the context of a space-based adventure. Each level involves specific challenges directly linked to physics concepts. To complete these challenges, students need to learn and apply many principles related to mechanics (e.g., impulse, inertia, vector addition, elastic collision, gravity, velocity, acceleration, free-fall, mass, force, projectile motion).Each level highlights one or two topics, and levels allow students to connect the concepts together and to see the relations that exist among the topics. For example, the initial levels do not include gravity or friction. However, as the game progresses, gravity and then friction are gradually introduced. This approach allows students to gain a firm grasp of a concept before new concepts are introduced.

Assessment Methods

Assessment in SURGE involves standard experimental design in terms of random assignment of participants within classrooms across experimental groups. In addition, SURGE is conducting formative quantitative and qualitative analyses of student learning during development/pilot-testing phases. Student learning in SURGE is measured (a) in terms of intuitive understanding of "spontaneous concepts" through students' performance in the actual game levels and (b) in terms of formal understanding of "instructed concepts" through items from the Force Concept Inventory (FCI) (Hestenes, Wells, & Swackhamer, 1992; Jackson, 2007). In-game performance is measured via data recorded as students employ concepts of velocity, force, and gravity to spheres of varying mass through a series of obstacle courses. We are also utilizing visualization tools to map connections between students' performance and choices in the game (intuitive concepts) with the formal academic assessments (instructed concepts).



Data and Results

The first SURGE study took place in summer 2009. We analyzed 24 undergraduate and graduate students playing SURGE. A paired-samples t-test was performed on the pre/post items and revealed a significant gain from pre to post ($p = .037$). One of the largest gains on an individual item was the one about vector addition. The second SURGE study involved 180 eighth grade students in Taiwan that showed significant gains in 3 test items dealing with Newton's First Law. The gains observed are not dependent on gaming experience and apply to both genders. The items in which gains were observed are those most closely aligned with the experience of controlling the player-object in SURGE. These items deal with things in SURGE players *do*, rather than *see*. The third SURGE study focused on the complexity of formal physics representations to optimize student learning about the physics concepts and representations. The study involved 138 undergraduates enrolled in an introductory calculus-based physics course at a large university. Students in "full" condition (components and resultant velocity vector) did better on vector addition problems (76.7% versus 69.5%), and the post-test (average gain of 11.0% versus 6.8%) than those in "simplified" condition (only resultant velocity vector).

Significance

The results of these first studies suggest that the sequence and structure of the models and representations designed in the SURGE game are effective in changing how students think about the formal instructed concepts in a manner that transfers to certain items from the Force Concept Inventory, but care must be taken to ensure that the ideas that students take away from the game are the ones intended by the designers. In post-gameplay interviews, students remark that the game helps them understand how to improve their answers on the posttest even though they weren't consciously thinking about their learning while they were playing the game. Ongoing work will focus on the balance of guidance and freedom in the gameplay mechanics, the structuring of mechanics to focus students on key concepts, as well as on the nature of representations that best support learning in a gaming context.

References

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York: Palgrave/Macmillan.
Gee, J. P. (2004). *Situated language and learning: A critique of traditional schooling*. London: Routledge.
Gee, J. P. (2007). *Good video games and good learning: Collected essays on video games, learning, and literacy.* New York: Peter Lang.
Hestenes, D. & Halloun, I. (1995). Interpreting the FCI. *The Physics Teacher, 33*, 502-506.
Hestenes, D., Wells, M., & Swackhamer, G. (1992) Force Concept Inventory. *The Physics Teacher, 30*, 141-158.
Jackson, J. (2007). Simplified Force Concept Inventory.
Vygotsky, L. S. (1986). Thought and language (Abridged from 1934; A. Kozulin, Trans.). Cambridge, MA: MIT Press.

Developing and validating a web-based learning environment for helping 6th grade students appreciate subjectivity and uncertainty in science

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Abstract: This study reports on the development and research validation of a web-based learning environment (LE) for helping students, ages 12-14, to appreciate uncertainty and subjectivity in science. The environment was implemented once and the research results are used for revising it to better address the learning objectives. Results in relation to students' understanding of subjectivity and possible emerging modifications of the LE are discussed.

Aim of the Study

The tremendous progress witnessed in the fields of science and technology tends to bring about dilemmas on a range of socio-scientific issues (SSI), such as global warming. Science education aims at preparing students to engage with such SSIs in an informed manner. One of the resources underpinning this ability is awareness relating to the nature of science (NOS) (Sadler et al., 2004). However, evidence suggests that students and lay adults do not possess informed ideas. Clearly, there is a need for developing teaching innovations, especially for elementary grades (Lederman, 2007).

This study draws on the paradigm of design-based research (Barab, 2006). It seeks to design a learning environment (LE) dealing with certain aspects of NOS, and refine it on the basis of the data collected during its implementation in classroom settings. In particular, we have developed a LE for helping students aged 12-14 appreciate the subjective and uncertain nature of science and develop simple criteria for evaluating the validity and reliability of scientific claims. Empirical data from the first enactment of the LE were collected and analysed so as to inform its refinement. Due to space limitations, we only report data on students' understanding of subjectivity and present how these results are used for refining the LE.

Methodology

Participants

Thirty eight students from two 6th grade classrooms (19 students in each class) of a public school in Cyprus participated in this study. Students were working in pairs or triads. The implementation lasted 10 weeks (24 40-minute sessions).

The learning environment

The LE was hosted on the STOCHASMOS web-based platform. The context of the investigation is a topical SSI, namely the bovine tuberculosis problem in cattle in the UK. Each group of students assumed the role of scientists who represent relevant organizations, as a means for illustrating that scientists' agendas may lead to different scientific claims on the same issue. Students' goal was to study the data and construct scientific claims on how the problem could be best solved. The learning sequence provided students with multiple opportunities to construct and evaluate scientific claims and it systematically engaged them in explicit reflective discourse on relevant epistemological ideas such as the role of uncertainty and subjectivity.

Assessment task

A task for assessing understanding on subjectivity focused on the extent to which students are able to appreciate that scientists studying the same phenomenon might subscribe to different interpretations and to identify possible reasons for this. Students were presented with simplified versions of the man-made and natural theory regarding the global warming causes and a dialogue between two students who argued whether scientists can disagree. Students needed to agree with one of the two positions stated in the dialogue and explain their reasoning. The task was administered prior to and after the implementation. Thirteen students (34%) also participated in interviews (pre, post) for additional insights into their reasoning.

Results and consequences for the refinement of the learning environment

Students' responses were analyzed in order to identify qualitatively different categories of responses (Table 1). Only justified responses are included in this table. Interestingly, fewer students justified their responses in post tests (N_{pre}=27, 71%, N_{post}=19, 50%). Examining the responses without justification, both the number of students believing that scientists can disagree (N_{pre}=8, 21% overall, N_{post}=12, 32% overall) and of those believing that they need to agree (N_{pre}=0-0% overall, N_{post}=5-13% overall) increases. Although there are no interview data from these students, the fact that more students believe scientists need to agree has probably emerged as a byproduct of their interaction with the LE: Students judged claims that were at variance with available data as invalid, as this was the validity criterion they were guided to develop. Incidentally, students ended up with just one valid claim. This might reinforced the belief that scientists eventually agree on the same claim. This suggests the need to modify the LE so as to increase the likelihood for multiple valid claims and, hence, facilitate discourse on subjectivity.

Justified responses suggest a decrease in the number of students who discussed disagreements in relation to how productive they are (category 3, N_{pre}=9, 34%, N_{post}=3, 16%) and in students attributing disagreements to scientists themselves because, as human beings, they have the right to disagree (category 2, N_{pre}=17-63%, N_{post}=7-37%). Interestingly, while no students considered the role of data in relation to subjectivity (category 1), 9 students (47%) gave such post responses. This category is thought to be more informed than categories 2 and 3 because students take into account the role of data in science. However, no students referred to the possibility of having different claims due to different interpretations. This fact may also be connected to certain aspects of the LE: Even though students were scaffolded to appreciate the distinction between data and their interpretation (by asking them to separately refer to these constructs when reporting scientific claims), they did not seem to make this distinction to a satisfactory extent. It is possible that explicit discourse on this distinction and comparisons of different interpretations could help them recognize the possibility of having various claims due to different interpretations.

Table 1: Students' pre & post justified responses in relation to subjectivity and typical student responses

	PRE		POST	
	N=27	%	N=19	%
1.Disagreements in science are attributed to the variability of the information that was reviewed.				
Scientists can disagree because they rely on different information. *"It is possible for scientists to disagree because they might have different information."* (D17)	0	0	9	47
2.Disagreements in science are attributed to scientists (as persons and to the way they work).				
Scientists can disagree because they have the right to have different opinions. *"Many scientists disagree with each other many times when they are on new research because each person has its own opinion."* (D32)	16	59	7	37
Scientists need to agree because they work in groups. *"It is not possible to disagree because this would mean that they are against the other group."* (D12)	1	4	0	0
3.Disagreements in science depend on how productive they are.				
Scientists can disagree because disagreements are useful for the progression of scientific knowledge. *"It is possible to disagree with each other because this is a way to find more solutions to their problems."* (D36)	1	4	0	0
Scientists can disagree because this stimulates further research. *"If scientists did not disagree with each other, then there would be no reason to work more on a subject. But now they work more on a subject, their answers are more certain."* (D31)	2	7	0	0
Scientists can disagree because it enables them to recognize fallacies they might have run into. *"It is possible that scientists disagree with each other because if they agree they might be both wrong (and then we are left with no claim on an issue)."* (D24)	1	4	0	0
Scientists need to agree because disagreements hinder scientists from achieving their goals. *"Scientists make research in order to find a solution. It is not possible to disagree."* (D39)	5	19	3	16
4.Mixed responses				
Scientists may have different information and different opinions. *"Every scientist has his/her own opinion and his/her own information on a subject."* (D2)	1	4	0	0

The LE sought to help students appreciate that scientists' objectives might influence the data collection and/or interpretation as sources of subjectivity. This perspective addresses the role of both scientists (category 2) and data (category 1) in constructing claims and, thus, this kind of responses were coded as mixed (category 4). There was only one such response in the pre-tests but the student referred to the role of scientists and data separately. Even though there were not any written mixed responses after the enactment, such responses were discerned in the interviews, as shown in the next quote [Student (D2)].

> "Each group of scientists will collect the data that relate to what they represent or think. Scientists who thought that temperature increased due to some gases, tried to find data to prove this. On the contrary, the others tried to find supporting evidence for their position. Each group might have studied the same data but focused on parts fitting their position. […] this is sometimes unintentionally done depending on the goals and beliefs of the group you belong to."

However, not many such responses emerged and this also has implications for the revision. For example, more activities may be added so as to facilitate students' adoption of their role. The LE could also be enriched with explicit discourse in relation to existing interpretations of data of other topical SSIs so as to give more opportunities for discussing this learning objective.

Conclusions

This study contributes to existing knowledge on elementary students' initial ideas on uncertainty and subjectivity in science, the difficulties they encounter when trying to understand about these aspects and the extent to which it is possible to impact through the use of inquiry-based LEs. Although the results show that students can learn about NOS aspects with such LEs with embedded explicit discourse in the context of SSIs, the LE has limits and weaknesses. For instance, we discerned difficulties that were not anticipated during the design, while some learning objectives were not achieved to a satisfactory degree. These suggest the need for refinement through multiple cycles of design-evaluation-revision until an effective LE is established (Andersson, 2004). The study also provides insights into how empirical results can be used for further refining the LE.

References

Andersson, B., & Bach, F. (2004). On designing and evaluating teaching sequences taking geometrical optics as an example. *Science Education*, 1-23.

Barab, S.A. (2006). Design-based research: A methodological toolkit for the learning scientist. In R.K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences*. Cambridge, New York: Cambridge University Press.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 831-879).

Sadler, T. D., Chambers, F. W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education, 26*(4), 387-409.

Mapping topological relationships in context

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Abstract: In order to better understand how people construct maps when they are located within the setting they are mapping, we compared how people drew maps between two contexts. Thirty subjects drew maps that included three topological features: the lagoon, the edge of Lake Michigan, and the land between these two bodies of water. We present preliminary data that suggests the accuracy and coherence of the maps generally improved with experience in both contexts.

Motivation

Using and building maps to see the big picture is a complex cognitive task, drawing upon direct perception and requiring reasoning with multiple pieces of spatial information visualized from different perspectives (Uttal, 2000). Constructing a map view of a large-scale local landscape requires knowledge for building relationships among topological features as well as strategies for thinking about space as a collection of organized and systematic relations among features that fit into a coherent whole (Liben, 2006; NRC, 2006). In taking a situated approach to thinking and learning (Greeno, 1998), our motivation with this exploratory study was to understand how mapping a local landscape depends on the context in which the mapping is located. In particular, we were interested in knowing how people construct maps when they are located within the setting they are mapping, and how direct navigational experiences compare to mapping from digital photographs.

Procedure

Of the 30 adults recruited through flyers posted around campus, 23 were students, and seven were university staff, neighbors, or former students. Subjects were randomly assigned to either the indoor or the outdoor condition. Each subject was fitted with a digital audio and video camera that attached to the bill of a hat and continuously recorded what was said and how the maps were drawn.

In the outdoor condition, 14 subjects walked around a man-made lagoon while being clinically interviewed about the lagoon and surrounding "lakefill," stopping periodically to complete a variety of interview tasks (see Figure 1). In the other condition, 16 subjects were clinically interviewed as they viewed photographs of the lakefill on a computer screen inside a building near the lagoon, These subjects were asked to imagine they were on a walk around part of the lagoon and viewed eight high-resolution panoramic digital photographs shot from strategic points on the lakefill. Each interview lasted approximately 45 minutes and followed the same semi-structured protocol that included questions about the history and future of this part of the campus and predictions about how the lagoon could change over various spans of time.

Partway into the interview, the subjects were handed a clipboard, white typing paper, and a pen and asked to draw a map that shows the entire lagoon, the edge of Lake Michigan, and the land beside the lake and the lagoon. Near the end of each interview, the subjects drew a second map and were provided the same instructions to do so. After each mapping task, subjects described the map they drew, how they drew it, and they indicated north, if they hadn't already done so. We measured the three principal topological relationships the subjects mapped and compared them to the actual ratios.

Preliminary Findings

In both conditions, the mapping tasks started and ended at approximately the same time during the interview (see Table 1). The indoor interviews lasted on average about 15% longer than the outdoor interviews mostly due to additional time needed for image resizing and management and toggling between photographs. The mapping tasks usually lasted around three minutes, with the exception of the second outdoor mapping task, which took noticeably less time to complete.

Initially, in the outdoor condition, subjects tended to map the lagoon as an elongated oval shape ($NS/EW_{lagoon} > 1$) with a wide patch of land depicted between the lagoon and the Lake ($EW_{lagoon}/ EW_{Land.} \leq 1$) (see Table 2). In the indoor condition, however, the lagoon was typically represented relatively long, but without much space for land between the lagoon and the Lake. In both conditions, after having seen and experienced more of the lakefill, or perhaps having had the experience mapping, subjects drew the relationships among features closer to the actual values, portraying the lagoon more like a bulb or bean than like an oval and depicting the land beside the Lake relatively more narrow (see Figure 2A). Interestingly, after walking around the lagoon, more than twice as many subjects in the outdoor condition (n=8) than subjects who mapped from photographs in the indoor condition (n=3) lengthened the lagoon by including the football field shaped feature near its southern tip (see Figure 2B). This observation suggests that certain features of this landscape may be easier to grasp by being in the actual location than by viewing representations of that place. We find that constructing maps from digital photographs, just like being in the location being mapped, can be a productive and meaningful context for representing a local landscape. Future work will investigate how learners construct and use maps and other symbolic representations to learn science across contexts, in class and on field trips.

Figures and Tables

Table 1: Average interview length and durations of mapping tasks within and across contexts.

Time (min:sec)	Outdoor	Indoor
Average Interview Length	42:06	49:48
Average Start-Finish Times for First Mapping Task	11:24 - 14:50 (3:26)	14:09 - 17:28 (3:19)
Average Start-Finish Times for Second Mapping Task	35:40 - 38:00 (2:20)	43:00 - 45:54 (2:54)

Table 2: Average ratios of distances between three topological features.

	First Mapping Task		Second Mapping Task		Actual Ratio
Topological Relationship	Outdoor	Indoor	Outdoor	Indoor	
EW_{lagoon}/ EW_{Land}	1.3	2.0	2.0	2.5	3.0
NS/EW_{Land}	3.6	5.7	5.5	4.2	3.8
NS/EW_{lagoon}	2.2	1.5	1.6	1.5	1.3

Figure 1. The route walked or viewed through photographic representations during each interview.

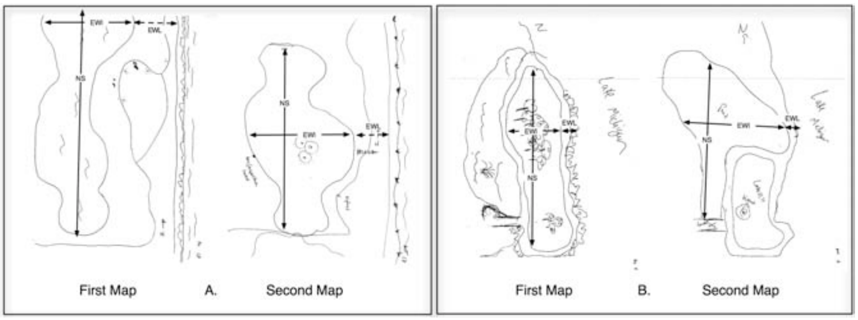

Figure 2. Two example drawings. A. At the widest part of the lagoon, note the shift in lagoon width relative to land width. B. This subject chose to include a rectangular tail toward the south.

References

Greeno, J. G. (1998). *The situativity of knowing, learning, and research*. American Psychologist, 53, 5-26.

Liben, L.S. (2006). Education for Spatial Thinking. In: Renninger, K.A., Sigel, I.E. (Eds.). *Handbook of child psychology, sixth edition, vol. 4: Child psychology in practice* (pp. 197-247). Hoboken: Wiley.

National Research Council. (2006). Learning to Think Spatially. Washington, D.C.: National Academies Press.

Utall, D. H. (2000). Seeing the big picture: Map use and the development of spatial cognition. *Developmental Science*. 3, 247-286.

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Children Learning Science through Engineering: An Investigation of Four Engineering-Design-Based Curriculum Modules

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Abstract: This research investigates the use of engineering design challenges as the basis for primary school science learning environments. We used pre-post tests to compare engineering-based students' science content gains to those of students using their district's typical science curriculum. Across the domains of animal adaptations, simple machines, material properties, and sound, the engineering-based science students showed significant pre-post learning gains, and for all domains except sound, their gains were significantly higher than those of comparison students.

Introduction

Recent investigations of the use of technological design activities as contexts for secondary science instruction have produced promising findings (e.g., Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004). Primary students may be even more receptive to design-based science instruction, since children of this age have been found to exhibit less apprehension toward designerly endeavors than do adults or adolescents (Baynes, 1994). When children engage in design activities that require specific scientific expertise, they may make progress toward two important learning outcomes: knowledge of and skills in engineering design (Pearson & Young, 2002) and improved understanding of the science they use in the service of design completion (Layton, 1993).

We have developed four new curriculum modules to investigate the impact of using engineering design in primary-grade science learning environments. Our approach to incorporating engineering design problems into primary-level science instruction draws upon the Learning by Design™ approach to middle-school science instruction (Kolodner, 2006). It also reflects the perspectives of situated cognition (Brown, Collins, & Duguid, 1989) and socio-constructivistism (Driver, Asoko, Leach, Mortimer, & Scott, 1994). We view science learning as comprised of both social enculturation into practices and personal construction of ideas. Engineering design is one social activity that requires the use of both science practices and science content knowledge.

Method

We are exploring the research question: what are the consequences of using engineering-design-based activities as contexts for specific science content instruction in the upper primary grades? To investigate this question, we have collaborated with local teachers to develop and implement four design-based science curriculum modules for third- and fourth-grade classrooms. Each module poses an overarching engineering design challenge as a motivator for science investigations within a particular science domain, uses interlocking (LEGO ™) construction elements and electronic sensors as tools for prototyping, and requires approximately 12 hours of instructional time. The *Design a Musical Instrument* module centers on the science of sound, *Design a Model House* focuses on the properties of materials and objects, *Design an Animal Model* emphasizes the structural and behavioral adaptations of animals, and *Design a People Mover* focuses on the force-distance trade-offs of simple machines. The module learning objectives are aligned with local and national science content standards.

Fourteen third- and fourth-grade teachers from six urban public schools in the northeastern United States volunteered to implement at least one of the four engineering design-based science modules. Before and after module enactment, their students completed paper-and-pencil science content tests. These pre-post tests were also administered in twelve comparison classrooms of the same grade levels and in the same geographical area. We refer to these as comparison classrooms because their science curricula had been chosen by teachers and district supervisors to meet local and national science learning standards on animal adaptations, simple machines, material properties, or sound, but they did not use LEGO-engineering design activities. That is, the comparison teachers used their typical science instruction methods to address the same learning objectives addressed by the engineering-design-based modules. There was one science test form for each of the four science domains. The material properties and sound tests each had four open-response and five multiple-choice items. The animal adaptations and simple machines tests each had five open-response and five multiple-choice items. Each item addressed one learning standard from the relevant science domain.

Results

The students' responses to the open-response items were scored by two raters according to a 2-point rubric. Inter-rater reliability and percent exact match were above 0.8 for all questions. Multiple-choice responses were scored either 0 or 1 point. Total test scores were computed by summing the item scores and dividing by the maximum possible number of points. Thus, all tests scores are represented as percentages.

Overall, paired t-tests revealed significant gains from individual pretests to posttests, across all four domains and both treatment groups. However, there was a main effect of treatment on the magnitude of pre-post gain score. On average, in three of the four science domains (material properties, simple machines, and animal adaptations), the engineering-design-based science students improved significantly more ($p<.01$) than the comparison students, as shown in Figure 1. In the domain of sound, the engineering students' average gain was higher than that of the comparison students, but this difference was not significant. However, as shown in Figure 2, the engineering students earned equivalent sound posttest scores, despite having significantly lower sound pretest scores than the comparison students. Thus, after the engineering-design-based curriculum module on sound, students were able to achieve at levels equal to those of comparison students who had previously been outperforming them. In fact, on the posttests, students in engineering-based science classrooms achieved at statistically equal or higher levels in all domains but animal adaptations.

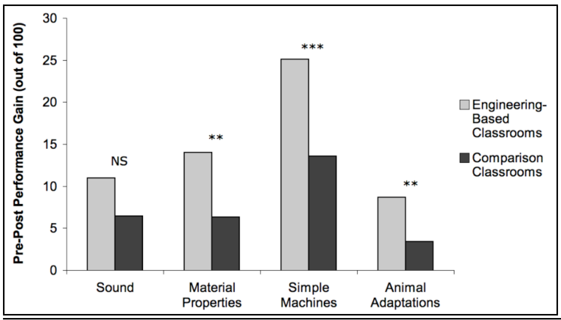

Figure 1. Average learning gains after engineering-design-based and comparison science instruction.

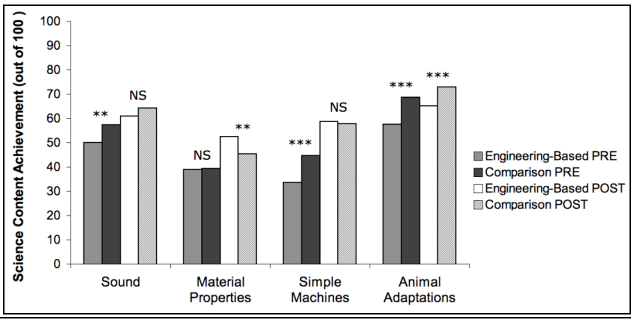

Figure 2. Average pretest and posttest scores in engineering-design-based and comparison classrooms.

Discussion

These results suggest that using engineering design as the basis for science learning environments may facilitate children's learning in the domains of sound, material properties, simple machines, and animal adaptations. However, for young students, the impact of engineering-design-based science curricula appears to vary across science domains. In this study, animal adaptations was the only domain in which students in engineering-design-based classrooms performed significantly lower at posttest than did comparison students, despite having shown significantly greater gains from pre- to posttest. We speculate that students in the comparison classrooms outperformed students in the engineering-based classrooms on the animal adaptations posttest because this domain is within the discipline of life science, which primary grade teachers have traditionally favored. Though the engineering-based *Design an Animal Model* curriculum was effective, comparison curricula were also effective because primary grade teachers have developed strong instructional programs for life science. In contrast, in the discipline of physical science, which includes the sound, material properties, and simple machines domains, there may be more room for design-based science to make an impact on children's learning.

References

Baynes, K. (1994). Designerly play. Loughborough, England: Loughborough University of Technology.

Brown, J.S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher,* 18(1), 32-42.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher,* 23(5), 5-12.

Fortus, D., Dershimer, R. C., Krajcik, J. S., Marx, R. W., & Mamlok-Naaman, R. (2004). Design-based science and student learning. *Journal of Research in Science Teaching, 41*(10), 1081-1110.

Kolodner, J. L. (2006). Case-Based Reasoning. In K. L. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 225-242). Cambridge: Cambridge University Press.

Layton, D. (1993). *Technology's challenge to science education: Cathedral, quarry or company store?* Open University Press.

Pearson, G., & Young, T. A. (Eds.) (2002). *Technically speaking: Why all Americans need to know more about technology.* Washington, D.C.: National Academies Press.

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Robot Diaries: Encouraging and Enabling Technological Creativity

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Abstract: The ubiquity of new technologies has led many educators and researchers to wonder about the best way to prepare students for participation in a digital world. The *Robot Diaries* workshop provides an opportunity for adolescent girls to engage with technology in creative ways. Preliminary analysis suggests the workshop enables three patterns of creative technology engagement: technical, integrative, and expressive. These findings have implications for understanding the range of fluency pathways available in such settings.

Research conducted on out-of-school technology use suggests that even school-aged children have frequent access to technologies such as computers, game systems, and mobile phones (Sefton-Green, 2006). But what type of engagement do most children experience with technology? A survey of British children between the ages of 9 and 18 suggests that the most common computer activities in this population include writing and searching the Internet, while more creative endeavors such as making websites, animations or films were reported less frequently (Kent & Facer, 2004). Were we to characterize the technology engagement of the students interviewed by Kent and Facer, those that primarily engage with computers by using word processing programs or searching the Internet might fall into the category of technology 'consumer' (Resnick & Rusk, 1996). In other words, they are comfortable navigating and utilizing existing technologies but stop short of creating or designing. These consumers represent the mid-point on a continuum of technology engagement, with non-users of technology on one extreme and fluent technologists on the other. Existing research provides rich descriptions of individuals at multiple points along the continuum (e.g., Barron, 2006; see also NRC, 1999).

The question remains of how best to encourage movement along the fluency continuum. The current work explores this question by defining habits of mind associated with fluent technology engagement, and examining the implementation of a learning environment designed to support them. *Robot Diaries* is an out-of-school workshop that promotes the development of technological fluency through participation in creative robotics (see Hamner et. al, 2008, for a description of earlier workshops).

Research Context

The Robot Diaries workshop is designed to support the development of three habits of mind consistent with fluent technology engagement:

- Approaching technology both as a tool and as a creative medium, and understanding how to express one's own interests with, in, or through technology.
- Understanding how to engage in a design process.
- Seeing one's self as competent to engage in acts of technological creativity.

In the workshop, middle school-aged girls (roughly ages 10-13) build expressive communication robots using a combination of crafts and robotic materials (e.g., motors, LED's, sensors). Each girl designs and builds her own programmable robot, which can use light, sound, and movement to tell stories, express emotions, make statements, or otherwise engage in communication (see figure 1). A networking site allows workshop participants to share their robot programs with other members of the group.

The data presented in this paper are drawn from a Robot Diaries workshop run as part of a homeschool enrichment program. Participants were seven homeschooled students (all female) between the ages of 9 and 14. Two homeschooling parents ran the workshop. The instructors, both female, were trained on the curriculum and technology prior to the start of the workshop. Each instructor had a daughter in the workshop. Researchers observed the workshop, conducted interviews with participants, parents, and instructors, and collected workshop related artifacts (e.g., design journals, video journals) for analysis.

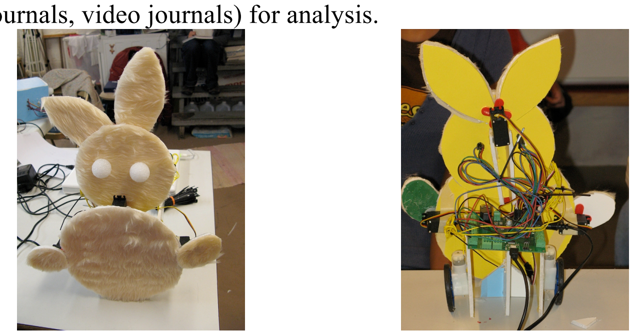

Figure 1. Technology built by a participant during a *Robot Diaries* workshop (front and back views).

Research Questions
The primary research questions for Robot Diaries concern the workshop's ability to forward the habits of mind identified above. For each habit of mind, we can ask: (1) Did participants move towards this understanding, and (2) What aspects of the workshop facilitated their movement? The current paper examines participants' movement towards the first habit of mind, seeing technology as a creative medium.

Preliminary Findings
Amabile's (1996) definition of the term 'creative' provides a useful framework for understanding technological creativity: "a product or response will be judged as creative to the extent that (a) it is both a novel and appropriate, useful, correct or valuable response to the task at hand, and (b) the task is heuristic rather than algorithmic" (p. 35). This definition, which emphasizes the novelty (to the individual) and appropriateness or value of the response, leaves room for the creation of technologies that respond or react to situations, circumstances, or events in functional or aesthetic ways.

A preliminary analysis of the Robot Diaries workshop data suggests three primary categories of creative response to the technology: technical, integrative, and expressive.

Technical Creativity
Technically creative responses include those that required participants to adapt their technical knowledge to achieve a particular outcome. For example, the creator of the robot pictured above wanted her robot to move on wheels, but was concerned that the two wheels would not properly coordinate if they needed to be programmed separately. Her solution was to plug the wires for each wheel into the same port, so that they were subject to the same programming controls.

Integrative Creativity
Participants achieved 'integrative creativity' by integrating the technology with a personal or fictional narrative. Examples of integration with a personal narrative include one participant's spoof of a presidential campaign commercial (in her commercial, the robot expresses its support for a candidate in the 2008 election), and another participant's 'trick or treat' robot which was dressed up for Halloween and used its sensor and speaker to request candy from passers-by. Examples of a fictional narrative include creating a 'persona' for the robot, such as one participant's desire to build a robot whose actions suggest it is afraid of the dark.

Expressive Creativity
Participants achieved 'expressive creativity' by developing novel ways of communicating emotion in their robots. Examples include one participant's use of light patterns to simulate moving feet on her robot.

Conclusions
Preliminary analysis suggests that Robot Diaries participants displayed a variety of creative responses. This analysis helps us understand the range of fluency pathways that may exist inside such a community. Future analysis will examine the prevalence of each pathway and consider the impact of workshop design.

References
Amabile, T. M. (1996). *Creativity in context*. Boulder, CO: Westview Press.

Barron, B. (2006). Interest and self-sustained learning as catalyst of development: A learning ecology perspective. *Human Development*, *49*, 193-224.

Hamner, E., Lauwers, T., Bernstein, D., Nourbakhsh, I., & DiSalvo, C. (2008). Robot diaries: Broadening participation in the computer science pipeline through social technical exploration. *Proceedings of the AAAI Spring Symposium on Using AI to Motivate Greater Participation in Computer Science*.

Kent, N., & Facer, K. . (2004). Different worlds? A comparison of young people's home and school ICT use. *Journal of Computer Assisted Learning*, *20*, 440-455.

National Research Council (NRC). (1999). *Being fluent with information technology.* Washington, DC: National Academy Press.

Resnick, M., & Rusk, N. (1996). The computer clubhouse: Preparing for life in a digital world. *IBM Systems Journal 35*(3&4), 431-439.

Sefton-Green, J. (2006). *Literature review in informal learning with technology outside school* (Tech. Rep.). Bristol, UK: Futurelab.

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Patterns of interaction and everyday knowledge sharing in Social Network Environments

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Abstract: Our research explores online social networking sites to describe the patterns of participation and knowledge sharing in these spaces. We examine how knowledge is shared and how participation is potentially shaped by social or material resources of the space. Our presentation will focus on data gathered from two different types of social networking sites.

Theoretical Background

Educational researchers have begun to explore how people learn in a range of informal contexts, where free-choice learning is the dominant focus, and which involves participation within social networks of families, hobbyists, or other communities (e.g. Bell et al., 2009; Dierking & Falk, 1994). A fundamental characteristic of informal learning is that learners have some choice over what they want to learn, and is thus tightly connected to individual interests or intentions (Bell et al). Investigations of informal learning have been conducted within contexts such as museums (Ellenbogen et al, 2004; Falk & Dierking, 2002), farming (Saxe, 1991), and game playing (Nasir, 2002). Learning in informal settings can be framed within sociocultural perspectives, where learning is viewed as individual participation within a community of practice (Ellenbogen et al, 2004) and where cognitive shifts in individual reasoning are closely linked with the social processes that are part of the sociocultural setting (Nasir, 2005). Thus, learning can be considered as participation in everyday, situated activities that arise from interaction with material and social resources (Barab & Roth, 2006).

Online learning communities are often studied in classroom or professional development contexts. Online communities can be either created by design or emerge in more self-organized ways because of their function in the world (Barab, 2003; Barab & Roth, 2006; Hoadley, in press). Our goal is to examine participation in informal, online social networks. Broadly characterized as social network sites (identified by Boyd & Ellison, 2007), these online spaces offer individuals the opportunity to establish an identity within a bounded context and interact with others that share similar interests (Gunawardena et al, 2009). These activities closely resemble Wenger et al's (2002) definition of a community of practice as a group of individuals who share interests about a topic and engage with one another to deepen knowledge. The communities we are exploring foster networks of weak relational ties solely online, differentiating them from notions of community with sustained history or common heritage (Barab & Duffy, 2000). Network theory allows the study of some of these aspects, by exploring the nature of ties between the community -- i.e., how are nodes (or actors in the network) connected to other nodes with ties. For example, communication ties show who talks to whom, workflow ties show who provides and receives resources, and proximity ties show who is spatially/electronically close to someone else in the network (Katz et al., 2004).

Our research explores how everyday, online social worlds create opportunities for participation that are quite different from those encountered in formal educational settings. Yet, these spaces nonetheless may serve to mediate knowledgeable participation and accomplishment of goals in everyday life worlds (Barab & Roth, 2006) of people. Third spaces (Moje et al., 2004), which is closely associated with hybridity theory, is a theoretical construct that may provide a useful perspective for considering everyday learning in online social network spaces. Third spaces describe spaces where new forms of participation are established through a merging of a first space (e.g., everyday home contexts) and a second space (an institutional space like schools or work, or formal technical or scientific discourse) (Bell et al., 2009; Moje et al.). Bell et al. forward the notion that virtual worlds, like chat rooms or game worlds, might be considered third spaces because they are neither home nor work spaces, and provide a "unique potential for the development of identity where new resources and constraints evolve in the social milieu of the virtual space" (p. 264). Bell et al (p. 264) further note: "Whereas geographic, cultural, and technical boundaries have historically constrained cultural exchange among groups and individuals, virtual environments can facilitate transactions across these barriers, opening up new intersections of people, tools, and traditions to support identity development."

Research Questions

The following questions guided our research:

What patterns of participation are visible in various social network communities?

- How are patterns of participation related to membership within the community?
- How do participants share knowledge within the group?

Research Context and Methodology

Our research examines existing social networking sites. We focus on data gathered from two different types of social networking sites: (1) public hobby sites (e.g., ESPN Fantasy Sports-Basketball); and (2) self-directed learning social network sites (e.g., language, health). . We use primarily a descriptive research design to observe participant discourse without influencing it. Data were based on discussion posts within social network sites. Social Network Analysis (using *UCI-Net)* and content analysis were conducted for some of the sites.

Preliminary Findings and Implications: *What patterns of participation are visible in informal social networking communities?*

To address questions about the relationship between patterns of participation and community membership, our data analysis has thus far focused on examining social networks within the Fantasy Sports site. The site attracts a large number of participants, approximately 1300 or more, who contribute between 50,000-80,000 messages per year. We accessed data for two years from 2004-05 and 2005-06, totaling about 150,000 messages. Our initial analyses of the networks in this site produced a dense, highly connected sociogram (leftmost image in Fig. 1), which was difficult to parse. We subsequently focused attention on cliques with 30 or less actors to identify highly connected individuals and patterns of participation within those cliques. By identifying these cliques, we hoped to gain a better understanding of actors (participants) who were most prominent in the networks. The two right most sociograms in Fig. 1 indicate cliques from 04-05 and 05-06, which show participation by some of the same actors, i.e., the nodes marked 8, 9, and 19. As is visible in the sociograms, we see that the participant represented by node #9 has moved into a more central position in the clique in the second year of participation, while the participant represented by node #8 has moved only a bit closer to the center of the network. Participant #19 remains at a similar location of centrality in both years. We hypothesize that this change in degree centrality (i.e.,the total number of ties that connect the participant -- both ingoing and outgoing) could be related to personal connections with other actors in the network and the quality of communication. Until this point, social network analysis has helped to focus our attention on specific groups of interest within this overall community, as well as on specific individuals with greater prominence within each of the cliques. Our next step is to qualitatively explore the ties between these participants to identify the nature of participation, knowledge and resource sharing, and identity enactments.

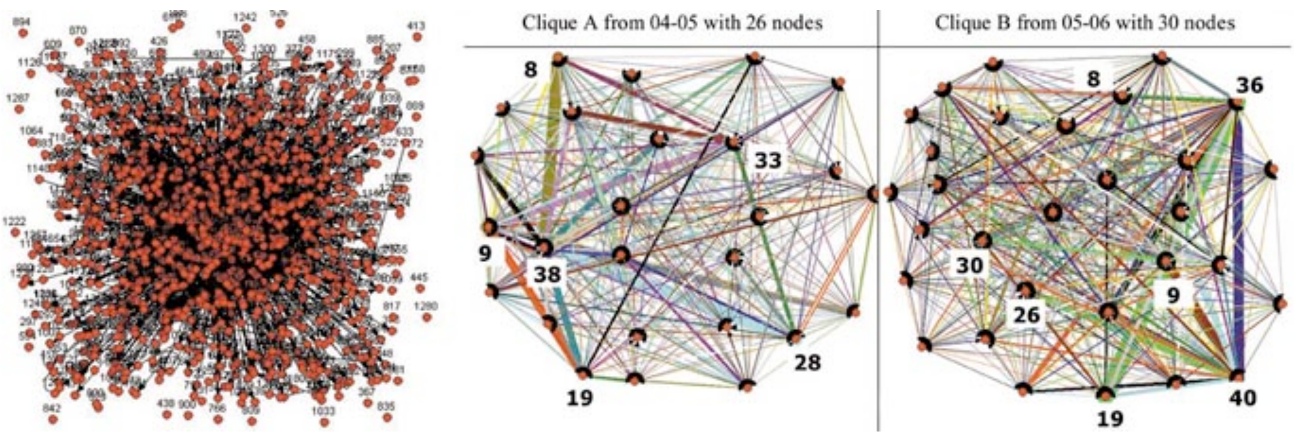

Figure 1: Sociogram for the whole fantasy sports network 2004-2005 and cliques from 04-05 and 05-06

To examine knowledge-sharing practices in social network spaces, we identified recurrent patterns of discourse that emerged from several online community discussion boards. Patterns included: (a) knowledge telling; (b) seeking advice/explanation; (c) experience sharing; (d) public deliberation; (e) mutual goal setting and achievement; (f) data sharing to improve practice.

Potential Significance

The potential significance of this work lies in its contribution to the growing literature on lifelong, informal learning (Bell et al., 2009). Our research studies online spaces where people voluntarily go to learn and to participate in a shared goal or activity. This research may add to the knowledge base of how participants exchange knowledge and practices, as well as extend what is known about online virtual spaces as "third spaces" for everyday learning (Moje et al., 2004).

Bibliography

Barab, S.A. (2003). An introduction to the special issue: Designing for virtual communities in the service of learning. *The Information Society, 19*, 197-201.

Barab, S. A., & Duffy, T. (2000). From practice fields to communities of practice. In D. Jonassen and S. Land (Eds.), *Theoretical foundations of learning environments*. (pp. 25–56). Mahwah, NJ: Lawrence Erlbaum Associates.

Barab, S. A., & Roth, W.-M. (2006). Curriculum-Based Ecosystems: Supporting Knowing from an Ecological Perspective. *Educational Researcher*, *35*(5), 3-13.

Bell, P., Lewenstein, B., Shouse, A., & Feder, M. (Eds.). (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington, DC: National Academic Press.

Boyd, D. M., & Ellison, N. B. (2007). Social network sites: Definition, history, and scholarship. Journal of Computer Mediated Communication, 13(1), article 11.

Dierking, L. D., & Falk, J. H. (1994). Family behavior and learning in informal science settings: A review of the research. Science Education, 78(1), 57 – 72.

Ellenbogen, K. M., Luke, J. J., & Dierking, L. D. (2004). Family Learning Research in Museums: An Emerging Disciplinary Matrix? Science Education, 88(S1), S48-S58.

Falk, J. H., & Dierking, L. D. (2002). Lessons without limit : how free-choice learning is transforming education. Walnut Creek, CA: AltaMira Press.

Fields, D. A., & Kafai, Y. B. (2009). A Connective Ethnography of Peer Knowledge Sharing and Diffusion in a Tween Virtual World. International Journal of Computer-Supported Collaborative Learning, 4(1), 47-68.

Garcia, A., Standlee, A., Bechkoff, J. & Cui, Y. (2009). Ethnographic approaches to the internet and computer-mediated communication. *Journal of Contemporary Ethnography, 38* (1), 52-84.

Gunawardena, C. N., Hermans, M. B., Sanchez, D., Richmond, C., Bohley, M., & Tuttle, R. (2009). A Theoretical Framework for Building Online Communities of Practice with Social Networking Tools. Educational Media International, 46(1), 3-16.

Hoadley, C. (in press). Roles, design, and the nature of CSCL. *Computers in Human Behavior*.

Katz, N., Lazer, D., Arrow, H., & Contractor, N. (2004). Network Theory and Small Groups. Small Group Research, 35(3), 307-332.

Leander, K., & McKim, K. (2003). Tracing the Everyday 'Sitings' of Adolescents on the Internet: a strategic adaptation of ethnography across online and offline spaces. *Education, Communication, & Information 3* (2), 211-240.

Miller, D., & Slater, D. (2000). The Internet: An ethnographic approach. New York, NY: Berg.

Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working Toward Third Space in Content Area Literacy: An Examination of Everyday Funds of Knowledge and Discourse. Reading Research Quarterly, 39(1), 38-70.

Nasir, N. i. S. (2002). Identity, Goals, and Learning: Mathematics in Cultural Practice. Mathematical Thinking and Learning, 4(2-3), 213-247.

Nasir, N. i. S. (2005). Individual Cognitive Structuring and the Sociocultural Context: Strategy Shifts in the Game of Dominoes. Journal of the Learning Sciences, 14(1), 5-34.

Wenger, Etienne, McDermott, R., & Snyder, W. (2002) *Cultivating communities of practice: a guide to managing knowledge*. Cambridge, Mass.: Harvard Business School Press.

Small Groups, Big Mistakes: The Emergence of Faulty Rules During a Collaborative Board Game

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Abstract: Recent research using games as learning environments has provided us with examples of situated learning processes (e.g., Gee, 2007). Board games, in particular, foster rich think-aloud cognition and small group reasoning (Smith, 2007). This study uses a collaborative board game as a site for understanding sense-making in small groups. We investigate how groups 'reconstruct' rules, and unpack how and when they coordinate an understanding of goals. We suggest this is done with the aid of. *handles*: concrete signifiers, such as physical objects, words, or gestures that players use as substitutes for complex rules.

Introduction

Recent research using games as learning environments has provided educational researchers with new examples of situated learning processes (e.g., Gee, 2007). Many of the most recent studies have focused on computationally based games, but we maintain the position that the affordances of game environments, both for observing and orchestrating learning, are not restricted to the computational medium. Board games, a similarly rule-based and interactive game environment, constitute an especially promising class of games for study because foster the kinds of think-aloud cognition and small group reasoning that is the target of empirical research and educational reform efforts (Smith, 2007). In this study, we use a collaborative board game as a site for understanding sense-making in small group collaboration. We examine a situation where players are provided with all the materials packaged with a collaborative board game and unpack how and when they coordinate an understanding of their individual and group goals. In our pursuit of this endeavor, we have noticed a phenomenon across our samples thus far in which rule reconstruction goes awry. Essentially, players make up their own rules without realizing they are creating something new that deviates from what is prescribed by the rulebook. Upon iterative review, and as we will describe in this paper, these faulty rules are seeded by players grasping at what we describe as a "*bad handle"*.

As will be illustrated by our case, handles serve in these social sense-making situations as material anchors (Hutchins, 2005) around which players share and build knowledge. Handles are concrete signifiers, such as physical objects, words, or gestures, which players repeatedly use or reference as stand-ins for more complex concepts and rules. Problems arise when the group's understanding of a complex rule is shaped by a handle that they have (perhaps unwittingly) chosen. The original referenced meaning is lost or converted into something new.

The interest of this work to the Learning Sciences community is two-fold. First, it is an expansion of the recent interest in research related to learning that takes place in and around games and gaming practices (e.g., Squire & Barab, 2004). The second point of interest in this work is in small group collaboration. Collaborative discourse has long been an interest in the Learning Sciences (e.g., Barron, 2003; Engle & Conant, 2002). What we intend to do is carefully consider how the signifiers that we describe as "handles" are instrumental to the sense-making and discourse that takes place.

Handles and Material Anchors

Our term *handle* is a targeted extension of Hutchins' (2005) definition of material anchor to this context. Hutchins uses the term material anchor to describe how physical objects (or signifiers thereof) solidify group understanding of a particular metaphor. An example he provides is that subjects will be more successful in identifying the correct answer in statement 2 than statement 1:

1. If x is true, then y is true. We know that y is not true. Is x true?
2. If this is a garnet, then it is a semi-precious stone. We know that this isn't a semi-precious stone. Is it a garnet?

Statement 2 is easier to understand, because subjects can use outside information (D'Andrade, 1989).

Groups do not have a facility for sharing the same understanding of the rules other than through concrete signifiers in the world. Thus, material anchors are a necessary mediator of group understanding – they form one of only a few anchors around which groups can share understandings of an abstract concept (Kripke, 1982). However, the outside information that individuals unconsciously use to understand these material handles colors how they process the problem. Fauconnier & Turner (2002) describe this mix of unconscious understanding and target content as involving *conceptual blending*. A *bad handle* can be understood as an anchor that results in conceptual blending that, as it is taken up by the group, nudges groups away from correct interpretations of shared information toward jointly agreed-upon misunderstandings.

Example: Role Handle

For this work, we collected multiple video-recorded observations of four groups as they were provided with a collaborative board game about disease spread, *Pandemic*, to learn and play. The participants gathered for up to three two-hour game play sessions. Twelve of the sixteen participants were undergraduate students at a large university in the American West. The other four were a group of adults from the same regional area. Participants were told at the beginning of the game sessions that the researcher would not participate nor answer any questions related to the game, and as much as possible, the players should act as if the researcher and camera were not there. Transcripts were generated of the initial game sessions for all four groups.

We present a short example to illustrate how a handle can be taken up and seed bad information. The group from the excerpt below used a bad handle to misunderstand the word 'role' in relation to the game. At the beginning of each game of *Pandemic*, each player is randomly assigned a permanent game role through distribution of 'role cards'. Each role has unique capabilities that allow that player to take different "special" actions throughout in the game. The error that the group made was to overlook an entire phase of the game because of how they handled of the word 'role'. Only when their game was entirely finished did they begin to notice where the problem had been:

Andi: [reading from the instructions] Special event: the next player to play the infector phase can skip their turn entirely.

Jesse: How come we haven't had any outbreaks [i.e., difficulty increases in the game]?

...

Elena: [in reference to Andi's reading] What's the infector phase? The infector example, lets see: [she reads from instructions] "Brandon's playing the infector. To finish his turn the infector marker is on three to end the infector rate." Oh... whose, is anyone's role card the infector?

Jesse: This [an unused role card, face down, located to the side of the board] is the infector right here.

Throughout the game, the group had conflated the existence of the "infector phase" with a role one must play and, in turn, with the "role card." They substituted the "role card" concept in every situation in which the "infector phase" should have been played the game. This substitution provided a convenient 'handle' with which to incorrectly interpret large chunks of the game.

Conclusions

Small, self-directed groups can make big mistakes when building rules. Sometimes this can occur when ideas are not heard or built upon (e.g., Barron, 2003). However, we have seen instances here where listening to others and building up on ideas leads to errors. Individuals were all attempting to coordinate understandings through physical and verbal externalizations their individual rules, and, as such, the group ultimately changed the content of the rules for the game as a whole. Our work thus serves to add to our understanding of how interacting with signifiers might change collaborative rule construction. Through this poster, we demonstrate some of the potential for Learning Sciences games research can involve board games, and in particular how some of the observable interactional phenomena can be traced to group interactions and handles. Although still preliminary, we conjecture from these observations that small design changes to target bad handles could manifest in significant learning gains in the domain of a complex gaming activity. A future paper will outline the effect of specific design implications for collaborative rule-building.

References

Barron, B. J. S. (2003). When smart groups fail. *Journal of the Learning Sciences, 12*(3), 307-359.

D'Andrade, R. G. (1989). Culturally based reasoning. In A. Gellatly, D. Rogers & J. A. Sloboda (Eds.), *Cognition and social worlds*. Oxford University Press.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition & Instruction, 20*(4), 399-483.

Fauconnier, G., & Turner, M. (2002). *The way we think : conceptual blending and the mind's hidden complexities*. New York: Basic Books.

Gee, J. P. (2007). *What video games have to teach us about learning and literacy.* New York: Palgrave Macmillan.

Hutchins, E. (2005). Material anchors for conceptual blends. *Journal of Pragmatics, 37*, 1555-1577.

Kripke, S. (1982). *Wittgenstein on Rules and Private Language*. Oxford: Blackwell.

Leacock, M. (Creator). (2007). *Pandemic*. Mahopac, NY: Z-Man Games.

Smith, H. (2007). The Social and Private Worlds of Speech: Speech for Inter- and Intramental Activity. *Modern Language Journal, 91*(3), 341-356.

Squire, K. & Barab, S.A. (2004). Replaying history. *Proceedings of the International Conference of the Learning Sciences (ICLS-04)*, Los Angeles, CA.

Investigating teacher growth in the context of content innovation

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Abstract: Our study expands current literature on the professional growth of experienced teachers in educational innovations. Using a case study approach, we investigate changes in instructional practice of an experienced science teacher over two cohorts of students in the context of a content innovation, and reveal the reasons behind these changes. The Interconnected Model of Teacher Professional Growth framework is used to interpret findings.

Introduction

Teachers continually draw upon a range of experiences and information to help mediate their learning and teaching in new contexts, but these vary according to their beliefs, attitudes, and perceptions (Clark & Hollisworth, 2002). Although theories and models of teacher learning and growth already exist, most studies focus on novice teacher learning, and very few have examined teacher learning and growth for more than a year (Henze et al., 2009; Mouza, 2009). Our study-in-progress investigates the changes in instructional practice of an experienced science teacher over two cohorts of students. We compare changes in instructional practice when novel nanoscience content is taught for the first time in 2008 and again in 2009. We make the assumption that when teachers implement innovations learned through professional development (PD), they undergo stages of change that are a result of underlying factors across various salient domains (Mevarech, 1995).

Theoretical Framework and Research Questions

Drawing from novice-expert and cognitive science literature, we define professional growth as a process of change in teachers' mental models, beliefs, and perceptions regarding children's minds and learning, and knowledge and competencies concerning teaching (Richardson & Placier, 2001). There are several models that offer explanations for teacher professional growth. Sprinthall et al. (1996) classify them into three categories: craft, expert and interactive. Interactive models integrate both craft and expert models and recognize that growth is enhanced through reflection of experiences and supported by PD. The Interconnected Model of Teacher Professional Growth (IMTPG) is one such model (Clark & Hollisworth, 2002). According to IMTPG, change occurs through mediating processes of reflection and enactment in four distinct domains: personal; practice; consequences; and external. IMTPG acknowledges the non-linearity of professional growth by identifying the multiple growth pathways between domains. It also posits that any interpretation of growth requires an appreciation of the changes across these interconnected domains. As this interactive perspective aligns with our belief that teachers should be actively involved in professional growth through reflection and enactment, we chose IMTPG as our analytical tool for interpreting the changes in instructional practice of the teacher as he repeats the implementation for the second year. Two research questions are formulated: 1) how do the instructional practices of an experienced teacher in a content innovation change from the first to the second year of implementation; and 2) what are the reasons for these changes?

Methods

This study is a slice of a larger project aimed at increasing opportunities in science for students and teachers in underserved schools. Our project specifically addresses knowledge and workforce development goals in the emerging field of nanoscience. Teachers participate in a three-week summer PD workshop, where they construct and pilot nano-related curricular units anchored in cognitively-rich pedagogies, real-world applications, and information and educational technologies. The participant for this study was Mr. R, an eighth grade science teacher in a small public K-8 school with six years teaching experiences. The students had Mr. R as their science teacher for at least two years thus he had a good understanding of students' prior knowledge and aptitudes in science. A case study approach was adopted to compare the two cohorts of students (C1 and C2) as they engaged in activities to learn about nanoscience in the fall semesters of 2008 and 2009. The same researcher observed every 'nano' lesson over the two years. Field notes were analyzed for themes that indicated changes in his instructional practices through an iterative process together with the primary investigator of the larger project. Teacher interviews conducted at the end of each implementation gave insights into the reasons for the changes.

Preliminary Findings and Discussion

Mr. R conducted the same activities for both cohorts of students. These included experiments, a problem-based learning project and a digital media production. We illustrate in depth only one difference in the implementation due to space constraints; the other difference had to do with Mr R's shift in instructional emphasis from simply delivering the novel content and fulfilling the requirement of the project to facilitating deeper student understanding of the novel content. In terms of general sequence and structure, Mr. R infused the new nanoscience content within the atomic theory unit of physical science curriculum for C1, whereas for C2, the new content was introduced only after the atomic theory unit had been taught. Mr. R explained that the change in the implementation sequence was for organizational coherence in the way the content was taught and the pre-requisite understanding of other concepts.

> [It is] organizationally *easier* to do nano at the end of the standard unit. I want to complete the syllabus first before I go into nano. Last year, it was some nano, then atomic theory, then nano again. It's *messy*. So this year, I tried a different approach . . . Because I teach 8th grade, not high school, I have to teach so much of the background stuff first before I can get to the problem. I *can't* teach about unique properties of nanotechnology if the kids don't know what properties are. (Interviews, Oct 22 and 24, 2009)

We used IMTPG to map the reasons for the changes: i) For C1, Mr. R infused nanoscience concepts into the curriculum because he was told to do so during the PD. This is a straightforward case of an external domain enacting on the domain of practice; ii) The instructional sequence resulted in a change in Mr. R's domain of consequence as he reflected that the organization of the curriculum was "messy"; iii) Subsequently for C2, Mr. R tried a new sequence with the knowledge and experience of the first year outcomes; iv) With the second experimentation, a more coherent sequence was developed; v) Mr. R reflected and preferred the revision. His belief in this new organization was affirmed, causing a change in his personal domain. The observation of his initial implementation corroborates Mevarech's (1995) findings where experienced teachers in implementing innovations were observed to depend extensively on the inservice designers and mentors in applying the new knowledge in classroom practice, behaviors consistent with those of novice teachers. The follow-up observations of the subsequent implementation allow us to see the changes and infer the active processes of enactment and reflection undertaken by the experienced teacher. This suggests that while the external domain may have initiated the innovation and dictated how it is implemented, the domains of consequence (i.e., outcomes) and practice (i.e., experimentation) play a more significant role in the adaptation of the implementation. And although still at a preliminary stage of analysis, anecdotally we observed that student products for C2 showed greater depth of understanding of the novel content. The improved student learning outcome may also have served to reinforce Mr. R's preference in his revised organization.

Conclusions and Implications for Further Research

Few studies have compared changes made by experienced teachers to the instructional practice between the first and subsequent implementations of educational innovations. However, such investigations are crucial because they give important feedback to professional developers on how and why innovations are adapted and/or sustained. In our study, we have identified domains of consequene and practice playing significant roles in the adaptation of our innovation. From this finding we suggest that PD incorporates scaffolds to help teachers during the implementation, especially one that encourages both classroom experimentation and reflection as deliberate active processes of change, may enhance the success of innovations in terms of adaptation to specific classrooms and sustainability. Developing such a scaffold will be our long term research goal. Further research will also include other teachers with different characteristics (e.g. age and teaching experience) engaged in similar innovations for a more generalizable and definitive conclusion.

References

Clark, D., & Hollisworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education. 18*, 947-967.

Henze, I., van Driel, J.H., & Verloop, N. (2009). Experienced science teachers' learning in the context of educational innovation. *Journal of Teacher Education, 60*(2), 184-199.

Mevarech, Z.R. (1995). Teachers' paths on the way to and from the professional development forum. In T.R. Guskey & M. Huberman (Eds.). *Professional Development in Education: New Paradigms and Practices* (pp. 151-170). New York: Teachers College Press.

Mouza, C. (2009). Does research-based PD make a difference? A longitudinal investigation of teacher learning in technology integration. *Teachers College Record, 111*(5), 1195-1241.

Richardson, V., & Placier, P. (2001). Teacher change. In V. Richardson (Ed.), Handbook of Research on Teaching. (pp. 905-947). Washington: American Educational Research Association.

Sprinthall, N.A., Reiman, A.J., & Thies-Sprinthall, L. (1996). Teacher professional development. In J. Sikula, T.J. Buttery, & E. Guyton (Eds.), Handbook of Research on Teacher Education. New York: Macmillan.

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Title: Formative Feedback Handheld Tools for Teachers

Abstract: Formative assessment has been found to improve teaching and learning but formative feedback tools are often left out of school data systems. Via a Design-Based Research process we collaborated with 11 elementary school teachers, leaders, and staff to examine data collection practices and design handheld formative feedback tools for classroom practice. The iterative design process revealed surface-level differences but deep functional similarities across teachers and highlighted the tension between data and tool standardization and customization.

A prior NSF-funded study that explored how leaders help their schools develop the capacity to act on achievement data demonstrated the important role played by formative feedback systems (Halverson, Prichett, Grigg, & Thomas, 2005; Halverson, Prichett, & Watson, 2007). "Formative feedback systems are systems of structures, people, and practices that help teachers and administrators translate testing data into practical information for everyday use" (Halverson, Prichett, & Watson, 2007). The study revealed that school data systems typically consist of two levels. One level is a technologically-complex, district-sponsored summative system that meets external accountability requirements. The second level is a distributed, fragmented, teacher-driven formative system located in the classroom. The research found that 1) information was rarely exchanged formally across these levels largely because of the lack of attention paid to the teacher level, 2) tools that provide teachers the kinds of formative information necessary for student learning are often left out of holistic district-school-classroom data system designs, and 3) formative tools that exist are often low-tech paper-and-pencil designs which result in data fragmentation between classroom-based data systems as well as the district system. Therefore, we were interested in understanding specifically how teachers collect, track, make sense of, and reflect on student classroom data and instruction. We wanted to fully describe the classroom-centric formative feedback system that has an immediate, direct impact on learning. Based on these findings, we intended to explore how a software tool could reveal, support, and stretch teacher formative feedback practices. Because we are in an era of mobile technology, we can now think of education as "a conversation in context enabled by continual interaction through and with personal and mobile technology" (Sharples, Taylor, & Vavoula, 2005). In addition, as Roschelle, Penuel, Yarnall, & Tatar (2004) found, teachers need ways to increase the quality of assessment information and need tools that "informate" rather than "automate" existing assessments." This poster describes the preliminary findings from our design experiment to build digital handheld formative feedback data tools with and for the highly mobile classroom teacher.

Method

We selected a design-based research approach for our study as "design is central in efforts to foster learning, create usable knowledge, and advance theories of learning and teaching in complex settings…and for understanding how, when, and why educational innovations work in practice" (Design-Based Research Collective, 2003). A design-based model for research surfaces the real constraints and affordances that shape what professionals see as possible. Such a collaborative, iterative model identifies the moments for which formative feedback tools might be constructed and provides a real-world participatory opportunity for testing and customizing the new tools in context**.**

We collaborated throughout the research process with 11 teachers, leaders, and staff in a rural intermediate school (grades 3-5). We selected the school because of its reputation for effective data use to inform student learning and its established record of improving student test scores as discovered via the prior Data-Driven Instructional Systems study (Halverson, Prichett, Grigg, & Thomas, 2005). We worked with the principal and instructional coach and by purposive sampling, recruited experienced (had taught between 8-18 years) educators who were knowledgeable about both school-wide and classroom-centric data and assessment programs and processes. The participants included two teachers from each of the three grade levels (who teach core academic subjects) as well as the art teacher, instructional coach, literacy specialist, school principal and the district technology coordinator.

We collected 40 teacher-level student data collection and assessment documents. These documents consisted of grade sheets, student-teacher conference tools, weekly quizzes and assessment tools from grade-level subject-matter third-party curricula, observation checklists, rubrics, report cards, and student self-evaluation forms. All teacher-level artifacts were paper-based and half included student data that was de-identified. Via content analysis we developed a detailed typology of assessment practices and codes to inform the tool design in a way that would both support and stretch practice. Parallel to and integrated with the document analysis, we observed the teachers during instruction in order to identify the junctures for which digital formative feedback tools might be used in practice. We also engaged in focus group design meetings. At these meetings we discussed and applied assessment practices to the designs, reviewed assessment software tools and devices, examined interface sketches, and discussed tool feature and functionality needs and priorities.

Preliminary Findings

During the design process, underlying assumptions on formative data practice and use surfaced while the team discussed needs and practices and identified common and individual tools, symbols, and symbol meanings. Our classroom observations suggested that a tool for formative feedback would integrate best with individual and small group activity in the classroom. Our document analysis revealed data collection practices and idiosyncratic assessment symbol system consistencies and variances across teachers and disciplines (See Table 1).

<u>Table 1: Example teacher-centric formative assessment symbol systems</u>

Subject	Teacher 1	Teacher 2	Teacher 3
Math	5, 4, 3, 2, 1, blank, absent	A, N, A/N, N/A ½, 2/3, ¾	+, √, – , blank, abs, LATE
Literacy – Reading Comprehension	3, 2, 1	4/ ☺, 3, 2, 1/ ☹	3, 2, 1, blank, abs, – ◤, ◥

Like our initial document analysis, the design-based research process highlighted a tension between standardization and customization; although we found patterns in how teachers collected and recorded data within disciplines, we also found that teachers generally valued the ability to customize their data-collection tools as well as the data types. Although teachers thought about data collection in terms of the curriculum and assessments already in place in their school, they wanted data collection tools that could be customized to their own needs. Teachers repositioned our initial plan to build a completely standardized tool and encouraged us to enable as much customization as possible.

Conclusion

We intend for this research to contribute to understanding of the formative aspects of school data systems and inform designs for compatible tools that might alleviate the tension between standardization and customization. We hope to stretch formative classroom practices and initiate dialogs about data to influence learning and teaching in new, positive ways. Despite the differences between teachers' formative feedback tools and systems, we believe that we are able to accommodate for deep structural similarities across teachers' formative feedback practices as well as individual differences. Our tool designs could therefore enable informate conversations across teachers and the district data system. We will demonstrate *KidGrid* Apple iPhone/iPod Touch application we built during the poster session in conjunction with a poster of our design-based research process and preliminary findings.

References

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32(1), 5-8.

Halverson, R., Grigg, J., Prichett, R., & Thomas, C. (2005, September). *The new instructional leadership: Creating data-driven instructional systems in schools* (WCER Working Paper No. 2005-9). Madison: University of Wisconsin–Madison, Wisconsin Center for Education Research.

Halverson, R., Prichett, R., & Watson, J., (2007, May). *Formative feedback systems and the new instructional leadership* (WCER Working Paper No. 2007-7). Madison: University of Wisconsin–Madison, Wisconsin Center for Education Research.

Roschelle, J., Penuel, W. R., Yarnall, L., and Tatar, D. 2004. Handheld Tools that "Informate" Assessment of Student Learning in Science: A Requirements Analysis. In Proceedings of the 2nd IEEE international Workshop on Wireless and Mobile Technologies in Education (Wmte'04) (March 23 - 25, 2004). WMTE. IEEE Computer Society, Washington, DC, 149.

Sharples, M., Taylor, J., Vavoula, G. (2005) Towards a theory of mobile learning. To be published in Proceedings of mLearn 2005 Conference, Cape Town.

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The Effect of Teachers' Beliefs and Curricular Enactments on Student Learning in High School Science

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Abstract: This study focuses on a high school urban ecology curriculum that was enacted by twenty-two teachers. We investigated how teachers' beliefs about science instruction and enactment of the curriculum impacted student learning. Results from the hierarchical linear model suggest that teachers' use of lecture, incorporation of group work, level of adaptation of the curriculum and beliefs about argumentation all significantly impact student achievement.

Theoretical Framework

Learning environments consist of a variety of different social and material supports that can interact synergistically to support students in developing rich disciplinary knowledge (Tabak, 2004). Historically, the role of the teacher has been overlooked when examining the impact of curriculum on student learning (Ball & Cohen, 1996). Yet the teacher is essential in enacting curriculum materials in terms of the culture of inquiry that is fostered in the classroom, which ultimately impacts students' development of rich conceptual understandings (Puntambekar, Stylianou & Goldstein, 2007). Teachers' understanding of the curriculum as well as their beliefs about teaching and learning influence their enactment of curriculum (Ball & Cohen, 1996).

Recent research emphasizes the importance of moving away from a traditional model of instruction in which the teacher's main role is that of transmission of information to a new model of a community of learners in which students actively construct their own conceptual understandings (Sawyer, 2006). Although there are numerous qualitative studies investigating the role of such environments, large-scale quantitative studies still need to be conducted to validate these findings and link teaching practices to student outcomes (Thadani, Stevens & Tao, 2009). The large scale studies that have been conducted in science education provide mixed results on student achievement with studies finding that standards-based inquiry teaching practices have a positive effect (Kahle, Meece & Scantlebury, 2000), both positive and negative effects (Von Secker & Lissitz, 1999), and no significant positive or negative effects (Lee, Penfield, Maerten-Rivera, 2009) on student learning. Furthermore, none of these studies investigate teacher beliefs in conjunction with their instructional practices. Consequently, our research question is: How do teachers' beliefs about science instruction and their enactment of an inquiry-oriented high school science curriculum impact students' learning in science?

Study Design

This study took place in the context of a year-long high school urban ecology curriculum entitled *Urban EcoLab: How Can We Develop Healthy Cities?*. The curriculum consists of eight modules covering different topics including patterns of land use, climate change, hazardous waste, public health and biodiversity. Each module consists of approximately 10 lessons that include different activity structures such as inquiry investigations, development of models, role-play, computer simulations, field investigations of their city, and environmental action plans.

The participants in this study included 22 teachers from 21 different schools piloting the urban ecology curriculum and 366 students. The schools were located in three regions of the United States: Northeast, Midwest, and Southwest. Student demographics among schools varied within a spectrum with some schools serving predominantly one race (Black, Hispanic or White) of student and others serving a more diverse group of learners with similar representations of two or more races. Over 50% of the students in most schools participated in a free or reduced lunch plan with only five schools falling below 20% participation. Teacher experience ranged from 1-29 years with an average of 10 years for all teachers.

We collected a variety of data sources to address our research question. Teachers completed a pre-survey, which asked questions about their beliefs about science content, scientific inquiry, and instructional practices. During the enactment, teachers completed module surveys that asked about the level of completion, the level of adaptation, and the amount of time using different activity structures (e.g. lecture, discussion, group work, etc.). The students completed an identical two-day pre and posttest that consisted of twenty-one multiple-choice items and four open ended questions. The open-ended responses were scored by one rater using a rubric. Twenty percent of these open-ended test items were randomly sampled and scored by a second independent rater. Estimates of inter-rater reliability were calculated by percent agreement. Interrater reliabilities for the four questions were 94%, 88%, 96%, and 95% respectively.

Determining the impact of teachers' beliefs and curricular enactment on student achievement is complex because students in the same class are not independent. Multi-level modeling recognizes the dependence and grouping of data, which leads to a more correct estimation of effects and variance. We used Hierarchical Linear Modeling (HLM) in a two-level format to investigate the teachers' beliefs and enactments on student learning (Raudenbush & Bryk, 2001). The creation of the model consisted of three steps. First, we created a fully unconditional model (FUM) to compute the intraclass correlation coefficient (ICC). Next we created a level 1 or within-teacher model to examine the effect of student level variables (e.g. demographics and pre-test) on student achievement. Finally, we developed a level 2 or between-teacher model to examine the effect of teacher level variables (e.g. teacher beliefs and curricular enactments) on student achievement.

Results and Discussion

The fully unconditional model (FUM) suggests that there was a significant difference in student achievement between teachers, $\chi^2 = 255.58$ ($df = 21$), $p < .001$. The reliability of the FUM is high, 0.87, suggesting that it is appropriate to use the adjusted ICC ($\tau/(\tau + (\lambda\sigma^2))$). The adjusted ICC is 0.426, which suggests that 42.6% of the variance in student achievement exists between teachers.

The within-teacher model explored the effects of students' gender and pretest scores. The preliminary results suggest that gender did not have a significant effect, while students' pretest scores did significantly predict their achievement on the posttests, $t = 6.746$ ($df = 363$), $p < .001$. Adding students' pretest scores to the model explained 12% of the variation at level 1.

The between teacher model investigated the impact of teacher beliefs and enactments on student achievement. We first examined the effect of eight enactment variables and seven teacher belief variables on student achievement separately. Three enactment variables had a significant effect on student achievement: the more group work students completed had a positive effect, the more a teacher lectured had a negative effect and the more the teacher adapted the curriculum had a negative effect. Only one of the teacher belief variables significantly impacted student achievement: the more frequently a teacher reported the importance of having students engage in argumentation and the sharing of ideas, the greater student achievement. We then examined each combination of two variables. The only significant combination included both that 1) the more group work students completed had a positive effect on student achievement, $t = 2.096$ ($df = 19$), $p < .05$, and 2) the more the teacher adapted the curriculum had a negative effect on student achievement, $t = -2.248$ ($df = 19$), $p < .05$. Including these two teacher level variables in the model explained 48% of the variance at level 2.

One limitation of this study is that it is dependent on teacher self-report. Self-report of teacher practices can be limited in part because of a lack of shared language between teachers and researchers (Thadani, 2009). Yet these findings suggest that teachers who report having classrooms that align more with a community of learners perspective in which students actively construct their own knowledge (Sawyer, 2006), specifically through argumentation, group work and less lecture, results in greater student learning. Previous research suggests that teacher instructional practices in inquiry science instruction can have different impacts on students' conceptual understanding when measured by multiple-choice items competed to open-ended questions (Puntambekar, et al., 2007). For the final version of this poster, we will extend our analysis to include two separate models for the multiple-choice and open-ended items to investigate whether the effect of teachers' beliefs and enactments was different depending on the measure of students' disciplinary knowledge.

References

Ball, D. L., & Cohen, D. K. (1996). Reform by the book: What is—or might be—the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher, 25*(9), 6-8, 14.

Kahle, J. B., Meece, J. & Scantlebury, K. (2000). Urban African-American middle school science students: Does standards-based teaching make a difference? *Journal of Research in Science Teaching, 37*(9), 1019-1041.

Lee, O., Penfield, R., & Maerten-Rivera, J. (2009). Effects of fidelity of implementation on science achievement gains among English language learners. *Journal of Research in Science Teaching, 46*(7), 836-859.

Puntambekar, S., Stylianou, A., & Goldstein, J. (2007). Comparing classroom enactments of an inquiry curriculum: Lessons learned from two teachers. *The Journal of the Learning Sciences, 16*(1), 81-130.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical Linear Models: Applications and Data Analysis Methods, 2nd Edition.* Newbury Park, CA: Sage Publications

Sawyer, R. K. (2006). Analyzing collaborative discourse. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 187-204). New York, NY: Cambridge University Press.

Tabak, I. (2004). Synergy: A complement to emerging patterns in distributed scaffolding. *The Journal of the Learning Sciences, 13*(3), 305-335.

Thadani, V., Stevens, R. H., & Tao, A. (2009). Measuring complex features of science instruction: Developing tools to investigate the link between teaching and learning. *The Journal of the Learning Sciences, 18*(2), 285-322.

Von Secker, C. E. & Lissitz, R. W. (1999). Estimating the impact of instructional practices on student achievement in science. *Journal of Research in Science Teaching, 36*(10), 1110-1126.

Broadening Participation through Scaffolding

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Abstract: This research project aims to examine how participation in authentic community-situated science contributes to adolescent apprentices' sense of the scientific enterprise and identity development in this discipline. Using a theoretical framework based on the current research perspectives on informal science learning, learning science in the context of the local community, and research on communities of practice, we examine how apprentices develop an identity in science while also strengthening ties to their own community.

Issues Addressed

Our research follows adolescent youth through a year-long community-based science apprenticeship program (CBSA), composed of their peers and members of an oceanographic lab on a large university campus in the Pacific Northwest. The program aims to positively influence the learning trajectory of adolescent apprentices from groups that are underrepresented in the sciences; engage the local community in scientific inquiry through community relevant, researchable questions; and cultivate and showcase the scientific skills and interests of the youth apprentices through presentations of findings through public venues. The guiding research questions are: How does the identity of individual apprentices as science learners shift over the course of their participation in a CBSA? How does their sense of the scientific enterprise change?

Potential Significance

Understanding how adolescent apprentices begin to solidify a scientific identity while leveraging that identity within their own community has implications for future study design in informal science learning. This research can help to bridge the gap between school and community science and provide a new framework for practitioners, as well as for future research.

Theoretical Framework

In order to serve as a bridge between school and community, informal science programs must be culturally-responsive, utilize cognitive apprenticeship models, and focus on authentic, interrelated science practices.

The program should be tailored to the needs, interests and values of the local community (NRC, 2009). Project stakeholders partner to identify specific mentoring supports, educational experiences, and research activities. The focus on youth science learning in CBSA is based on prior approaches taken in ocean science education research (Tzou, Scalone &Bell, submitted).

CBSA is premised on a cognitive apprenticeship model in which novices develop an understanding of disciplinary thinking and practices through scaffolded inquiry, structured feedback, and guidance from more expert mentors (Collins, Brown & Holum, 1991). Participation in bona fide ocean science research projects associated with a university-led citizen science effort allows apprentices to identify and investigate hypotheses of interest to them. Learning trajectories must be considered long-term pursuits associated with deepening participation and emergent problems over multiple years of involvement in disciplinary research and learning (Lave & Wenger, 1991).

CBSA participants include youth from non-dominant groups and scientists who are primarily from the dominant cultural group. Thus, there is a critical need for cultural bridging among participants in order to promote a generative and inclusive educational experience for the youth apprentices (Banks, et al., 2007; Bell, et al., 2006). Educational supports must be responsive and appropriate in order to promote the academic achievement of youth from historically non-dominant groups (Banks, et al., 2007; Gordon, Bridglall & Meroe, 2004).

In contrast to pursuing science "content" and "process" goals as is typical in science standards and curriculum, the current perspective in research on science learning is that goals should reflect an integral vision of interrelated science practices. The notion of science practices outside of school is elaborated in the NRC's (2009) report *Learning Science in Informal Environments* which describes six strands of scientific proficiency in nonschool settings. Focusing on these strands of learning in the informal environment of the apprenticeship program will lead to more equitable participation in the scientific community. Our research focuses most heavily on Strand 1 and Strand 6. These state that in ideal informal learning environments, learners who engage with science:

- …experience excitement, interest, and motivation to learn about phenomena in the natural and physical world (Strand 1); and
- …think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science (Strand 6). (NRC, 2009, p. 43)

Specifically, this research addresses these issues by examining apprentices' identity as science learners through analysis of their participation. We are exploring the ways in which participation in authentic community-situated science contributes to the apprentices' sense of the scientific enterprise and sense of identity regarding science.

Data Collection

Data collection will include three parts:

- Baseline, pre interviews with participants about their familiarity with water quality, their interests in environmental science, and their academic and career goals science.
- Videorecording of social interactions. The primary data collection activity of the study will consist of videorecording the youth apprentices across settings of the scientific work: in data collection, analysis and interpretation, and in public events related to disseminating findings. As we are interested in how participation in particular scientific activities relates to understanding the scientific enterprise and identity in science, we will conduct systematic discourse analysis on this video data. We employ a theoretical framework premised on "professional vision" (Goodwin, 1994), "distributed cognition" (Hutchins, 1995), and "collaborative repertoires of practice" (Barron et al., 2009).
- Delayed post-interviews approximately three months after the end of the year-long apprenticeship. We will document post-apprenticeship learning, apprentices' interest and sense of identity in scientific research.

Research findings are still emergent. Initial insights suggest that apprentices see only vague connections between science and their local communities. Their understanding of science is that it is something that happens in a classroom or a lab and requires expertise in specific scientific domains. We anticipate that through participation in this program, this distinction will begin to blur- that apprentices will begin to recognize their place in the scientific community, and the science in their local community.

References

Banks, J. A., Au, K. H., Ball, A. F., Bell, P., Gordon, E. W., Gutierrez, K., et al. (2007). *Learning in and out of school in diverse environments: Life-Long, Life-Wide, Life-Deep*. Seattle, WA: UW Center for Multicultural Education.

Barron, B., et al. (2009). Repertoires of Collaborative Practice. Symposium CSCL 2009 conference. In the Computer Supported Collaborative Learning (CSCL) 2009 conference proceedings, Rhodes, Greece.

Bell, P., Bricker, L. A., Lee, T. R., Reeve, S., & Zimmerman, H. T. (2006). Understanding the cultural foundations of children's biological knowledge: Insights from everyday cognition research. In S.A. Barab, K. E. Hay & D. Hickey (Eds.), *Proceedings of the Seventh International Conference ofthe Learning Sciences (ICLS)* (pp. 1029-1035). Mahwah, NJ: LEA.

Collins, A., Brown, J. S., & Holum, A. (1991, Winter). Cognitive Apprenticeship: Making Thinking Visible. *American Educator, 6*(11), 38-46.

Goodwin, C. (1994). Professional Vision. *American Anthropologist, 96*(3), 606-633.

Gordon, E. W., Bridglall, B. L., & Meroe, A. S. (2004). *Supplementary Education: The Hidden Curriculum of High Academic Achievement*. Lanham, MD: Rowman & Littlefield.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: The MIT Press.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge, MA: Cambridge University Press.

National Research Council. (2009). Learning science in informal environments: people, places, and pursuits. Committee on Learning Science in Informal Environments. P. Bell, B. Lewenstein, A.W. Shouse, & M.A. Feder (Eds.). Board on Science Education, Center for Education, Division of Behavior and Social Sciences and Education. Washington, DC: The National Academies Press.

Tzou, C., Scalone, G., & Bell, P. (submitted). The role of environmental narratives and social positioning in how place gets constructed for and by youth: Implications for environmental science education for social justice.

Impasses to innovation in the development and design of new media curriculum

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Abstract: The purpose of this study is to examine discourse as a way to identify evidence of impasses to innovation in the development and design of new media curriculum within an in-school/ out of school digital arts program. Using data collected in a 3-year ethnographic study, we use qualitative coding and conversational analysis methods to provide examples of diverse discourses competing in the development of a new media curriculum.

Major Issues Addressed:

- What happens when informal new media knowledge and experiences are brought into the schooling context through curriculum design and implementation in an in school and after school digital arts program?
- How does the positioning of knowledge affect innovations to the curriculum?

Schooling contexts now must compete with new media contexts for youth engagement and learning (Ito et al, 2008). New media technologies and communications have created "new digital divides" between informal, out of school learning, and formal, in-school learning. This post-industrial society requires that individuals are able to communicate, make meaning and construct knowledge within diverse social situations and settings (Gee, 2008). However, if educational institutions are to adapt to emergent social / cultural demands of new media literacies that are inquiry, project-based, collaborative and production orientated, educational institutions must provide spaces for students to learn to be literate with new media tools and within new media environments. However, integrating new media education into the schools will require schools to undergo "a paradigm shift in understanding how people learn and what people need to learn to be literate members of society(Buckingham, 2007, p.7)." However, this shift can be difficult to implement within institutionalized settings such as schools that are built around very specific norms and practices that are not necessarily preparing youth for a post-industrial age. Consequently, opportunities to learn and develop knowledge and practices related to the digital arts and new media literacies have traditionally been implemented as informal, after school programs (Collins and Halverson, 2009).

Potential Significance of the Work

The purpose of this study is to examine discourse as a way to identify evidence of impasses to innovation in the development and design of new media curriculum within an in-school/ out of school digital arts program. In this paper, we examine the discourses that emerge within one year of a professional development program that was designed to teach seven digital artists pedagogical knowledge through the development of a new media literacies curriculum and instructional framework. This program design was part of an out of school / in school digital arts program where one facilitator, a former high school English teacher and literacy coach was in charge of leading and directing the professional development meetings and one on one coaching sessions with seven individual digital artist-mentors. The task was to develop a new media education curriculum and learn to apply and adapt pedagogical practices to this emerging new media curriculum. The artist-mentors were positioned as experts within their subject areas and the facilitator was positioned as expert in pedagogical practices.

Using qualitative coding and discourse analysis methods, we will provide examples of diverse discourses competing in the development of a new media curriculum. We will examine schooling, pedagogical discourses and how these discourses created impasses to innovation and learning through the silencing of competing non-schooling, artist discourses. We believe that understanding the nature of schooling discourses can offer ways of using D/discourses as a tool to create safe and equitable conditions that promote innovations in new media curriculum development.

Theoretical & Methodological Approaches:

Discourse analyses within K-12 schools in the United States reveal how schooling cultures, contexts and systems are supported and reinforced through the discourse of schooling (Gee, 2004). Studies have shown that this schooling discourse tends to support monolingual, mono cultural and conflict avoidant ways of learning as a way to "silence" other discourses (Smith, 2005). Thus, a monologic rather than dialogic stance when making meaning and constructing knowledge can hinder innovation to take place (Gutierrez, 1999; Wells, 2006) Further, this tendency of schooling Discourses to silence "other" discourses can be problematic as schools look to collaborate with experts from outside the school setting when building and designing new media curriculum.

In order to understand the culture and practices of a professional development program, one researcher was positioned as a participant observer within a larger ethnographic study of the digital arts program. The participant observer attended the whole group meetings and occasionally participated when asked by the facilitator. Twelve whole group meetings were documented. Each meeting was audio recorded, field notes were drafted and materials that were used in the meeting were collected. The field notes for the whole group meetings were coded for content and themes that emerged within each meeting as they related to individual mentor and facilitator talk about assessments (Ryan and Bernard, 2003). Descriptive field notes that were coded will later be transcribed for a conversational analysis as a way to locate discourse.

Findings, Conclusions, and Implications:

Using an inductive approach to guide the preliminary analysis of the data, emergent themes related to talk about assessments has revealed that impasses to innovation within new media curriculum development appeared to be more prevalent within the less verbal digital domains such as music, graphic design and video game design. This difficulty appears to be due to an inability of both the facilitator and mentors within these domains to build understandings across content and pedagogy. When examining instances of talk about assessments, the facilitator did not have enough content knowledge in music, graphic design and video game design, and the mentors in these domains did not have enough pedagogical background and in some cases a willingness to adopt particular schooling practices such as creating new media literacy standards across all digital domains.

Analysis has revealed that the facilitator's prior knowledge was based on a pedagogical knowledge rooted in traditional reading and writing literacy. The traditional literacy practices were reproduced in the design and implementation structures of the professional development meetings in several ways. 1) Readings that were used to guide the professional development sessions and facilitate talk about assessment were based on traditional reading and writing literacy. 2) Although the mentors had created rubrics for their respective digital domain, the facilitator predominately used the digital storytelling rubric within professional development settings. 3) Instructional strategies and assessment strategies that were introduced and expected to be adapted into all digital domains required verbal interactions between mentor and students. In order for the mentors to have access to the pedagogical knowledge presented within the rubric, readings and instructional strategies, the mentors needed to be able to apply the more verbal, traditional literacy paradigm to their digital media domain. Digital domains that do not emphasize verbal interactions within that domain's cultural practices can make application of a verbal and written assessment tool an inauthentic and awkward instructional practice. The more digitally technical and non-verbal digital domains such as music, graphic design and video game design did not easily fit within the traditional literacy paradigm thus, making access to the pedagogical knowledge within these domains more difficult for the facilitator and mentors to identify and incorporate into the new media curriculum.

References:

Buckingham, D. (2007). Media education goes digital: an introduction. *Learning, Media and Technology, 32,(2):111–119*

Collins and Halverson (2009). *Rethinking education in the age of technology*. New York, NY: Teacher's College Press.

Gee, J.P. (2004). *Social linguistics and literacies: Ideology in discourses*. New York, NY: Routledge

Gutierrez, K.D, Baquedano-Lopez, P., & Tejada, C. (2000). Rethinking Diversity: Hybridity and Hybrid Language Practices in the Third Space. *Mind, Culture, and Acitivity*. 6(4), pp. 286-303.

Ito, M., Horst, H.A., Bittanti, M., boyd, d., Herr-Stephenson, B., Lange, P.J., Pascoe, C.J., & Robinson, L. (2008). *Living and Learning with New Media: Summary of Findings from the Digital Youth Project.* [White Paper]. Accessed on Nov. 23, 2008 from http://digitalyouth.ischool.berkeley.edu/report.

Ryan, G.W. & Bernard, R.H. (2003). Techniques to Identify Themes. *Field Methods*, 15 (1), 85-109

Smith, E.R. (2005). Learning to Talk Like a Teacher: Participation and negotiation in co-planning discourse. *Communication Education,* 54 (1), 52-71.

Wells, G. (2006). Dialogue in the Classroom. *The Journal of the Learning Sciences*. 15(3), pp. 379-428.

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Math Anxiety in Middle School Math Teachers: Implications for Teacher Practice and Professional Development

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Abstract: We examine math anxiety in a sample of 33 middle school mathematics teachers in a large socioeconomically disadvantaged urban district. Most reported some math anxiety. Furthermore, findings suggest that math anxiety may adversely affect teachers' practices: the intensity negatively correlated with the emphasis they placed on instructional practices critical to students' development of both mathematical understanding and productive dispositions. We discuss the necessity to address math anxiety in research and practice in teacher professional development.

Introduction

Math anxiety is common in the classroom, in the workplace, and in many adults' everyday experience. It is classically defined as a "feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972). For students, it is strongly associated with disengagement from mathematical activities, failure to enroll in advanced math courses, poor mathematics performance, and failure to graduate from high school.

Our study focuses on math teachers, those most directly responsible for facilitating student learning and shaping students' lifelong mathematical dispositions. Although research has documented the occurrence of math anxiety among elementary school teachers (e.g., Hembree, 1990), little work has examined math anxiety in the middle school teaching population and the impacts it might have on practice. The middle school years are a particularly important and vulnerable transition point in the school trajectory, as mathematical concepts become increasingly difficult and abstract, and many students begin to lose interest in mathematics, fall behind in achievement, and consolidate their motivational attitudes toward mathematics. Ideally, teachers at this level should be able to support students' development of conceptual understanding and create a learning environment that facilitates students' development of productive dispositions toward mathematics. A teacher's own math anxiety could potentially undermine his or her capacity to engage with complex student thinking and model the mindset that will support successful future studies in higher level mathematics.

Within the context of a larger study examining the teaching practices, mathematical knowledge, and attitudes and beliefs of veteran middle school math teachers, we will examine four research questions:

1. To what extent do these middle school math teachers exhibit math anxiety?
2. What is the relationship between teachers' math anxiety and their mathematical knowledge?
3. What is the relationship between teachers' math anxiety and their teaching practices, particularly those supportive of the development of student thinking and productive dispositions?
4. What do middle school math teachers do when they encounter mathematical content that is unfamiliar?

Research Design

The data was collected as part of a study that is exploring the construct of adaptive expertise in middle school math teaching. We are investigating the tendency for teachers to approach the professional practice of teaching as a lifelong learning process. We are examining the relationships among habits of mind, pedagogical and content expertise, teaching practices, approach to professional development, and teaching effectiveness.

Veteran middle school math teachers were recruited via mass mailing from a large urban district in California serving large populations of primarily economically disadvantaged students (mean of 69% of campus-level students qualifying for free or reduced-price lunch). The sample was composed of 33 teachers. The mean years teaching was 14.1 (SD = 7.5) with a range of 5 to 33; 56% were female; the ethnic distribution was 61% White, 13% African American, 13% Hispanic, and 9% Asian.

Teachers did an in-depth phone interview, a written survey, and a written assessment of mathematical knowledge for teaching (MKT) middle school mathematics. In this analysis, we focus on their responses to (1) the Abbreviated Math Anxiety Rating Scale (AMAS; Hopko, Mahadevan, Bare, & Hunt, 2003), a 9-item scale (alpha = .90) that measures anxiety in math-related situations, with an emphasis on learning new mathematics; (2) an assessment MKT emphasizing the mathematics necessary to teach core NCTM Focal Points for seventh- and eighth-grade mathematics; (3) a questionnaire about how much teachers emphasize various practices in their mathematical instruction; and (4) teachers' interview responses to the questions about their formative assessment practices and how they deal with unfamiliar mathematical content.

Preliminary Findings

Teachers exhibited a range of math anxiety. Scored as an average of items rated on a 5-point Likert scale, the mean AMAS score was 2.1 (SD = 0.58), with a minimum of 1.2 and maximum of 3.5. Female teachers were slightly higher in math anxiety (mean of 2.3 versus 1.9; $t(32) = 2.1$, $p < .05$). MKT did not differ significantly. In a preliminary analysis of the interview data, we encountered a range of approaches that teachers took to unfamiliar mathematical content, from highly motivated learning to complete avoidance. An example of the latter was Abby in our pilot. She admitted that she still did not understand several mathematical concepts in her sixth-grade curriculum. When asked what she does when she gets to these topics each year, she said she simply skips over them because they are not important.

As shown in Table 1, teachers' math anxiety was negatively correlated with their self-reported emphasis on several important teaching practices. Their MKT negatively but not significantly correlated with their math anxiety ($r = -.18$, n.s.) and was only significantly related to emphasis on one of the probed practices.

Table 1. Correlations between self-reported emphases on various teaching practices and the AMAS and MKT.

Teaching Practice	AMAS	MKT
Increasing students' interest in mathematics.	-.501**	.359*
Developing students' conceptual understanding.	.019	-.052
Having students learn mathematical procedures and algorithms.	.081	-.096
Having students learn to reason mathematically.	-.265	-.033
Helping students understand the logical structure of mathematics.	-.571**	.196
Proof and justification/verification (e.g., using logical argument to demonstrate correctness of mathematical relationship).	-.217	-.069
Problem solving (e.g., finding solutions that require more than merely applying rules in a familiar situation).	-.362*	-.090
Communicating (e.g., expressing mathematical ideas orally and in writing).	-.415*	.023
Connections (e.g., linking one mathematical concept with another; applying math ideas in contexts outside of math).	-.386*	-.007
Representations (e.g., using tables, graphs, and other ways of illustrating mathematical relationships).	-.324	-.201

* $p < .05$; ** $p < .01$

Discussion

The findings suggest that math anxiety is present in the middle-school teacher population, and that it may adversely impact practice in important ways. Most teachers reported at least some math anxiety. In examining relationships with practice, math anxiety was negatively related to emphases on practices critical to student's development of conceptual understanding (e.g., understanding the logical structure of mathematics, problem solving, communicating, making connections) and productive dispositions (e.g., increasing students' interest in mathematics). Math anxiety was not significantly related to MKT in this small sample; however, the negative trend aligns with previous research that consistently shows negative relationships between math anxiety and math knowledge (Hembree, 1990). MKT was related to an emphasis on increasing students' interest in math.

In the poster, we will expand on these results with our qualitative analysis of teachers' responses to questions about how they approach formatively assessing and responding to student thinking in the classroom. We will also expand on the results of the analysis of how teachers approach unfamiliar content.

These findings point to an important issue in research and practice in teacher professional development. Math anxiety may entail an experience of fear and risk for teachers, contributing to an avoidance of practices that require their engagement with more difficult mathematics. It may also entail the transmission of negative attitudes, consciously or unconsciously, to students. Although the impacts of math anxiety can be deleterious, substantial evidence shows that there are effective strategies for significantly reducing it. For example, for students, a number of psychological approaches such as anxiety management training and cognitive restructuring have been shown to both reduce math anxiety and increase math achievement (Hembree, 1990). Adapting such strategies to adult populations and incorporating them into pre-service and in-service teacher training could substantially reduce teachers' math anxiety and enhance their capacity to support their students' development of conceptual understanding and productive dispositions.

References

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education, 21*(1), 33–46.

Hopko, D. R., Mahadevan, R., Bare, R. L., & Hunt, M. K. (2003). The Abbreviated Math Anxiety Scale (AMAS): Construction, validity, and reliability. *Assessment, 10*(2), 178-182.

Richardson, F. C., & Suinn, R. M. (1972). The mathematics anxiety rating scale. *Journal of Counseling Psychology, 16*, 551–554.

Incorporating Affect in an Engineering Student's Epistemological Dynamics

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Abstract: Research has linked a student's *affect* to her *epistemology* (Boaler & Greeno, 2000), but those constructs often apply broadly to a discipline and/or classroom culture. Independently, an emerging line of research shows that a student in a given classroom and discipline can shift between multiple locally coherent epistemological stances (Hammer, Elby, Scherr, & Redish, 2005). Our case study of Judy, an undergraduate engineering major, begins our long-term effort at uniting these two bodies of literature.

Introduction

In this poster, we incorporate an affective node into a fine-grained toy model of an engineering major's cognitive dynamics during a clinical interview. We seek to characterize Judy's annoyance toward a particular kind of homework problem in her Circuits course, and its consequences. In our model, affect is not just an add-on; we use it to account for aspects of her conceptual and epistemological thinking that epistemology-only models can't and don't explain.

This kind of affective modeling responds to a specific literature gap between emotion and cognition. Many well-known studies link learners' affect and epistemology with large, often group-level constructs (Boaler & Greeno, 2000; Duit & Treagust, 2003; Lee, Hansen, & Wilson, 2006; Pintrich, Marx, & Boyle, 1993). Those constructs provide broad descriptive power, but tell us less about contextualized, in-the-moment student behaviors. Conversely, sensitive accounts of students' conceptual and epistemological cognition are plentiful in fine-grained details (diSessa, 1993, 2006; Hammer et al., 2005), but sparing in relating emotion to conceptions and epistemologies.

Summary of Three Patterns of Judy's Thought and Behavior

In a one-hour clinical interview, we probed Judy's views about her Circuits course and her approaches toward problem-solving. Working as a group we then identified four cognitive patterns in her responses to certain prompts, seeking confirmatory or non-confirmatory evidence elsewhere in the data (Miles & Huberman, 1984).

(1) Annoyance at conceptual problems: Like many students in her class, Judy distinguished between two types of homework and exam problems: traditional equation-based problem-solving vs. conceptual problems asking for explanations of what's going on physically. Judy repeatedly emphasized that conceptual problems were *annoying* in words ("they are kind of annoying"), gestures, and facial expressions (frowns and facial distortions).

(2) Conceptual reasoning as useless: Judy sees conceptual reasoning as useless for practical purposes and considers equation-based problem-solving as "more helpful" and "more important."

(3) Real/ideal gulf: In Judy's view, her course spends too much time discussing "ideal circuits and theoretical methods," which "are not related to the actual circuit" or to "a professional engineer's job." This unbridgeable gulf between ideal and real circuits, she says, is what makes the conceptual problems annoying; those problems call for students to use concepts that apply only to ideal circuits.

(4) Non-activation of (3) during traditional problem-solving. When talking about or engaging in equation-based problem solving, Judy displays positive affect, and we find no evidence that in these moments she is ever thinking about the real/ideal gulf. Crucially, the equations she uses encode the same idealizing assumptions she disparages elsewhere in the interview. Her epistemological view about the real/ideal gulf is thus context-dependent: present when she *discusses* conceptual problems, but absent when she *solves* traditional ones.

The Need for Affect in Toy Models of Judy's in-the-moment cognition

The four patterns discussed above are consistent with a context-dependent but affect-free toy model (Fig 1 (a)) in which Judy's epistemological view about the gulf between real and ideal circuits reinforces and is reinforced by her sense that the conceptual problems are useless. But two other episodes from the interview show the inadequacy of this model.

Disconfirmatory episode A. Near the end of the interview, Judy builds momentum using conceptual reasoning to (re)solve a homework problem from earlier in the course. She thinks in terms of "squeezing" the area under a voltage vs. time curve to change the peak voltage without affecting the average voltage. In her successful solving, she shows positive affect. Afterward, the interviewer asks about the squeezing: "Do you ever

…think about the mathematics that you use in that way?" Judy laughs, says "no no no," and adds "No, I never think of that before…. Yeah, I mean it's I feel like it's not very formal [smiles], but it's very useful." The toy model in figure 1 (a) doesn't predict such a reversal of her epistemological stance towards conceptual reasoning.

Disconfirmatory episode B. At one point, not discussed above, while Judy was still thinking about her annoyance at the conceptual problems, the interviewer probes her views about *both* the real/ideal gulf *and* conceptual reasoning: "So do you think if you're analyzing a real-world circuit, it's important to know about the physical aspects of the circuit?" Judy responds, "Not very important." The two-node model in figure 1 (a) didn't predict this.

To explain these two episodes *and* the four patterns discussed above, we must modify our toy model to include an affective state, Judy's *annoyance* at conceptual problems, as mediating the connection between her epistemological stance and her view that conceptual problems are useless (Fig. 1(b)). Our proposed three-node toy model explains how suppressing *annoyance* can cue Judy's epistemological reversal in Episode A. It also explains explains Episode B, because targeting Judy's epistemology (by focusing on *real* circuits) without addressing Judy's affect fails to suppress Judy's view that conceptual reasoning is "not very important." Ultimately, though limited to one student in one interview, our analysis shows the importance and feasibility of incorporating affect into fine-grained models of cognitive dynamics.

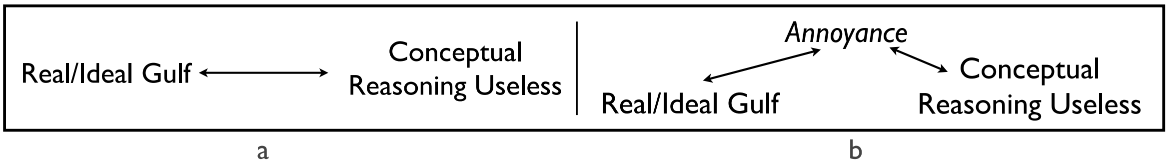

Figure 1 - Toy cognitive model with (a) only epistemological nodes and (b) incorporating affect (annoyance) with epistemology. The model in (b) better explains the contextual dynamics of Judy's epistemological stances.

Acknowledgments

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References

Boaler, J., & Greeno, J. G. (2000). Identity, agency, and knowing in mathematical worlds. In J. Boaler (Ed.), *Multiple Perspectives on Mathematics Teaching and Learning*, International perspectives on mathematics education (pp. 171-200). Westport, CT: Ablex Pub.

diSessa, A. A. (1993). Toward an Epistemology of Physics. *Cognition and Instruction*, *10*(2/3), 105-225.

diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In R. K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 265-282). Cambridge: Cambridge University Press.

Duit, R., & Treagust, D. F. (2003). Conceptual change: a powerful framework for improving science teaching and learning. *International Journal of Science Education*, *25*(6), 671-688. doi:Article

Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, Framing, and Transfer. In J. P. Mestre (Ed.), *Transfer of Learning from a Modern Multidisciplinary Perspective*, Current perspectives on cognition, learning, and instruction. Greenwich, CT: IAP.

Lee, L. A., Hansen, L. E., & Wilson, D. M. (2006). The impact of affective and relational factors on classroom experience and career outlook among first-year engineering undergraduates. Presented at the 36th ASEE/IEEE Frontiers in Education Conference. Retrieved from http://www.fie-conference.org/fie2006/papers/1796.pdf

Miles, M. B., & Huberman, A. M. (1984). *Qualitative Data Analysis: A Sourcebook of New Methods*. Beverly Hills: Sage Publications. Retrieved from http://lccn.loc.gov/84002140

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond Cold Conceptual Change: The Role of Motivational Beliefs and Classroom Contextual Factors in the Process of Conceptual Change. *Review of Educational Research*, *63*(2), 167-199.

Reflection Tools in Modeling Activities

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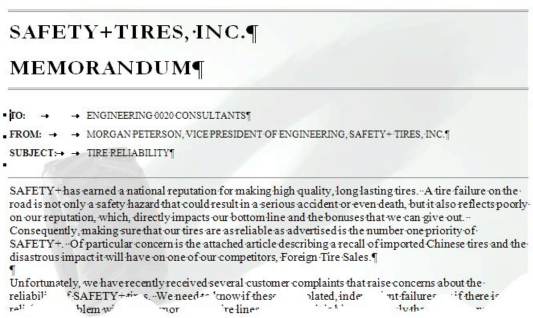
Reflection and self-regulated learning are important skills for college level students to learn. We have developed Model Eliciting Activities (MEAs) to integrate these activities while teaching students engineering concepts. A multi-tier design approach is used with MEAs as an element of change for students, instructors and researchers. Three generations of reflection tools have evolved to document how student teams' work on resolving a posed problem and what have they learned from the experience.

Introduction

Reflection is seen increasingly as a valuable part of a portfolio of self-regulatory competencies in learning. One of the most promising research topics in fields such as complex reasoning, problem-solving, critical thinking, or modeling involves reflective activity. This poster addresses research on reflection in modeling. A focus on modeling in problem-solving (creating structured and manipulable representations of a problem-situation) has proven productive in research on mathematical cognition in applied or real-world settings, including engineering. In particular, the paper reviews how devices called Reflection Tools, or RTs, have been conjectured to improve modeling competencies, or the abilities of students to draw upon, use, and change models in mathematical and engineering team problem-solving.

A companion website (http://modelsandmodeling.net/icls2010) furnishes a fuller set of modeling scenarios and the data to which this paper refers. The research is supported by a Type III Collaborative Scale-Up grant from NSF's Course, Curriculum and Laboratory Improvement (CCLI) Program (NSF Award 0717861). The instructional improvements sought involve the use of model-eliciting activities, or MEAs – in undergraduate learning. MEAs are specialized problem simulations that are treated at length in numerous sources recapped at http://modelsandmodeling.net. They were originally developed as tools to understand the micro-evolution of mathematical cognition. That is, they were used to trace how, in small teams, learners expressed conceptual models as ways to describe a problem, and then manipulated or revised their models to create a better fit to the problem and to test solutions to it. Over the course of a first generation of research in modeling eliciting activities, several crucial observations became foundational to the current generation of research. One is that although MEAs were useful for exposing conceptual models and their evolution, they also proved to have intrinsic instructional value. That is, as students participated in MEAs, they grew in the modeling competence. Indeed, some of the strongest performance changes came from youngsters for whom little was expected in terms of mathematical achievement. The applied problem-solving settings of model-eliciting activities and the opportunity to express, test and revise models nourished and expanded mathematical skills while students were serving as research subjects. Eventually, MEAs were developed for engineering students, and introduced in the first year curriculum of one of the largest engineering programs in the nation, at Purdue University, as an instructional approach. Not only did students develop new expertise as they were immersed in MEAs, but teachers and professors who focused on learner modeling and changes therein changed their own approaches to instruction. A third observation is that the various research teams began altering their own models of modeling. The collective observation of multiple dynamic levels of progress towards greater expertise (in modeling by students; in focusing on student modeling and development by teachers; and in recasting the type of emphases on problem-solving studies by researchers) eventually gave rise to what has been referred to as multi-tier design methodology.

One other observation became incorporated into current model-eliciting-activity research. Students engaged in MEAs began sharing reflections about modeling in small groups that mimicked, at a metacognitive level, the phenomena of teachers become more astute observers of student learning. That is, as students became more sophisticated in reflecting on their

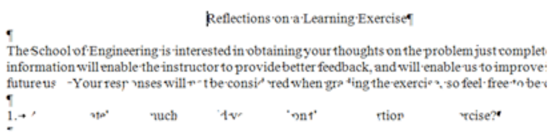

SAFETY+TIRES, INC.
MEMORANDUM

TO: ENGINEERING 0020 CONSULTANTS
FROM: MORGAN PETERSON, VICE PRESIDENT OF ENGINEERING, SAFETY+TIRES, INC.
SUBJECT: TIRE RELIABILITY

SAFETY+ has earned a national reputation for making high quality, long lasting tires. A tire failure on the road is not only a safety hazard that could result in a serious accident or even death, but it also reflects poorly on our reputation, which, directly impacts our bottom line and the bonuses that we can give out. Consequently, making sure that our tires are as reliable as advertised is the number one priority of SAFETY+. Of particular concern is the attached article describing a recall of imported Chinese tires and the disastrous impact it will have on one of our competitors, Foreign Tire Sales.

Unfortunately, we have recently received several customer complaints that raise concerns about the reliabi[illegible]

Figure 1: The Tires Reliability MEA
(fully appearing at http://modelsandmodeling.net/icls2010)


Reflections on a Learning Exercise

The School of Engineering is interested in obtaining your thoughts on the problem just complet[illegible] information will enable the instructor to provide better feedback, and will enable us to improve future [illegible]

Figure 2: Reflection Tool (Generation 2)
(all forms fully appearing at http://modelsandmodeling.net/icls2010)

modeling, they became more sophisticated modelers. This led to theorizing about the role of guided reflection and theorizing about using formal reflection tools as part of or subsequent to modeling activities. The focus entails emphasizing how representations of the structure of a problem-situation – that is, a model - can evolve through short-term cycles of expressing, testing and revising the representations in a team.

The Tires Reliability MEA and Associated Reflection Tool

The Tires Reliability MEA depicted in Figure 1 entails a set of reliability statistics that a team of three students are expected to analyze in advance of preparing a report on the safety of a line of automotive tires. The website for this work-in-progress paper includes the full problem, data, reflection tool versions, and student reflections. The Tires MEA requires students to develop a general model for determining if a tire production run meets acceptable reliability and then apply that model to specific cases: three different grades of tires to determine if they are within a "gold" standard. Students must use the data set to determine the shape of the distribution, use probability plots and fully understand the concept of variance. A grading rubric is also available on the website. Of interest here is the use of a reflection tool that evolved through three generations of administering the MEA. Table 1 reflects each generation of the tool, the rationale for revising the tools, and the strengths and weaknesses that emerged from the revision. We are using reflection in two ways: both as a learning intervention and as an assessment tool.

As instructors and researchers we are searching for deeper understanding of the use of reflection tools in concert with MEAs. Do student reflections help researchers suggest the most productive ways to guide students and when to let them struggle with ambiguity? Can reflection tools be designed to provide a fuller picture of the team problem solving and modeling processes? The revision of the reflection tools will also help researchers elaborate on whether and to what degree reflection tools help students think about modeling, and whether it leads to stronger modeling competencies.

Table 1: Summary of Revisions in Three Generations of a Reflection Tool

Refl. Tool →	Generation 1	Generation 2	Generation 3
Where Used	Technical elective, upper class students, during lecture time; experienced instructor to MEAs	Stats course, required for some students; new instructor to MEAs	Required Stats course, sophomores; experienced instructor to MEAs; also branched out into other engineering courses
Characteristics of reflection tool	Focus on team process, through Wiki statistics (number of contributors, number of edits, questions posed in postings, number of drafts)	Concept learning assessed through exam questions; in process assessment; on paper; 6 question format, See Figure 1	Identify misconceptions in learning; pre/post concept inventories used; provide high quality and timely feedback to students; focus on modeling skills; 12 question format online.
Strengths	Rubric focused on: iteration (express-test-revise), ethics, mathematical concepts, problem solving)	Individual reflections blended into team narratives; short, concise; drawing graph and label it provided rich insight	Learning experience for student; defined important terms; guides students' thinking of teamwork, concepts learned and skills used; reinforcing targeted concepts
Weaknesses	Instructor interpretation of process	In process assessment very difficult; used unfamiliar terms with open ended questions, wide variety of responses; closed question made assumptions about student feelings	Long, almost all open ended questions with multiple parts
Reason for new generation	More insight needed into team process ; try to use repetition to move students from novice to expert problem solvers	Move to standardization and easier implementation; move to electronic version	Reintroduce draw team progress chart and description

References

E. Hamilton, R. Lesh, F. Lester, and C. Yoon. (2007) The use of reflection tools to build personal models of problem-solving. In R. Lesh, E. Hamilton, J. Kaput, J. (Eds.), Models & Modeling as Foundations for the Future in Mathematics Education., Lawrence Earlbaum Associates, NJ, Inc.

Shuman, L.J., and M. Besterfield-Sacre "E-MEAS: Introducing An Ethical Component To Model Eliciting Activities", *2009 ASEE Annual Conference & Exposition*, Austin TX, June 2009.

Yildirim, T.P., L.J. Shuman, and M. Besterfield-Sacre, "Model Eliciting Activities: Assessing Engineering Student Problem Solving and Skill Integration Processes," accepted for publication *International Journal of Engineering Education*.

From Visualization to Logical Necessity, Through Argumentative Design

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Abstract: We show that a meticulous design can encourage students in dyads to shift from informal reasoning (visual, inquiry-based) to reasoning moved by logical necessity (abductive and deductive). We describe a case study in which one dyad solves a series activities purposely designed. We show that argumentation first relies on intuition, and then intertwines the activities of conjecturing and checking the conjectures though the use of different gestures.

With the multiplicity of tools available in mathematics education, instructional design can do miracles: in this study, we show that one can encourage students to shift from informal reasoning to reasoning moved by logical necessity. We show how various kinds of reasoning processes (visual, inquiry-based, abductive and deductive) can stem from interactive argumentation. The activity of proving which was always difficult to trigger, can stem from argumentation. The use of special software helps to prop on intuitions, and on visualization. In a proper environment, dyads use gestures that accompany verbal argumentation. Productivity of collective argumentation consisted not only in a shift in reasoning type (towards deductive considerations), but in co-construction of knowledge – in the progressive emergence of geometrical principles combined in arguments. These positive outcomes resulted from collaborative rather than adversarial interactions as the students tried to accommodate their divergent views.

The research design experiment

Leading researchers have recognized the importance of CSCL tools in learning mathematics (e.g., Stahl, 2009). Researchers in mathematics education have invested a special effort in designing situations incorporating computerized tools for learning (e.g., Hadas, Hershkowitz & Schwarz, 2001, 2002). In the present study, (1) we design an activity in geometry as an inquiry-based activity that invites participants to raise and check hypotheses and encourages them to engage in argumentation which is productive in the sense that it leads to deductive reasoning; (2) we identify and analyze the various kinds of reasoning processes students adopt (visual, inquiry-based, deductive) while they are engaged in such an activity and show how these ways of reasoning are interwoven in collective argumentation; (3) we trace dynamic changes and development of individuals' and collective's argumentation processes of peers of students, working on such a designed activity - from what is usually called: "informal" kinds of reasoning to more "formal" ways. (Rasmussen et al, 2005).

Research subjects

The subjects in this research are pre-service teachers trained to teach mathematics at the elementary school level. They participate in a course about "Geometry and Computerized Environments", in a Teacher's college in Jerusalem. The pre-service teachers (called 'students' onward) generally worked in dyads. They were familiar with Dynamic Geometry software tools.

Analysis of data

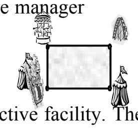
We adopted a methodological approach used by Rasmussen and Stephan (2008), who used Toulmin model of argumentation for tracing and analyzing the argumentation process. We analyzed with this method the protocol of each dyad in each task. We identified the characteristics of the arguments the dyad developed, including the resources and reasons (warrants and backings) invoked. We looked at the kinds of interactions that developed; also we discerned shifts in the argument schemes in the collective argumentation within or between tasks.

To achieve the research goals, we had first (as we mentioned before) to design the activity, its environment and conditions, in such a way as to encourage students to engage in argumentative processes that would lead to the elaboration of logic deductive argumentation

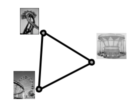
The designed activity

Figure 1 shows the activity we designed. It was designed according to three design principles: (1) creating a conflict situation (2) creating a collaborative situation (3) providing an environment for raising and checking hypotheses. It is organized in three successive tasks. In each of the three tasks, students were asked to go through similar phases: i) to find individually a solution for the shape that was drawn on the worksheet. In this phase they could check their solution with a first hypothesis testing device, a ruler for measurement ii) to work in dyads and to reach a consensus concerning the solution (collaboration principle) iii) to check their conjectured solution. At this phase, the hypothesis testing device was the Dynamic Geometry software with which they could undertake manipulations (hypothesis testing/checking principle). In case they made a wrong conjecture, they were asked to make a new conjecture and recheck it with the DG tools.

Task 1:
A recreational park has a rectangular shape. At each vertex of the rectangular park there is an attraction. The manager of the park decided to locate the ticket booth at an equal distance from the four vertices of the rectangle.
Find the point in the rectangle, which fits for the ticket booth



Task 2:
Another park has the shape of an equilateral triangle. At each vertex of this triangular park there is an attractive facility. The manager decided to locate the tickets booth at an equal distance from the three vertices of the triangle.
Find the point in the triangle that would satisfy the requirements.



Task 3:
What if the recreational park has the shape of a scalene triangle?
Find the point (if any) in this triangle that would satisfy the requirements.

Figure 1: The sequence of tasks (A shortened version)

The purpose of Task 1 is to get acquainted with the issue of finding a point which is equidistant from the vertices of a given figure. In Task 2, the shape of the recreational park is an equilateral triangle. Our assumption was that students would choose "special lines" – the three medians, the angle bisectors, or altitudes, and would find the intersection point of the three special lines, as a solution for the task.
Our assumption was that the students would imagine that the methods they used in Task 2 would be suitable for Task 3 as well, meaning that the solution would be the intersection point of the medians, or of the angles' bisectors, or of the altitudes. None of the above is the right solution, so students enter a conflict situation. Intuitions could certainly help in Task 1 and probably in Task 2, but naturally led to a wrong conjecture in Task 3 (conflict principle). In cases that they faced conflict - their conjecture was wrong; they were "pushed" to propose a new conjecture and to justify it.

Analysis and Implications

The activity we will analyze, invited the use of concrete methods and visualization in argumentation, but at the same time offered opportunities that point out the limitations in adopting such methods. We will present a case-study, in which students realize the importance of using Dynamic Geometry software for checking their conjectures, and yet find themselves in a dead-end position (conflict situation) and face the need to adopt logical-geometrical reasoning to find and justify the solution of their problem.

All dyads that coped with the activity were led to believe that the methods they used in the second task would be suitable for the third task as well, so the designed conflict situation was achieved. On the poster we will focus on the story of one dyad. We will demonstrate through this story how argumentation developed from being based on intuition and visual considerations to deductive considerations. The apparatus in which argumentation develops – different tools at disposal and the presence of two collaborating students, affords shifts in argumentation, not only in the person leading it, not only in its structure (focused on reasons instead of claims), but in the nature of arguments evoked, as reasons (warrants, backing) progressively become deductive. In this transformation, multimodality plays a central role. We will show that visual elements can serve as precursors of arguments, but sometime they are not enough and deductive considerations are the only solution. We argue that beyond the general lessons that we will present concerning the importance of design principles for learning in dyadic interaction, the specific achievement of this study, is the fact that the outcome of the dyadic interaction was deductive proving as an activity that convinces its actors.

Selected references

Andriessen, J. E. B. & Schwarz, B. B. (2009). Argumentative design. In N. Muller-Mirza and A. N. Perret-Clermont (Eds.), *Argumentation and Education – Theoretical Foundations and Practices* (pp. 145-174). Springer Verlag.

Hadas, N., Hershkowitz, R., & Schwarz, B. B. (2001). The role of surprise and uncertainty in promoting the need to prove in computerized environment. *Educational Studies in Mathematics, 44*(1&2), 127-150.

Rasmussen, C. & Stephan, M. (2008). A methodology for documenting collective activity. In A.E. Kelly, R. A. Lesh & J. Y. Baek (Eds.), *Handbook of design research methods in education* (pp. 195-215). New York and London: Routledge Publishers..

Stahl, G. (2009). Mathematical discourse as group cognition. In G. Stahl (Ed.), *Studying Virtual Math Teams* (ch. 3, pp. 31-40). New York, NY: Springer.

Using Social Network Analysis to Understand Online Homeschool Network Interactions

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Abstract: With the rise in Internet use in recent years, homeschoolers have been able to connect with each other across vast distances. This connectivity has opened avenues to various resources, and for ways to build and utilize social capital. This study provides a description of how one online homeschool network communicates, shares resources, and responds to the needs of its members through a social network analysis.

Introduction

Advances in information and communication technology have given homeschoolers more access to educational resources, such as lesson plans and curriculum, as well as social and emotional support, including online social networks and homeschool groups. These resources have prompted homeschoolers to redefine the experience – where once it was a mother with her children going through a textbook, now groups have collaborated to form co-operatives, virtual charter schools, and support groups. Not only do these new approaches to homeschooling challenge popular myths about isolated and unsocialized children (Basham, 2001) and weak or overly religious curricula (Apple, 2000), but they represent a new problem – information overload. Any time spent on an Internet search engine looking for educational resources and one is confronted with hundreds or thousands of sites offering lesson plans, activities, text and workbooks, games, videos, standards, assessments, and more. Given the vastness of the terrain, it is no wonder that homeschooling families have begun to self organize into online social networks. It would reasonably follow that these groups offer access to opinions about the quality of resources from others who are actually using them. While many researchers have studied the outputs of this connectivity, such as SAT scores (Belfield, 2002), and others have examined the motivational factors that led to homeschooling (Collom, 2005; Basham, 2001), there is scarce information on the structures of these networks, how successful ones operate, and how they may be replicated. This study seeks to fill the gap in this literature by applying social network analyses to explore how information is exchanged in a robust online homeschooling network.

Theoretical Underpinnings

Previous research has focused on the individual homeschool student specifically in academic accomplishment (Basham, 2001), and parental motivations for homeschooling (Collom, 2005). Even in studies of homeschooling organizations, such as Collom's (2005) research on a homeschool charter school, the dependent variable is individual achievement. As more homeschoolers organize into collaborative groups, it becomes increasingly important to study the group as the unit of analysis. Recognizing this need in other educational domains, for example in understanding teacher networks (Bidwell & Yasumoto, 1999), social network analytical tools have grown in popularity over the last decade. Social network analysis has been used to describe and illustrate the interactional patterns among groups of learners (Gloor et al., 2006; Yoon, 2008), with the goal of improving access to the group's resources. Gloor et al. (2006) studied intra- and inter-group emails sent by undergraduate students while working on a project to identify patterns in their communication structure that correlated with rates of performance. Similarly, Yoon (2008) used social network analyses in a middle school classroom during a curriculum and instruction intervention in order to determine the nature of information flow.

Methodology

This study focuses on one homeschooling group's online message board, which is used to share information among parents. Many in the group joined via a web search on homeschooling materials or support, which led them to both the message board and a voluntary weekly meeting at a local playground. There are approximately 150 members in this group who are active on the message board, and a small percentage of these members regularly attend the weekly meetings. The data source used for analysis of social network patterns is the message board in which over 2,000 messages were posted over four years, from March 2005 to December 2009. A sample of 133 of these messages, posted by 34 members from September 1, 2009, through October 31, 2009, was analyzed for structural characteristics of interaction. This two month period was selected due to a surge of activity that appeared to coincide with the beginning of the public school calendar. A sociogram analysis of member participation was conducted to identify patterns of interaction around types of posts, such as announcements or requests.

Preliminary Findings

Initial results of analysis yield simple frequency statistics relating to types of posts and average lengths of threads. Announcements, the most common type of post, receive the lowest number of responses, and requests or questions receive the highest number. Within these categories there also appear to be several key members who respond in greater frequency and with more detail than other members. In Gloor's (2006) terms, this would be the network's COIN (Collaborative Innovation Network), which works because the members feel strongly connected to the work. Those who do not post as often, who tend to soak up the posts and work of others, would be the CIN (collaborative interest network). They benefit from the effort of the core members, and remain most often as lurkers. Examination of the types of posts, in relation to the centrality of members creating them, offers opportunities to better understand the movement of both information and status, such as the path from newcomer, or one who most often posts requests or asks questions, to veteran, or someone who is more likely to respond to requests or advertise services. More in-depth analysis is required and forthcoming with the goals of examining the qualities of individual posts (De Wever et al., 2006) and how those qualities impact response rates, as well as identifying levels of prestige, such as how posts from different members are responded to.

Potential Contributions

Understanding the structure and content of online homeschool networks through social network analysis can provide valuable information to members about how to increase participation to improve access to information. For example, with respect to COINs and CINs, the structure and content of communication patterns can be used to encourage more interaction from less active members. In terms of future research, understanding the structure of this group will allow for a better conceptualization of how access to resources is acquired and used within this group. In addition structural analyses will be combined with surveys and interviews to ascertain member motivations for, and satisfaction with, participating in this online network. This will allow for the implementation of interventions to improve the experience of homeschooling for members of these kinds of networks.

References

Apple, M. (2000). The cultural politics of home schooling. *Peabody Journal of Education, 75(1-2)*, 256-271.

Basham, P. (2001). Home schooling: From the extreme to the mainstream. *Public Policy Sources, 51*, 3-18.

Belfield, C. (2002). *The characteristics of home schoolers who take the SAT* (Occasional Paper No. 62). New York: National Center for the Study of Privatization in Education, Teachers College, Columbia University.

Bidwell, C., & Yasumoto, J. Y. (1999). The collegial focus: Teaching fields, collegial relationships, and instructional practice in american high schools. *Sociology of Education, 72(4),* 234-256.

Collom, E. (2005). The ins and outs of homeschooling: The determinants of parental motivations and student achievement. *Education and Urban Society, 37(3)*, 307-335.

De Wever, B., Schellens, T., Valcke, M., & Van Keer, H. (2006). Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review. *Computers & Education, 46(1)*, 6-28.

Gloor, P., Paasviaara, M., Schoder, D., & Willems, P. (2006, September). Correlating performance with social network structure through teaching social network analysis. Paper presented at the 7th IFIP Conference on Working Enterprises, Helsinki, Finland.

Gloor, P. (2006) *Swarm Creativity: Competitive advantage through collaborative innovation networks.* Oxford University Press: New York.

Yoon, S. (2008). An evolutionary approach to harnessing complex systems thinking in the science and technology classroom. *International Journal of Science Education, 30(1),* 1-32.

Improvising in music: A learning biography study to reveal skill acquisition

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Abstract: This poster addresses a learning biography study which aims at analyzing learning histories of both expert and non-expert improvisers (five recognized expert improvisers and five renowned musicians lacking improvisational expertise). It was hypothesized that by choosing both experts and non-experts it is possible to distinguish successful and unsuccessful learning strategies and instructional methods. Results of within-case analyses and cross-case analyses are presented. Further, consequences for two subsequent experimental studies will be discussed.

Introduction

It is frequently stated that creativity is an important quality for both the individual and society at large, and that educating for creativity should be conceived a key mission in educational practice (Sawyer, 2006). Unfortunately, both education and psychology have not been able to deduce a universal set of instructional guidelines for creativity enhancement (Sweller, 2009). For some, this is reason to believe that creativity is inborn and not the result of training and practice. However, studies on expertise development contradict this belief and point out that differences in early experiences, training, and practice are the real determinants of excellent and creative performance (Howe, Davidson, & Sloboda, 1998). The question is what exactly comprises early experience, training, and practice regarding creativity enhancement

For the present study the domain of musical improvisational expertise development has been selected to answer this question. Musical improvisation can be described as the creation of musical novelty in real time. It is a performing activity that involves highly skilled responses to an unpredictable reality. This description fits Johnson-Laird's (2002) NONCE definition of creativity which claims that the outcome of a creative process is Novel for the person producing the result, Optionally novel for society at large, the result of a Nondeterministic process that is guided by Criteria or constraints, and that is based on existing Elements.

A learning biography study is set up to explore the learning histories of both recognized expert improvisers and non-expert improvisers. Retrospective interviews are used to reveal effective learning strategies, to generate effective instructional methods, and to determine whether improvisation can be learned. The learning biography study is fundamental to two subsequent experimental studies which are framed into the paradigm of deliberate practice (Ericsson, Krampe, & Tesch-Römer 1993) and holistic instructional design approaches to complex learning (Van Merriënboer & Kirschner, 2007).

Method

Participants. We invited ten musical experts to participate in this study. Five experts were renowned expert improvisers in music; five experts were recognized musicians in the same musical domain but not regarded to be expert improvisers. A group of peers, musical scholars, and critics selected the experts. Since it is often stated that expert performance is not reached with less than ten years of intense practice (Ericsson et al, 1993), the experts selected for this study completed at least a 10-year period of deliberate musical improvisation practice. Experts were below the age of forty (range between 25 and 40 years).
Data collection. A variant of the procedure for 'autobiographical self-thematisation' (Kelchtermans, 1999) has been used for collecting data from the experts. In this procedure respondents are stimulated to reflect on their career (auto-biographical) and narratively share their experiences and the meanings these hold for them. Data collection started with a questionnaire for recording (a) formal and non-formal musical and improvisation learning episodes (see Figure 1) and (b) critical environmental influences (critical incidents and critical persons). The questionnaire was followed by a semi structured interview which consists of two parts: a narrative biographical part where the interviewee is asked to describe his/her 'road to musical excellence', and a thematically structured part, directed at revealing improvisation learning on a detailed micro level. The narrative biographical part focuses on the dynamic dimension of the conversation, where the thematically structured part is more dialogic. The semi-structured interview can be regarded cued retrospective, since both parts of the interview build on results from previous data gathering stages (interview part one elaborates on answers questionnaire and interview part two elaborates on interview part one). Due to practical reasons (e.g.,

preparedness and availability of experts) it was decided to conduct one face-to-face interview. Internal validity is addressed by giving the subject the opportunity to reread and evaluate the (adapted) transcriptions of the interviews. The results of the interviews were finalized telephonically.

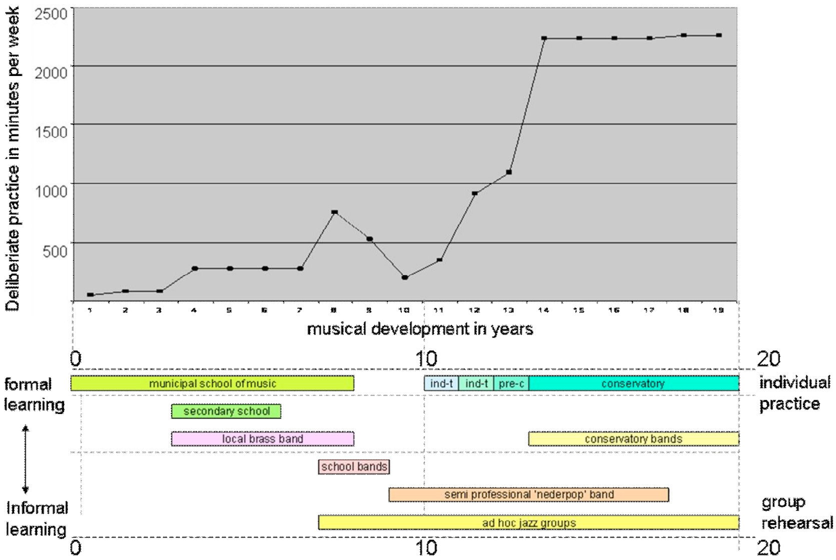

Figure 1. Example of input for semi-structured interview.

Data analysis. Interviews are tape-recorded and transcribed. Codes are both descriptive and interpretative (see Miles & Huberman, 1994). In the first phase a vertical or within-case analysis has been conducted. The second phase of the analysis included a horizontal or comparative analysis (cross-case analysis). During cross-case analysis the focus is on a comparison between the expert and non-expert improvisers.

Results and Conclusion

A pilot study proved that the procedure for collecting and analyzing data was feasible. Preliminary results of the main study indicate that the amount of practice is probably a decisive determinant for successful improvisational development. Based on the analysis of the some questionnaires and interviews non-expert improvisers seem to spend less time on deliberate practice (i.e., individual and group imitation tasks, completion tasks, and conventional tasks) and goal-free practice (i.e., 'messing about on the instrument') than expert improvisers (cf. Ericsson et al., 1993). However, beside (guided) practice, also intelligence is mentioned as an important factor for successful skill learning (cf. Ruthsatz et al., 2008). Further, personality is brought up as the key to creativity with a 'big C' (cf. Kaufman & Beghetto, 2009). At the ICLS Conference the final results of the learning biography study will be presented.

References

Ericsson, K. A., Krampe, R. Th., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*, 363-406.

Howe, M. J. A., Davidson, J. W., Sloboda, J. A. (1998). Innate talents: Reality or myth? *Behavioral and Brain Sciences*, *21*, 399-442.

Johnson-Laird, P. N. (2002). How jazz musicians improvise. *Music Perception*, *19*, 415-442.

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The four C model of creativity. *Review of General Psychology*, *13*, 1-12.

Kelchtermans, G. (1999). *Narrative-biographical research on teachers' professional development: Exemplifying a methodological research procedure*. Paper presented at the AERA meeting in Montreal (Canada) (ERIC-document ED 432 582).

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analyses: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.

Ruthsatz, J., Detterman, D., Griscom, W. S., & Cirullo, B. A. (2008). Becoming an expert in the musical domain: It takes more than just practice. *Intelligence*, *36*, 330-338.

Sawyer, R. K. (2006). Educating for innovation. *Thinking Skills and Creativity*, *1*, 41-48.

Sweller, J. (2009). Cognitive bases of human creativity. *Educational Psychology Review*, *21*, 11-19.

Van Merriënboer, J. J. G, & Kirschner, P. A. (2007). *Ten steps to complex learning*. Mahwah, NJ: Lawrence Erlbaum.

Virtual Math Teams: An Online Tool for Collaborative Learning in the Mathematics Disciplines

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Abstract: The Virtual Math Teams (VMT) service provides an integrated Internet-based environment for small teams of people to discuss math and to work collaboratively on math problems or explore interesting mathematical micro-worlds together. We are presenting an overview of VMT's traditional features and usage in K-12 teaching and group cognition research contexts, and the affordances of its new features, including the first collaborative Internet-based dynamic mathematics whiteboard.

The VMT Project

The Virtual Math Teams (VMT) Project has conducted research for the past seven years on how to support small teams of students around the world to collaborate online in discussions of stimulating mathematical topics. The project has developed an extensive Internet-based environment and conducted about 400 sessions of usage. Analysis of usage has resulted in over a hundred academic publications (Stahl, 2006, 2009; Çakir, Zemel & Stahl, 2009; Sarmiento & Stahl, 2008). The Math Forum of Drexel University offers the VMT free of charge to the world and also provides VMT professional development workshops to practitioners and school districts.

Various features of VMT have traditionally enabled its ability to enhance collaborative learning and teaching of mathematics:

- A social networking Web portal called the VMT Lobby (http://vmt.mathforum.org/VMTLobby/).
- A Java Web Start application that:
  - Integrates text chat (much like chat facilities found in instant messaging applications) with a shared whiteboard tab for synchronous collaboration. The chat panel includes social awareness indicators, so collaborators can easily see who is typing and who is graphically making changes.
  - Has an embedded Web browser linked to an asynchronous community wiki
  - Has an embedded Web browser linked to topic-based pages.
  - Includes referencing from chat to sections of Web pages in an embedded Web browser.
  - Includes referencing from chat messages to previous chat messages.
  - Includes referencing from chat to an area or an object in the whiteboard.
  - Features scrollable history of the chat and the whiteboards, allowing learners, educators, and researchers to see at any time the history of a group's interaction.

Dynamic Math

We wanted to tailor the system more to the discipline of school mathematics by taking advantage of new computer-based tools for dynamic math. We hypothesized that this would enhance mathematical exploration and communication in VMT to foster more powerful and precise inquiry of mathematical disciplinary content. Dynamic math tools (like Geometer's Sketchpad, Cabri, SimCalc, and GeoGebra) have been thought to have "revolutionized" K-12 math learning. We wanted to include this power in VMT. We selected GeoGebra as the most accessible (available in open source) and powerful (including algebra, geometry, spreadsheet, graphing and calculus). However, GeoGebra—like all available dynamic math systems—was only available as a single-user application and VMT is designed to support collaborative learning and group cognition.

A New Version of VMT

To improve inquiry of mathematical disciplinary content we implemented the first multi-user and synchronous dynamic mathematics whiteboard (see Figure 1). This was accomplished using the open source dynamic geometry/algebra/calculus GeoGebra system (http://www.geogebra.org). This new GeoGebra whiteboard includes all the history and chat referencing features of our traditional whiteboard. It also has all of the features of GeoGebra, including the ability to support importing and exporting of GeoGebra dynamic worksheets. This allows teachers and students to take advantage of available curricular materials. It also provides a multi-user version of GeoGebra for the community of teachers and students currently using the single-user versions of GeoGebra.

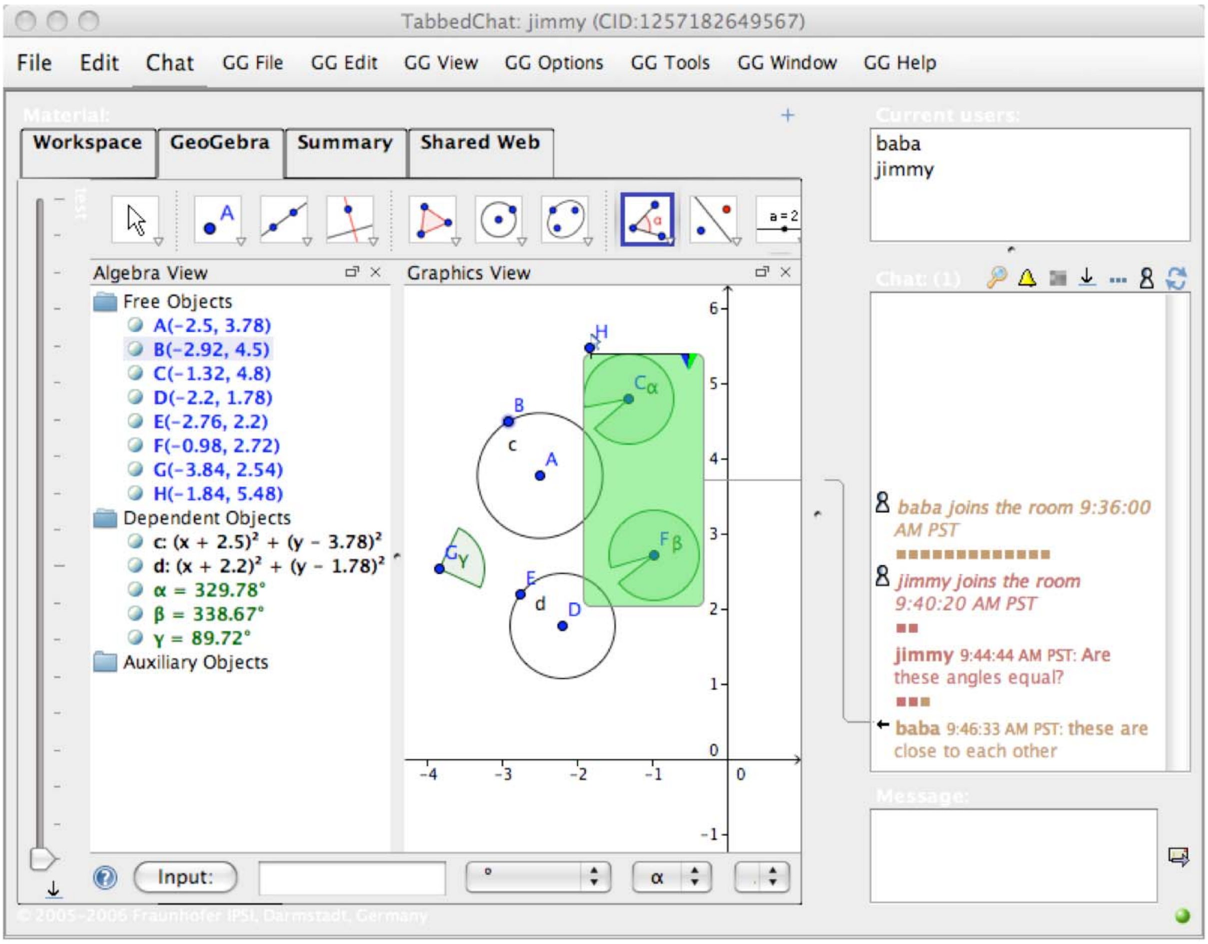

Figure 1. The GeoGebra Tab of VMT.

Despite the reputation of dynamic math systems to potentially transform the way that mathematics is taught and learned, there is relatively little research about the cognitive effects of these tools. In particular, there is almost no analysis of how these tools can mediate collaborative learning of the important discipline of mathematics. We have found that VMT provides excellent data sets for the study of how students learn in a collaborative, computer-supported environment by engaging in mathematical discourse. The VMT system includes a Replayer tool that reproduces an entire student session, allowing a researcher to study the interaction as closely as desired, progressing through the session like in a digital video and observing everything that the students observed. Because mathematical thinking is made visible in a collaborative problem-solving session (Stahl, 2006), it is possible to conduct a broad range of analyses (Stahl, 2009). For instance, one can describe in detail how students coordinate their graphical, narrative and symbolic constructions (Cakir, et al, 2009) and how they construct and reason about their joint problem space (Sarmiento & Stahl, 2008).

The Math Forum plans to release the new system for worldwide usage, providing a convenient online venue for students to engage in synchronous collaborative learning within a rich environment for mathematical inquiry and knowledge-building interaction. We also plan to release VMT to the open source communities.

References

Çakir, M. P., Zemel, A., & Stahl, G. (2009). The joint organization of interaction within a multimodal CSCL medium. *International Journal of Computer-Supported Collaborative Learning,* 4(2), 115-149. Available at http://dx.doi.org/10.1007/s11412-009-9061-0.

Sarmiento, J., & Stahl, G. (2008). *Extending the joint problem space: Time and sequence as essential features of knowledge building.* Paper presented at the International Conference of the Learning Sciences (ICLS 2008), Utrecht, Netherlands. Available at http://GerryStahl.net/pub/icls2008johann.pdf.

Stahl, G. (2006). *Group Cognition: Computer Support for Building Collaborative Knowledge*. Cambridge, MA: MIT Press. Available at http://GerryStahl.net/mit.

Stahl, G. (2009). *Studying virtual math teams.* New York, NY: Springer. Available at http://GerryStahl.net/vmt/book.

Student Conceptions of Number in Solutions Chemistry

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Abstract: Students' understandings of number in solutions chemistry were probed through a qualitative study. Through the use of a semi-standardized interview, students' various ways of understanding number were pooled so that coding categories could be formed. Preliminary data show that students experience number differently with respect to molarity and significant figures.

Introduction

The preliminary results of a full study, "Student Understandings of Solutions" have prompted another full study that examines how students understand number in terms of stoichiometry and significant figures within molarity. Students' conceptions of number are an important factor in learning because of the prevalence of number in many aspects of chemistry. This is especially true in solutions where measurements of mass, volume, moles, and concentration occur. An understanding of student conceptions of number affect instruction and learning in science, the use and refinement of standards, and efforts to understand how quantification helps or hinders student understandings of science, in particular chemistry. A qualitative study is being used in this research to document how students experience number, within the context of solutions chemistry. Specifically this study addresses the following research questions:

- What are students' conceptions of number in solutions chemistry problems involving molarity?
- What are students' conceptions of number with respect to molarity and volume?
- What are students' conceptions of significant figures in solutions chemistry?

A number without a unit in chemistry is useless because of all of these possible uses of number. In the same vein, because of all of the different possibilities for numbers in chemistry, students may have different conceptions of number for each possibility. Number is an essential component to the teaching of chemistry and students are often tested on their algorithmic skills. However, as studies suggest, students can perform algorithmically and have no understanding of the concept being tested (Nakhleh, 1993; Schmidt & Jignéus, 2003). This suggests that a study focused on students' experiences with numbers would be worthwhile. Solutions chemistry is a critical concept that connects to many other areas of science, such as earth, environmental and life sciences. Therefore solutions chemistry is an important area for students to master as they will encounter it many times in their academic careers.

Each state can create their own standards based upon the NSES and their own education requirements. Illinois has two sets of standards: the Illinois Learning Standards (ILS) which are the basis of the Illinois Science Assessment Framework (ISAF). A closer look at the ISAF statements shows that a vast majority of them involve number. Many of the statements are also related to solutions chemistry. Because more students are taking chemistry each year, we need to understand how they learn various concepts within the domain to better teach in the future

Methods

In light of the importance of number in standards based education and the paucity of research on how STEM students experience number, I have chosen a qualitative approach to study the experiences students have with number in chemistry, especially solutions chemistry for a more complete study. Students were interviewed through tasks probing their understandings of number in solutions chemistry. For example, in one task three bottles are labeled with the same molarity but different volumes. Students are asked what is the same and what is different in the bottles. Another task, has four bottles with the same volume but four different molarities. Students are asked what is the same and what is different in the bottles. Finally, during a dilution task, students are asked what happens when 50mL of a 100mL solution of 0.15M $CaCl_2$ is taken away. All of these tasks are designed to find various ways of understanding number.

Preliminary Results

Preliminary results from the larger "Solutions" project involving five students show that students are experiencing number with respect to molarity in a variety of ways. Students experienced molarity in an algorithmic way, citing the definition which is moles per litre of solution or they experienced molarity as a percentage of solution rather than the ratio that it is. For example, one student indicated that 0.05M was 5% less than 0.10M rather than being 50% less. This illustrates the need for further study of student understandings of number in solutions chemistry. An unusual preliminary finding that resulted from this study was that one student experienced molarity in relation to its significant figures, thinking that 0.05M was less significant than 0.10M because it has less significant digits and less was "looked at". Due to its unexpected nature, the task was not designed to afford this type of experience with number. This is another illustration of the need for further study of students' understandings of number in solutions chemistry as students held different conceptions than experts predicted. This is also an example of how a student could algorithmically solve a problem correctly yet hold a misconception about what the numbers mean. Instructionally, knowing what conceptions students hold with respect to number in solutions chemistry would facilitate student-centered learning. This could also inform the use of standards in that concepts of number could be tested rather than knowledge of an algorithm.

Finally, the dilution task revealed a conception that the molarity is decreased by half when half of a solution is poured out of the beaker. This conception does not involve the ratio of molarity, indicating varying ways of experiencing this type of number in solutions chemistry.

Conclusions and Implications

The preliminary results from this qualitative study indicate the need for further study of student conceptions of number in solutions chemistry. A study of student conceptions of number in solutions chemistry would be beneficial to science educators on three levels. First, teacher conceptions could differ from student conceptions and being aware of those differences could allow teachers to design instruction that will bridge that gap (Orgill 2007). Effective instruction needs to address the conceptions that students bring to learning tasks, especially when the conceptions conflict and differ from those accepted by the community. (Bransford, Brown & Cocking, 2000). Second, participating students may become aware of their own contradictions as they reflect (Marton 1986, Orgill 2007). Third, other educators could use the outcome space to inform their work. A study of students' conceptions of number in solutions chemistry also has implications for our current research project, instruction in science, and the use and refinement of standards. Equipped with an outcome space of student conceptions of number, we could design better interviews to see if quantification helps or hinders student understandings of solutions.

References

Bransford, J. D., Brown, A. and Cocking, R. (eds) (2000) *How people learn: Mind, brain, experience and school* National Academy Press. , Washington, DC

Marton, F. (1986) Phenomenography: A research approach to investigating different understandings of reality. *Journal of Thought*. 21, pp 28- 49.

Nakhleh, M. (1993). Are our students conceptual thinkers or algorithmic problem solvers—Identifying Conceptual students in general Chemistry *Journal of Chemical Education*, 70, pp 52-55.

Orgill, M. (2007) "Phenomenography" in George M. Bodner & MaryKay Orgill (Eds). *Theoretical Frameworks for Research in Chemistry/Science Research. (*pp 132-151). Upper Saddle River, NJ: Pearson Education.

Schmidt, H.J. & Jigneus, C. (2003). Students' strategies in solving algorithmic stoichiometry problems. *Chemistry Education: Research and Practice,* 4, 305-317.

The Video Mosaic: Design and Preliminary Research

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Abstract: The Video Mosaic is a collaboration portal that integrates the Davis Institute video collection capturing mathematics learning across a range of grades, schools and a span of 20+ years. We present preliminary research using the VMC for teacher professional development.

A common approach to teacher professional development (TPD) in mathematics education focuses on teachers' content knowledge for teaching by engaging them in tasks that represent major conceptual strands in mathematics, and encouraging them to connect lessons learned from this problem solving to classroom practice (Philip et al., 2007). Video allows learning to be studied in the complex contexts in which it naturally occurs (e.g., Brown 1992). An important aspect of video data is that it enables one to study how learning actually unfolds in context (Darling-Hammond, et al., 2005). Teachers do not ordinarily have the opportunity to study in detail how students in their own classrooms learn. This makes video especially useful for research on learning and teaching as well as for TPD (e.g., Lampert & Ball, 1998). Collections of video provide a source of data for careful analysis and reflection on practice. While large-scale projects often collect large amounts of video, often only a small subset of the video is relevant for addressing particular research questions. This video can be productively used beyond the projects for which they were collected with great investments of time, effort, and money. This argument echoes recommendations made by a recently-commissioned NSF report on video research in education (Derry et al., 2007), which emphasizes the important role of cyber-enabled video tools in achieving this goal. Video tools make it possible for teachers and researchers to observe students' learning of mathematics and reflect on students' potential for doing mathematics (Powell, Francisco & Maher, 2003).

The Video Mosaic

The Video Mosaic (VMC; www.videomosaic.org) is a collaboration portal that integrates the Robert B. Davis Institute for Learning Video Collection, which captures mathematics learning across a range of grades, schools and a time span of 20+ years, with a collaboration platform and tools designed to transform mathematics teaching and learning research (Maher, 2005). The VMC combines innovative research into the teaching and learning process with videos and tools to enable teachers, teacher educators and researchers to analyze and use the videos to make new discoveries in math education and the learning sciences (Agnew, Mills & Maher, 2010).

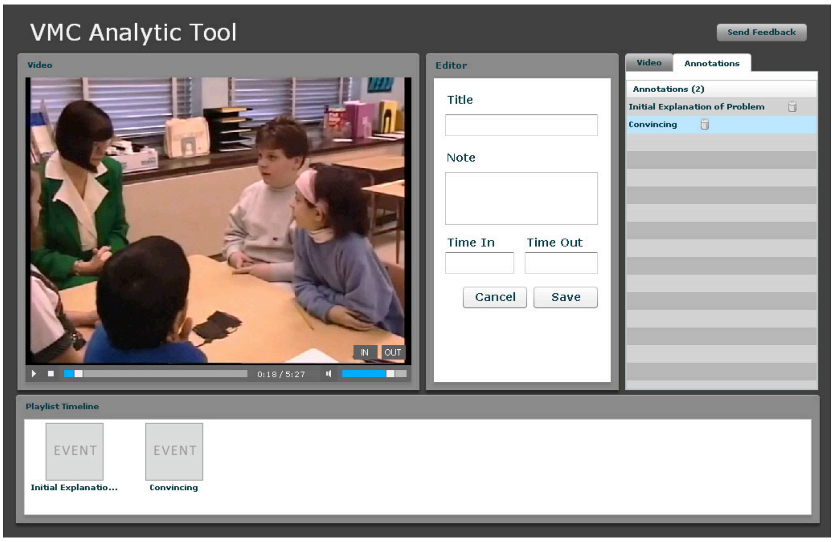

Figure 1. VMC Analytic Tool

This project has involved development of the VMC repository and pilot studies of TPD. The VMC has been constructed to preserve videos, catalog resources using the METS (metadata encoding and transmission standard) and develop a prototype analytic tool to enable individual and community use of videos (Agnew, et al, 2010). Developing an analytic tool for a large, complex video collection that would support both individual and collaborative analysis is a key challenge. Video analytics can range from simple coding to complex interpretive texts that must be associated with the appropriate video it analyzes, and are thus metadata; but these analytics are also creative works and need to be afforded the same treatment as the video that it analyzes. Analytics are thus information objects in the repository that can be associated not only with the video being analyzed but also another analytic, as when an instructor creates an analytic to critique a student's analytic.

Preliminary Design Research

We are studying the VMC through a program of design research (Bielaczyc, 2006). We conducted pilot studies using VMC in interventions that used video cases showing multiple forms of reasoning in a range of school settings, math content, and grades. We developed instruments to measure beliefs about teaching and learning mathematics, content knowledge, and a video assessment of ability to recognize forms of mathematical reasoning. These studies were conducted at three preservice sites and one inservice site with elementary and middle school teachers. In a typical intervention, teacher-learners collaboratively engaged in challenging mathematical tasks with manipulatives available for building models from which they could reason and develop solutions. They shared solutions, representations, and justifications. Following their own problem solving, teacher-learners studied children working on the same task. Our analysis of teacher beliefs (Table 1) shows that there are two factors: one related to beliefs about student learning and another about effects of teaching, and that these beliefs are positively affected (shown by lower scores) by participating in VMC interventions.

Table 1, Teacher Beliefs

	Factor 1 Score		Factor 2 Score	
	Pre	Post	Pre	Post
Mean	1.95	1.58	2.34	1.94
Standard Deviation	0.63	0.55	0.43	0.56
T(69), all *p <.001*	4.97		7.42	

Conclusions

The VMC is demonstrating the use of cyber-enabled technologies to build and share adaptable interventions for TPD that effectively make use of major video collections and have high promise of success at multiple sites. The cyber infrastructure provided by the VMC and significantly extended through this project is supporting development and documentation of furthers interventions for TPD using this video collection, as well as other videos that might be added in the future by teacher educators or researchers, including those working in other STEM domains. Future research will examine how interventions in different contexts over different iterations affect teacher learning and try to better understand the characteristics of different interventions.

References

Agnew, G., Mills, C. M., Maher, C. A. (2010). VMCAnalytic: Developing a collaborative video analysis tools for education faculty and practicing educators. *HICSS 2010 Proceedings.*

Bielaczyc, K. (2006). Designing social infrastructure: Critical issues in creating learning environments with technology. *Journal of the Learning Sciences*, *15*, 301-329.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2*, 141-178.

Darling-Hammond, L., Banks, J., Zumwalt, K., Gomez, L., Sherin, M. G., Griesdorn, J., & Finn, L-E. (2005). Educational goals and purposes: Developing a curricular vision for teaching. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers know* Jossey-Bass.

Derry, S. J. (Ed.) (July, 2007). *Guidelines for video research in education: Recommendations from an expert panel.* http://drdc.uchicago.edu/what/video-research-guidelines.pdf

Maher, C. A. (2005). How students structure their investigations and learn mathematics: Insights from a longitudinal study. *Journal of Mathematical Behavior*, *24*, 1-14.

Philipp, R., Ambrose, R., Lamb, L., Sowder, J., Schappelle, B, Sowder, L., Thanhesier, E., & Chauvot, J. (2007). Effects of early field experiences on the mathematical content knowledge and beliefs of prospective elementary school teachers: An experimental study. *Journal for Research in Mathematics Education*, *38*, 438-476.

Powell, A., Francisco, J. & Maher, C. (2003). An analytical model for studying the development of learners' mathematical ideas and reasoning using videotape data. *Journal of Mathematical Behavior*, *22*, 405-435.

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From Gettysburg to the Cuban Missile Crisis: Designing for Historical Reenactments with *Twitter*

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Abstract: TwHistory is a project designed to organize and promote a variety of historical reenactments using Twitter as a tool for computer mediated communication of historical events. Thus far, volunteers and educators have organized reenactments of the Battle of Gettysburg and the Cuban Missile Crisis while other efforts are underway. This poster will share an iteration of design and development for historical reenactments using Twitter and examine the initial feedback within the paradigm of design-based research.

Introduction

The issues surrounding historical thinking and reasoning have drawn a great deal of attention in recent years; with special attention as to the role technology has played in this endeavor (Wineburg, 2001). Few students have a deep understanding of the processes by which historical accounts are constructed or the perspectives that are brought to bear on the interpretation of historical events. Questions have arisen concerning the possible benefits of learning from original sources and resources. In other words, what affects students' thinking when experiencing accounts from other people who have access to the original sources? It is worth considering that future-oriented technologies may enable new means to improve how one relates to the past. This idea has been illustrated, for example, by research centered on computer games that show re-enactments of historical events, how they can promote student engagement, and how they can help to initiate reflection related to historical events (Squire, 2003). This poster presents the preliminary results of the design, development, and implementation a project involving historical re-enactments through the use of the *Twitter* Microblogging system.

Project History: *Twitter* and Microblogging

Twitter is a relatively well-known microblogging technology and used by those who comprise the "digital youth" generation (Ito et al., 2008). *Twitter* messages, or *tweets*, are sent and received from these profiles through varying protocols, mostly obtained through computers and hand-held devices. The 140 character constraint of tweets had been set as part of an effort to ensure compatibility with Simple Message Syndication (SMS) texting systems, and has remained even though texting technologies have advanced such that that limit is no longer necessary. As with other types of microblogs, tweets are often of a personal nature, involving commentary or description of one's activities and one's opinions about some current state of affairs (Nardi, Schiano, Gumbrecht, & Swartz, 2004). Increasingly, *Twitter* is being used for marketing purposes and in the political arena (Comm, 2009). Thus far, research regarding the potential of texting systems within education has yet to be fully explored.

Simulations, and in particular, participatory simulations have shown tremendous promise in supporting learning (Colella, 2000). With that in mind, the TwHistory project began in early 2009 with a participatory reenactment of the Battle of Gettysburg that took place over a period of two months. TwHistory is based on the idea that historical reenactments can take place online and have the same positive effects for volunteer participants and virtual onlookers. *Twitter* provides many of the necessary elements for a recreating a historical event: actors, communication, and relationships. Followers of *Twitter* reenactments receive tweets in real-time as the characters of a particular historical event communicate report from their perspective what is happening. In the original Gettysburg reenactment, generals, citizens, soldiers, and even Abraham Lincoln had profiles from which tweets reporting the events of the battle were sent out. A sample set of tweets is shown in Figure 1a.

Figure 1. Screenshots of *Twitter* feeds from (a) Gettyburg reenactment and (b) the Cuban Missile Crisis reenactment, as they appear in reverse-chronological order from within *Twitter*.

The initial instance of Gettysburg, once public, drew a diverse set of followers who subscribed to the *Twitter* feeds. One of the Gettysburg followers was a high school teacher in the American Midwest. With assistance, she adapted the Gettysburg model as part of her Cold War History course. Students played the role of President Kennedy, Nikita Kruschev, Robert MacNamara, and others in a reenactment of the Cuban Missile crisis (Figure 1b). While this reenactment took place prior to any planned research studies, it is motivating new work to research the learning gains for K-12 students who perform the reenactments as part of formal history instruction.

Data Sources and Implications

Data sources to inform design decisions include usage data obtained through the Twitter service, feedback messages from followers, and firsthand reports from volunteers who participated directly as actors in the historical reenactments. These sources are used to report on the geographic spread of TwHistory and provide accounts regarding the use of primary sources and subsequent learning gains of reenactment actors. Data from a new reenactment the Pioneer Trek of 1848 comprises one case analyzed from beginning to end presented in the poster. While still largely an exploratory report, researchers are observing that for volunteer actors, the synthesis of historical documents and accounts is leading to knowledge gains reflected in lesson plan goals. For example, in volunteer message boards, a reenactment author asks about references to markers that were used every ten miles along the trail and mentions the use of an odometer. Another author adds that it was Appleton Harmon who created a type of wagon wheel odometer during the pioneer trek. Currently, the researchers are preparing for classroom-based reenactments from which more systematic data collection and analysis allows for deeper examination of how students and teachers use primary sources as part of their research. Findings report what changes occur, both in individuals' knowledge and affective stances toward history, through use of TwHistory.

References

Colella, V. (2000). Participatory Simulations: Building Collaborative Understanding through Immersive Dynamic Modeling. *The Journal of the Learning Sciences; 9*(4), 471-500.

Comm, J. (2009). *Twitter power: How to dominate your market one tweet at a time.* Hoboken, New Jersey: Wiley.

Ito, M. et al. (2008). Living and Learning with New Media: Summary of Findings from the Digital Youth Project. Chicago, IL: MacArthur Foundation. Retrieved November 2, 2009, from http://digitallearning.macfound.org/site/c.enJLKQNlFiG/b.2029199/.

Nardi, B., Schiano, D., Gumbrecht, M., & Swartz, L. (2004). Why we blog. *Communications of the ACM; 47*(12), 41-46.

Squire, K. (2003). Replaying history: Learning world history through playing Civilization III. Unpublished Doctoral Dissertation. Indiana University. Bloomington, IN.

Wineburg, S. (2001). *Historical Thinking.* Philadelphia, PA: Temple University Press.

The CORDTRA Analysis Tool in Action: Experiences and Suggestions

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Abstract: This short paper presents the authors' experiences and reflections from using an existing tool (CORDTRA) for analyzing collaborative learning interactions evident in wiki and threaded discussion technologies. The paper aims to discuss the strengths and limitations of the tool, in terms of existing research, and provide thoughtful recommendations for its improvement.

A Brief Review of the Study

CORDTRA (Chronologically-Oriented Representations of Discourse and Tool-related Activity) provides "an innovative representation for analyzing the evolution of discourse and tool-related activity across time" (Hmelo-Silver, Chernobilsky, & Nagarajan, 2009, p. 3). This short paper presents a formative evaluation of the CORDTRA tool. We adapted the CORDTRA tool to investigate the collaborative learning (CL) interactions evident in wiki and threaded discussion technologies as students worked in groups to analyze a case. This work was part of a larger-scale study which examined the affordances of these two Web 2.0 technologies to promote or constrain successful computer-supported (CS)CL in online settings. We very briefly discuss the context of this work below, however the complete study is reported elsewhere (Ioannou & Brown, 2010).

We collected data from 34 graduate students enrolled in two sections of an online, learning theories course at a large public University in the Northeast USA. Additionally we collected data from 10 students enrolled in a blended e-learning learning, educational psychology course at a private University in Cyprus. During the 4-week investigation, students (in groups of 3-4) collaborated on case study analysis, online. Groups discussed two different case scenarios and produced a consensus plan suggesting a solution to the problem embedded in each case. Groups in the USA used WebCT's threaded discussion board and a wiki built in MediaWiki (the open-source platform originally written for Wikipedia) to support their collaboration. Similarly groups in Cyprus used Moodle's threaded discussion board and MediaWiki. Data included: (a) logs of groups' online discourse archived in MediaWiki discussion pages and threaded discussion board (i.e., day/time stamp, collaborator's name, collaborator's contribution), and (b) groups' consensus plans developed in wiki article-pages and Word documents attached back and forth on the threaded discussion board.

The online discourse of each group was analyzed using a coding-and-counting approach to Computer-Mediated Discourse Analysis (CMDA; Herring, 2004). Subsequently, the CORDTRA tool (a CORDTRA for each group) allowed the investigators to beyond coding-and-counting to carefully examine the relationships between the collaborators, the discourse they engaged in, the mediating tools they used, and the construction of their consensus plan (Hmelo-Silver et al., 2009). Each time-point on a CORDTRA diagram represents a collaborator, one or more discourse/construction categories, and the corresponding technology feature that the collaborator is using. The coding scheme and sample CORDTRAs will appear in the poster presentation.

Reflections on the Use of the CORDTRA Analysis Tool

CORDTRA seems to be an appropriate analysis tool for the study of CL using Web 2.0 technologies, such as wikis and threaded discussion. The diagrams are effective in revealing patterns in context in CSCL settings. Also, as a history flow visualization technique, CORDTRA may have advantages over more popular analytical techniques, such as social network analysis. Social network analysis graphically represents the patterning of people's interaction (i.e., who interacted with whom). Although this is useful information, it discards the content and nature of knowledge construction that take place in the interactions (Stahl, 2006). Instead, the CORDTRA diagram, in relation to the corresponding discourse, seems to support deeper understanding of CSCL. At the very least, this tool brings the investigator closer to what is happening between the students, the discourse they engage in while collaborating, and the mediating tools they use.

However, this tool does not come without its limitations. Firstly, generating the diagrams using Excel scatterplots is a quite labor intensive process. If CORDTRA is to be used extensively by the CSCL community, an automated process for generating these diagrams should be developed. In the literature, there are a few attempts to develop analytical and visualizing tools that automate the study of CSCL. Yet, there is a need for a toolset that supports, (a) data from different platforms (e.g., MediaWiki and WebCT discussion forum), and (b) different forms of data analysis (see Law, Yuen, Huang, Li, & Pan, 2007). With regards to integrating data from different platforms, Klamma and Haasler (2008) implemented a system for generating and visualizing wiki networks for wikis built on MediaWiki. Their goal was to study the evolution and dynamics of wikis, within a social network analysis framework. Additionally, Viégas, Wattenberg, & Dave (2004) developed a history flow user interface, again for MediaWiki, in order to study the evolution of Wikipedia. Using this interface the investigators were able to see the contributions on a wiki page, the authors who contributed, and a visualization of the history flow. Recently, Giguet and Lucas (2009) developed the "Calico Website"-- a tool that incorporates analytical and visualization features for the study of threaded discussion forums from different e-learning platforms, such as WebCT and Moodle. Nevertheless, none of those tools allows the development of chronological diagrams from data generated in both wiki and threaded discussion tools. Moreover, with regards to analyzing data in different forms, Law et al. (2007) argued that lots of time is wasted in transforming data into different formats for different analyses, because the tools for different kinds of analysis in CSCL are not yet integrated. The investigators experienced this difficulty during the study. Specifically, a significant portion of CMDA (Herring, 2004) was initially conducted in NVivo -- a specialized coding tool. Later, the investigators realized that all codes had to be re-entered in an Excel sheet in order to generate the CORDTRA diagrams.

A second limitation of the CORDTRA methodology involves the interpretation of the diagram, which requires significant additional time commitment on top of generating it. A CORDTRA makes sense only in relation to the corresponding discourse; patterns of collaboration are not clear from the diagram, unless one carefully considers the discourse and the diagram *together*. As Hmelo-Silver et al. (2009) explained, the investigator needs to zoom in on the areas of the diagram where interesting patterns exist to explore the phenomenon deeper, going back and forth between the CORDTRA and the coded discourse. A potentially useful functionality for the CORDTRA analysis tool would be the ability to select a particular instance on the scatterplot to see the corresponding lines of discourse. This would make the concurrent exploration of discourse and scatterplot more efficient. A similar functionality was implemented in the "Calico Website" for the study of threaded discussion forums (see Giguet & Lucas, 2009). Additionally, it would be practical to have a "zoon in" functionality for CORDTRAs to spread out the scatter plot around a particular time point. When there is significant activity, collaborators' discourse and actions overlap extensively on the diagram; this, not only makes it difficult to observe any patterns, but also underestimates the amount of activity taking place at that time. Such "zoom in" functionalities are currently implemented in video and audio editing software.

Our poster presentation will provide thoughtful recommendations for the improvement of the CORDTRA analysis tool. The presentation should be of interest to the scientific community using instruments of this nature for the study of CSCL.

References

Giguet, E., & Lucas, N. (2009). *Share and explore discussion forum objects on the Calico website*. Poster presented at the annual meeting of the computer supported collaborative learning, Rhodes, Greece.

Herring, S. C. (2004). Computer-mediated discourse analysis: An approach to researching online communities. In S. A. Barab, R. Kling, & J. H. Gray (Eds.), *Designing for virtual communities in the service of learning* (pp. 338-376). Cambridge & New York: Cambridge University Press.

Hmelo-Silver, C. E., Chernobilsky, E., & Nagarajan, A. (2009). Two sides of the coin: Multiple perspectives on collaborative knowledge construction in online problem-based learning. In K. Kumpulainen, C. E., Hmelo-Silver, & M. Cesar (Eds.). *Investigating Classroom interaction: Methodologies in action*. Sense Publishers.

Ioannou, A., & Brown, S.W. (2010, April). *Wiki and threaded discussion for collaborative case-study analysis: Do students use the technologies differently?* Paper to be presented at the annual meeting of the American Educational Research Association, Denver, Colorado.

Klamma, R., & Haasler, C. (2008). *Wikis as social networks: Evolution and dynamics*. Paper presented at the 2nd SNA-KDD Workshop on Social Network Mining and Analysis. Retrieved August 20 2009, from KNOW_Ralf_Klamma_Wiki_as_Social_Network.pdf

Law, N., Yuen, J., Huang, R., Li, Y., & Pan, N. (2007). A learnable content and participation analysis toolkit for assessing CSCL learning outcomes and processes. In C. A. Chinn, G. Erkens, & S. Puntambekar (Eds.), *Proceedings of the Computer Supported Collaborative Learning* (pp. 411-420). New Brunswick, New Jersey.

Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge*. Cambridge, MA: MIT Press.

Viégas, F., Wattenberg, M., & Dave, K. (2004, April). Studying cooperation and conflict between authors with history flow visualizations. *Proceedings of Conference on Human Factors in Computing Systems* (pp. 575 – 582).

Acknowledgments

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Validity Evidence for Games as Assessment Environments

Abstract: This poster provides empirical evidence of a highly specific use of games in education—the assessment of the learner. Linear regressions were used to examine the predictive and convergent validity of a math game as assessment of mathematical understanding. Results indicate that prior knowledge significantly predicts game performance. Results also indicate that game performance significantly predicts posttest scores, even when controlling for prior knowledge. These results provide evidence that game performance taps into mathematical understanding.

Games as assessment contexts

Games have long been attractive as learning environments given that games can entertain, motivate, and energize us. This poster will address a highly specific use of games in education—the assessment of the learner. Games can be used as formative (in-the-process-of-learning) assessments, as well as for criterion trials, either to determine the level of performance of an individual or to gauge the speed and agility with which a learner acquires a new set of skills in an unfamiliar game environment (Baker & Delacruz, 2007; Gee, 2008). When designed properly, the underlying game engine can enable increases in challenge, complexity, and the cognitive demands required as the game progresses such that game play can be one form of assessment. Assessment is a process of drawing reasonable inferences about what a person knows by evaluating what they say or do in a given situation. However, it is insufficient to state that an assessment task is or is not valid. Rather, determining the validity of assessment tasks requires creating an argument that examines how well assessments answer the questions they purport to answer, as well as ensuring the data obtained provide the appropriate evidential basis for the claims made about students (American Educational Research Association, American Psychological Association, and National Council for Measurement in Education, *Standards for Educational and Psychological Testing*, 1999). In this poster, we report findings from a study that investigated the validity of a mathematics game as assessment of mathematical understanding by examining the relationship between mathematical knowledge and performance in the game.

Puppetman as an assessment context

We developed a mathematics game, *Puppetman*, which targets two pre-algebraic concepts: defining a "unit" and addition of rational numbers (integers and fractions). Specifically, game play in *Puppetman* focused on the idea that all rational numbers are defined relative to a single, unit quantity (e.g., a unit of count, measure, area, volume) and that rational numbers can be summed only if the unit quantities are identical. *Puppetman* is a puzzle game in which players need to determine the appropriate "units" to navigate from a starting point to a goal. Players build trampolines using coils, which determine how far Puppetman will bounce. The trampolines can bounce Puppetman left to right (Figure 1), or right, up, and down (Figure 2).

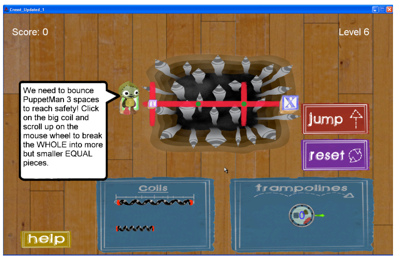


Figure 1. Screenshot of early level in *Puppetman*.

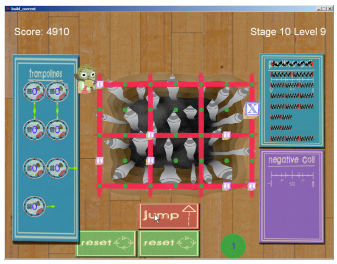


Figure 2. Screenshot of advanced level in *Puppetman*.

Method

Data were collected from 134 summer school high school students. A pretest was administered that included items comprised of adding fractions, determining the size of the unit in various graphical representations, and completing word problems. Students were given between 30 to 40 minutes to play the game. They then took a posttest, which included the same items on the pretest, some additional math items that incorporate game features from *Puppetman*, and a background questionnaire, which targeted attitudinal and interest information in both mathematics and games.

Analysis

In order to examine the validity of *Puppetman* as an assessment task, using a linear regression framework, we examined the predictive validity of pretest scores (i.e., prior knowledge) on game performance, and to obtain convergent evidence, we examined the predictive validity of game performance on posttest scores.

Puppetman was designed to get increasingly complex, with the latter levels requiring the most knowledge of mathematics to be successful. Thus, we used the last level attained as our metric for game performance.

We collected validity information by examining the relationship between various math outcomes scales: (1) pretest scores on pre-algebra items targeting rational number concepts (e.g., identifying numbers on a number line), (2) a smaller subscale of items on the pretest that directly relate to *Puppetman* content (e.g., symbolically adding fractions or identifying the size of a unit), and (3) and items on the posttest that comprised of both of the pretest scales above, as well as additional items that asked students to use the mathematics learned in the game to solve problems posed within the game context.

Results

Reliability analyses were conducted on three scales of math outcomes to ensure that the data of each scale had a unidimensional structure. First, the *pretest scale* was comprised of eight items on the pretest that targeted a range of conceptual understanding of fractions. These items asked students to translate graphical representations of fractions into its symbolic counterparts, identify fractions and define a unit on a number line. The Cronbach's alpha for this *pretest scale* was .63. Another scale was formed for four computational adding fraction items on the pretest. The Cronbach's alpha was for this scale was .73. Finally, the third scale was comprised of 21 items on the posttest. These included the same computational adding fraction items as the pretest, isomorphs of the symbolic items within the context of the game, and other items that asked students to define a unit and represent fractions. The Cronbach's alpha for this scale was .88.

Predictive Validity Results

Descriptive statistics were obtained on the *pretest* items, pretest *adding fraction* items, and game performance. For the 134 students, the average *pretest* score was 6.26 (*SD=3.40*). The average pretest score on the *adding fraction* items was 2.21 (*SD=1.44*). The average last level attained in the game was 14.01 (*SD=3.19*).

A linear regression analysis indicated that math pretest scores significantly predicted game performance, $\beta = .546$, $t(133) = 8.234$, $p < .001$. Performance on the math pretest also explained a significant proportion of the variance in game performance, $R^2 = .34$, $F(1, 132) = 67.698$, $p <.001$. Performance on the *adding fraction* items also significantly predicted game performance, $\beta = 1.036$, $t(115) = 6.084$, $p < .001$. Performance on the math pretest also explained a significant proportion of game performance, $R^2 = .22$, $F(1, 132) = 37.02$, $p <.001$.

Convergent Validity Results

Descriptive statistics were obtained on performance on the posttest items and game performance (Note: three students were dropped from the original sample because they did not take the posttest). For the 131 students, the average posttest score was 13.05 (*SD=5.51*). The average last level attained in the game was 14.09 (*SD=3.12*).

The linear regression analysis indicated that game performance significantly predicted performance on the posttest items, $\beta = .67$, $t(128) = 2.86$, $p < .05$. Game performance also explained a significant proportion of the variance in performance on the posttest items, even after controlling for pretest scores, $R^2 = .57$, $F(2, 128) = 86.38$, $p < .001$, with game performance explaining ***3% of the variance above and beyond*** pretest scores.

Conclusion

This study presented empirical evidence to support our claim that games can be valid assessment contexts. It is important to note that although space did not permit the presentation of survey results, responses to the survey indicate that many students did not perceive *Puppetman* to be a test and responded that they would like to play it at home and during school. While we present empirical evidence of validity of one game as an assessment context, this study demonstrates the potential for games to be valid assessments of understanding. We are currently analyzing the process data in the game play (e.g., time spent on each level, specific actions taken) as a formative assessment tool, to gain insight into the strategies that players employ while playing *Puppetman*.

References

American Educational Research Association, American Psychological Association, & National Council on Measurement in Education. (1999). *Standards for educational and psychological testing*. Washington, DC: American Educational Research Association.

Baker, E. L., & Delacruz, G. C. (2008). A conceptual framework for assessment of learning in games. In H. F. O'Neil & R. S. Perez (Eds.), *Computer games and team and individual learning* (pp. 21-38). Amsterdam, Netherlands: Elsevier.

Gee, J. (2008). Game-like learning: An example of situated learning and implications for opportunity to learn. In P. A. Moss, D. C. Pullin, J. P. Gee, E. H. Haertel, & L. J. Young (Eds.), *Assessment, equity, and opportunity to learn* (pp. 200-221). New York: Cambridge University Press.

Leveraging Multiple Representations to Support Knowledge Integration in Plate Tectonics

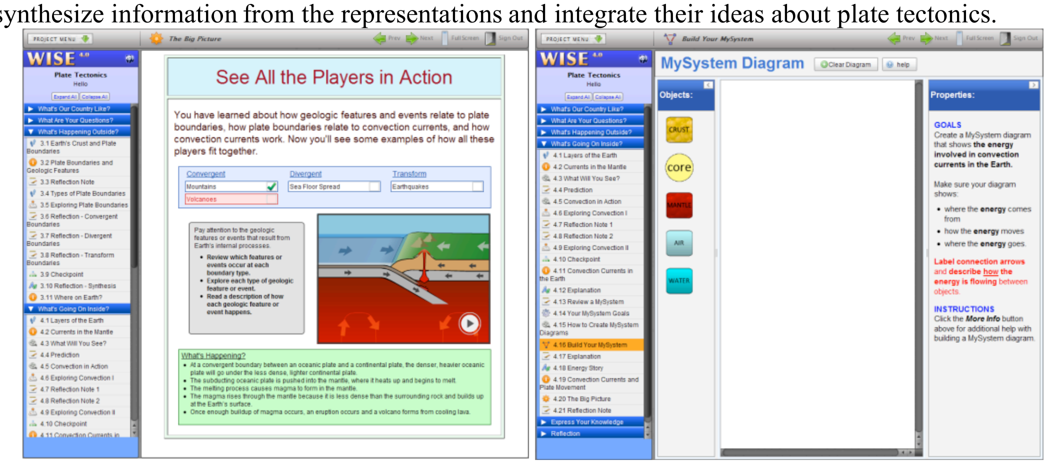
Abstract: This poster explores how students make connections between multiple representations to integrate their ideas about plate tectonics. An existing plate tectonics project was redesigned to incorporate interactive dynamic visualizations and activities in order to support students in making connections between representations and constructing a more coherent understanding of plate tectonics. Preliminary analysis of an observational study suggests that plate tectonics is a rich domain for investigating how multiple representations can support knowledge integration.

Introduction

This study examines how generating and interacting with multiple representations of plate tectonics helps students develop an integrated understanding of plate tectonics. Students study a six-day technology-enhanced curriculum project developed using the Web-Based Inquiry Science Environment (WISE, Linn, Davis, & Bell, 2004). Plate tectonics is a causal theoretical framework for past, current, and future geographical phenomena (Bencloski & Heyl, 1985). It is currently taught as an earth science unit in sixth grade in the state of California. It has traditionally been a difficult concept for middle school students, requiring students to learn about abstract processes and phenomena that lie outside of their direct experience and to integrate spatial, causal and dynamic information (Gobert, 2000). Prior studies have demonstrated that students often have difficulty integrating information from different representations and need support in making connections among them (Ainsworth, 2006). Yet the complexity of phenomena and necessity of integrating information across multiple levels make it advantageous for students to use powerful representations to learn plate tectonics.

The WISE Plate Tectonics Project

Building on a tested plate tectonics module, we revised the project based on prior results and a commitment to connect to the core scientific idea of energy (Varma et al, 2008). Guided by the integration framework (Linn, Eylon, & Davis, 2004), the revisions involved incorporating new dynamic visualizations and activities requiring students to make connections between representations as well as generate their own representations. The project elicited students' ideas about plate tectonics in the context of exploring geological patterns in the United States via maps, then guided them to link visible geological patterns on maps to sub-surface processes involving energy in plate tectonics. These included dynamic visualizations of convection in the mantle at the macroscopic level (involving heat flow) as well as at the molecular level. The project also asked students to generate explanations about the visualizations, as well as their own representations of the processes involved in plate tectonics, in ways that required them to synthesize information from the representations and integrate their ideas about plate tectonics.



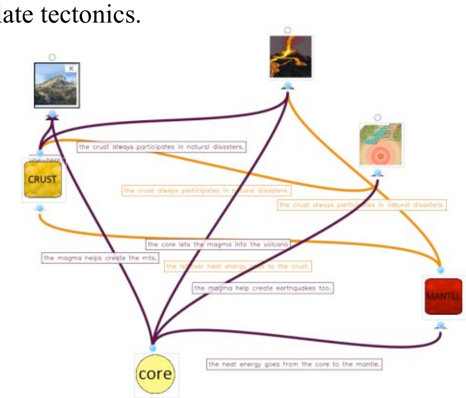
(a) (b)

Figure 1. The Plate Tectonics project. (a) A dynamic visualization of subduction. (b) The MySystem generation activity.

Methods

Nine teachers teaching 6th grade earth science classes (N≈600) implemented the newly redesigned plate tectonics project. Pre- and Post-tests were completed by individual students; project activities and embedded assessments were completed in pairs. Embedded assessments included short-response explanation prompts, reflection notes, visual models of energy transfer and transformation called MySystem diagrams (see Figure 1b), and longer narrative explanation prompts called Energy Stories (see Figure 2). Classroom observations and teacher interviews helped clarify the impact of the project.

Assessments were scored using rubrics based on the knowledge integration framework (Linn, Lee, Tinker, Husic, & Chiu, 2006). The rubric rewards coherence of ideas as represented by the number and complexity of connections students make between their ideas. We analyzed how the project helps students link ideas and representations about the plate tectonics.



(a)

The energy comes from the core and goes through the mantle, the upper mantle, the crust and back down to the core. It goes through the core by convection currents. This is how convection currents work. Well, the core is so hot and has so much heat energy it makes the molecules less dense than the air around it so it goes up. Once it goes up it doesn't have that heat source so it cools down and the molecules get less dense than the air around it so it goes back down. When it goes back down it is near the core, or its main heat source. So it goes again and the process keeps repeating. Whenever the energy goes through the upper mantle it then goes near the crust and it turns into kinetic energy. So beneath the crust the energy is going up and down and it eventually, (depending on which direction it's going), it will spread the crust through kinetic energy. So through convection currents it creates all sorts of new geological features, in the mantle, crust, and in the whole world.

(b)

Figure 2. Sample student responses. (a) A MySystem diagram. (b) An Energy Story.

Results

Implementation of the Plate Tectonics project was successful. Students gained understanding of the topic as measured by pretest/posttest improvements. In interviews, teachers attributed students' progress in understanding convection to their prior experience with conduction and to the revisions of the Plate Tectonics project. Comparison of performance on Energy Stories and MySystem diagrams demonstrated that these representations elicit complementary aspects of understanding. MySystem elicits connections without requiring students to generate correct terminology. Energy Stories elicit specific, nuanced ideas and can reveal confusions about geologic terminology such as mantel. Embedded assessments showed that students make valid connections between the various representations. For instance, students explain that the molecules in the mantle become less dense due to thermal energy transfer from the core, based on a molecular simulation showing the relationship between heat and density in water. They link their understanding of the results of convection to geologic features and events on the surface such as mountains and volcanic eruptions. Thus, different representations may have different affordances for assessing student understanding. These initial findings suggest that plate tectonics is a rich domain for exploring student learning with multiple representations that are both self-generated and imposed upon the learner.

References

Ainsworth, S. (2006). DeFT: A Conceptual Framework for Considering Learning with Multiple Representations. *Learning and Instruction*, *16*(3), 183-198.

Bencloski, J.W., & Heyl, R.J. (1985). Teaching plate tectonics with the aid of a model of seafloor dynamics. *Journal of Geological Education, 33*, 274-276.

Clark, D. B., Varma, K., McElhaney, K., & Chiu, J. (2008). Structure and design rationale within TELS projects to support knowledge integration. In D. Robinson and G. Schraw (Eds.), *Recent Innovations in Educational Technology that Facilitate Student Learning: Perspectives on Cognition, Learning, and Instruction*. Information Age Publishing; Charlotte, NC.

Gobert, J. D. (2000). A Typology of Causal Models for Plate Tectonics: Inferential Power and Barriers to Understanding. *International Journal of Science Education, 22*(9), 937-977.

Linn, M. C., Eylon, B. –S., & Davis, E. A. (2004). The knowledge integration perspective on learning. In M. C. Linn, E. A. Davis, & P. Bell (Eds.), *Internet environments for science education* (pp. 29-46). Mahwah, NJ: Erlbaum.

Linn, M. C., Lee, H.–S., Tinker, R., Husic, F., & Chiu, J. L. (2006). Teaching and assessing knowledge integration. *Science*, *313*, 1049-1050.

Investigating the Nature of Evidence 6th Grade Students Use When Constructing Scientific Explanations in Biodiversity

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Abstract: This paper investigates the nature of evidence that six grade students use when constructing scientific explanations in biodiversity situations. We employ a coding scheme that specifically targets the coherence of students' arguments and the way students use inscriptions when completing tasks. We found out that students use inscriptions differently depending on the nature of the inscription and that oftentimes, students' explanations have logical coherent reasoning regardless of scientifically accepted answers.

Introduction

Toulmin (1958) characterizes scientific arguments by a claim that is backed up by data that warrants the claim, and reasoning that explains how data or evidence supports the claim. This pattern has been widely used in the literature as a way to teach students how to construct scientific explanations. In their recent article, Songer and Gotwals (2009) describe a learning progression of ideas in classification, ecology and biodiversity and how those ideas can progress over three grades – 4th, 5th and 6th. Parallel with this content progression is the progression in inquiry skills, which is manifested with a four level progression describing increasingly sophisticated explanations, with each level also containing elements of scaffolding to guide students in their development. Moreover, Gotwals & Songer (in press) discuss the trajectories students follow in order to reason about biodiversity issues and categorize several kinds of reasoning that they call "middle knowledges" which are elicited by using assessment items based on writing scientific explanations. They found that even when students are scaffolded in formulating scientific explanations, there still existed "messy middle" knowledge, where students may understand content in certain types of situations, but not others. Also, even when students understood the science content in the tasks, constructing sound scientific explanations was often still difficult. Sandoval (2003) found that when learning about natural selection, students often failed to cite sufficient evidence to support their claim because they failed to recognize the importance of being explicit with evidence. He also found out that sometimes students' explanations were "coherent"; that is logical, even though they were not the "correct" scientific answer. Moreover, in later work, Sandoval and Millwood (2005) recognized that students often treated inscriptions in different ways when they considered them as evidence. For example, some students would consider the mere presence of a representation enough to consider it as evidence, and many times failed to explicitly explain how a certain representation provided evidence for the claim. This work investigates the difficulty that students have when they structure scientific explanations in ecology, and investigates the kinds of evidence that students use to back up their claim, specifically looking for coherence in the explanation. The work can also help to inform the literature about the pathways that students take as they learn to formulate more sophisticated scientific explanations in ecology. We address the following research questions:

a- How coherent are the students' claims in relation to evidence regardless of scientific correctness?
b- How do students use inscriptions as data or evidence to support their claims?

Method and Data Analysis

This work examines 6th grade students' written responses to assessment items who have participated in an inquiry-based biodiversity curriculum. The curriculum and assessment items were administered in six sections of 6th grade classrooms for a total of 170 students. The test contained 9 items which included questions about biodiversity with some multiple choice and food web questions in addition to complex scientific questions that required students to provide claim, evidence and reasoning for their answers. Originally, we coded the items using a rubric that focused mainly on scientific correctness, with codes from 0 to 4, with 4 being the highest code for correct scientific claim backed up by correct evidence and reasoning. For our current purpose, we recoded all of the selected questions based on whether there was a logical explanation with a claim backed by a logical evidence and/or logical reasoning. For example, even if the student did not give the scientifically correct answer, we still look at the logic of the explanation. Therefore in response to a question about destiny of large fish if all small fish in a pond, the student who answered: "All of the large fish in the pond will have to adapt to something else or they will die" has a logical claim even if this claim is not what the "correct" answer is. In order to further probe how students use inscriptions, we choose to examine item 9 that has two bar graphs of organisms in different habitats where students need to interpret the graphs in order to make a claim about which habitat likely has more food and shelter. Our new rubric distinguishes between the different ways students use the graph as evidence: those who don't use the graph as evidence, those who just mention that the evidence is in the graph, those who observe the higher bars in one graph and mention that their evidence is the graph with higher bars, and finally those who are able to interpret the bar graphs and mention how that supports their original claim.

Findings and Implications

The results indicate that even when students don't have the "right" answer, many are still reasoning logically about the questions and could either provide a logical claim or a logical claim backed up by logical reasoning and/or logical evidence. Due to space limitations we illustrate our point with examples from two questions. In item 2, which asks what happens to algae in a pond if fertilizers were added; the majority of answers which were scientifically incorrect had logical reasoning. A representative answer for this category is:

> *The algae would decrease because the river would dry up. By things you put in river it would affect the soil and soil will increase and dry up the river (DTF08550111)*

Note that the logic of the student above is based on an idea that the fertilizer affects the soil and the reasoning and evidence are based on common sense logic. It is probably safe to say that the student does not understand what a fertilizer does to the soil, but even with that, the student was able to make logical guesses that if it made the soil increase, then that is harmful for the algae thinking that it might take over the algae and make it decrease.

With regard to how students used inscriptions in item 9 with bar graphs comparing organisms found in two habitats, we found that the majority of students' responses somehow referenced the graph as evidence; however, many students were not explicit in comparing the numbers of different organisms between habitats. For example a common answer is represented by:

> *Habitat B, because you just look at it, if you look at the charts one is higher than the others (DTF08550303)*

The answer above is probably a necessary step in reasoning about the graph but it is insufficient to explain why one had more shelter than the other; that is, it does not explicitly specify what those bars are and how that is related to food and shelter. Moreover, we found out that while many students used some type of evidence from the graphs to answer the question, no student included scientific reasoning linking the evidence to the claim; they often just reiterated the evidence from graphs for the reasoning. An interesting dichotomy in our results was how very few students were able to mention correct evidence for item 2 (what would happen to algae with the addition of fertilizer) while many students referenced some evidence in item 9 (comparing organisms across habitats), but very few students were able to mention correct reasoning. One possible explanation for this result is that the evidence for question 2 did not originate from the representation; rather, the student had to know that fertilizers make algae grow. In contrast, in item 9 almost all students used the graph as evidence (even when they did not use that graph correctly), but were not able to mention correct reasoning because it somehow required relating it to the concept of biodiversity, something that was not explicitly evident in the question.

The different types of evidence used in the assessment items originated either from inscriptions (like bar graphs, or biological diagrams), individual experiences, knowledge of scientific phenomena, or what students learnt in the classroom. Many of students' responses were logically plausible even if they were not scientifically accurate. These findings compliment and add to the types of "messy middles" that Gotwals & Songer (in press) mention. Better understanding what types of messy middles students have helps to inform how educators can support students in moving from where they are to more sophisticated scientific reasoning, both in terms in content and reasoning.

References

Gotwals, A., & Songer, N. (in press). Reasoning up and down a food chain: Using and assessment framework to investigate students' middle knowledge. *Science Education.*

Sandoval, W. (2003). Conceptual and Epistemic aspects of students conceptual Explanations. *The Journal of Learning Sciences, 12*(1), 5-51.

Sandoval, W., & Millwood, K. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction, 23*(1), 23-55.

Songer, N., Kelcey, B., & Gotwals, A. (2009). How and when does complex reasoning occur? Empirically driven development of a learning progressing focused on complex reasoning and biodiversity.*Journal of Research in Science Teaching 46, 610-631.*

Toulmin, S. (1958). *The Uses of Argument.* Cambridge, England: Cambridge University Press.

The Function of Mathematical Terminology: The Case of 'Slope'

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Abstract: This poster presents a case study of one Grade 6 student to illustrate and consider the role of introducing key mathematical terminology as a semiotic means to objectify mathematical ideas at hand (Radford, 2003). The poster describes how in two classrooms mathematical terminology provided a context for discussing graphs of linear functions, whereas everyday language used for the same mathematics resulted in ambiguous or unproductive discussion. As a component of an eight-day unit, students (n=50) were introduced to the word form *slope* to describe and compare linear functions. The case reported here presents a student before and after the introduction of the word *slope*. Interviews provide reason to consider the productive role of mathematical terminology in the development of mathematical understandings.

In this poster, I provide an example of a mathematical term, *slope*, functioning as a semiotic means of objectifying (Radford, 2003) the mathematical properties of slope. The case described here gives examples of one student providing responses that are mathematically normative when using technical terms, yet ambiguous or incorrect when using everyday terms to describe the same mathematics. While to many having an appropriate word to describe an applicable phenomenon may seem obvious or straightforward, there is a complex phenomenon in mathematics education. Symbol systems and other semiotic forms, including terminology, may be difficult to teach to students who have not yet grasped the concepts that the symbols or terms represent; nevertheless, the concepts may be difficult to teach to students who have not yet mastered the symbols or terms (Uttal, Scudder & DeLoache, 1997). One task of mathematics educators is to address this tension and determine instructional techniques to overcome this paradox. The poster presents a case study in which a Grade 6 student, Carolyn, uses mathematical and everyday terminology to describe linear functions on a graph. In particular, the word form *slope* provided a way to talk about the rate of change of each function in a way that everyday terms—such as words like *faster* or *steeper* that proliferated throughout this instructional sequence—left unclear. The case illustrates the semiotic role of specific mathematical terminology in mathematics meaning making and conversely the ambiguity everyday language can bring to bear on the same mathematics.

For the purposes of this study, slope was defined as the ratio, of one variable to another. Instruction often fails to connect the value of slope to qualitative descriptions of linear functions. Slope is often taught in a strictly procedural way, the result of which is a reduction of the concept of *slope* to a formula without any foundation in patterns of change. Caddle and Earnest (2009) reported on Grade 7 and 8 students reciting various formula for slope who then failed to connect these ideas to a ratio of change in a particular story context, displaying some of the pitfalls of having learned slope only as a procedure without conceptual grounding. Likewise, Moschkovich (1996) described Algebra 1 students successfully refining everyday terminology involving the ideas of slope without the technical term; at the same time, she acknowledged that everyday terms, such as *steeper* or *less steep*, "that may be sufficiently precise for everyday purposes proved to be ambiguous for describing lines in the context of a mathematical discussion" (273). Yet unanswered is the question of *when* the introduction of such terminology may behoove students in their inquiry into graphing. The introduction of the word form *slope* to the classroom discourse served as a semiotic means of objectifying (Radford, 2003) the rate of change of a function, with student interviews serving as data points to determine how students might have appropriated such a term.

Since slope is a core idea to the study of linear functions, I focus on this concept and the possible semiotic means that can be used by students to objectify their emerging understandings of this concept. The research question guiding the design and subsequent analysis of this study included: How might the technical term *slope* serve as a semiotic means to objectify mathematical ideas of slope?

Theoretical Framing

Given the underlying focus on semiotics, the analysis demands a framework that allows for detailed exploration of meaning ascribed to particular representational features. For this reason, I use Saxe's form-function framework (Saxe, 2004; Saxe & Esmonde, 2005), a cultural development framework that provides an analytic foothold on various semiotic means of objectification as they emerge and shift in activity. The framework provides a way to describe how the same ostensible form may have varied meanings across individuals at a point in time, while at the same time, one particular function, such as comparing trends in two linear functions, may be satisfied by various forms across individuals.

Forms are the various artifacts that can be found and used in a particular setting; in a mathematics classroom, forms can be various symbols or artifacts. They may range from components of written representations, such as a tickmark on a number line or an axis on a graph, to a specific word form, for example, *even* or *odd*, or in this case study, *slope*, *faster*, or *steepness*. These forms have meanings that are negotiated in social activity. *Function* refers to the use of a form in activity. The functions of such forms may vary across individuals. At the same time, there may be a culturally normative function associated with a given form in the context of a particular activity. The analysis makes use of this framework by considering word forms and the various functions the forms may be serving to the focal student.

Methods and Materials

The case study was drawn from a larger data corpus, a study that involved a sample of 50 Grade 6 students in two classrooms in Northern California with a predominantly Latino and African American population. One teacher provided instruction in both classrooms. *Individual cognitive interviews* were given to 10 students, including the focal student presented here, to further understand student approaches to solving these particular tasks and reveal learning hurdles. These interviews drew upon ideas that came up during classroom observations, and materials included particular problems from written assessments about which the interviewer asked the student to reflect. These interviews sought to probe more deeply students' written and oral responses and test the stability or fragility of such responses. *Data Sources* included videotapes of 8 classroom lessons and cognitive interviews, as well as copies of written student artifacts. Videos were transcribed and written responses were coded for response frequencies and the functions of representational forms.

Preliminary Findings, Conclusions and Implications

I chose Carolyn as a case study because the pattern of her responses well-reflected overall trends in student responses over the unit, making her a typical case. She was also one of ten students that participated in a cognitive interview, providing further insight into her reasoning. This analysis treated technical terminology a semiotic means to both enable and constrain the focus of individuals' meaning making.

The poster will present Carolyn's interviews regarding the same problems given before and after the classroom intervention. Results show that Carolyn interpreted two interview questions designed to address the same content in different ways. For prompts using the word *slope*, Carolyn drew upon the graph as a resource to talk about the slopes of two different linear functions. However, for prompts that made use of everyday language such as *faster*, Carolyn provided different answers that communicated a less sophisticated understanding of the mathematics at play. The use of particular words in the given prompt resulted in Carolyn interpreting the graph in different ways.

The case study seeks to demonstrate the complexity of language, both everyday and mathematical, with which students grapple as they engage in mathematics. While the larger study was exploratory in nature, Carolyn's interview gives reason to consider technical terminology as a key mechanism by which instruction may focus on particular mathematical concepts. In this case, such concepts seemed to remain ambiguous absent of that terminology. Findings have potential implications for curriculum development and instruction, in addition to considering in future research what various semiotic means, such as technical vocabulary, bring to bear on student understanding.

References

Caddle, M.C., & Earnest, D. (2009). Slope as a procedure: The impact of axis scale. In M. Tzekaki, M. Kaldrimidou, & H. Sakonidis (Eds.), *Proceedings of the 33rd Conference of the International Group for the Psychology of Mathematics Education*. Vol. 2, pp 233-240. Thessaloniki, Greece: PME

Moschkovich, J.N (1996). Moving up and getting steeper: Negotiating shared descriptions of linear graphs. *The Journal of the Learning Sciences, 5*(3), 239-277.

Radford, L. (2003). Gestures, Speech, and the Sprouting of Signs: A Semiotic-Cultural Approach to Students' Types of Generalizations. *Mathematics Thinking and Learning, 5*(1), 37-70.

Saxe, G.B. (2004). Practices of quantification from a sociocultural perspective. In K.A. Demetriou & A. Raftopoulos (Eds.), *Developmental Change: Theories, Models and Measurement.* NY: Cambridge University Presss: 241-263.

Uttal, D.H., Scudder, K., & DeLoache, J.S. (1997).Manipulatives as symbols: A new perspective on the use of concrete objects to teach mathematics.*Journal of Applied Developmental Psychology, 18*(1), 37-54.

An Investigation into Students' Interpretations of Submicroscopic Representations

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Abstract: Applying a particulate model of matter requires learners to translate among several levels of representations–macroscopic, microscopic and symbolic. Successful instruction and assessment require that students properly interpret representations. As part of the development of validated assessments to place students along a learning progression, this study explores how students' interpretations of representations change and affect their responses to items as they progress through the science curriculum. We find that different representations may enhance different alternative conceptions.

A particulate model of matter provides a basis for understanding the structure and behavior of matter, and enables learners to explain a vast number of phenomena. Applying a particulate model requires learners to translate between the macroscopic representations of the phenomena that they can experience in their daily lives, and submicroscopic representations (e.g., molecules, atoms) that explain what is happening at the molecular level, as well as representations such as chemical symbols, formulas, and equations (Harrison & Treagust, 2002). The abstract nature of submicroscopic representations and symbolic representations make it difficult for students to connect them with macroscopic phenomena (Griffiths & Preston, 1992). When students first begin developing a particulate model of matter, they tend to focus on phenomena involving molecules (e.g., water in different phases; how smells travel). The terms particle and molecule are often used interchangeably to describe molecules, while individual spheres, multiple spheres or multi-lobed figures, may be used to represent them. As students progress, they are expected to be able to transfer between more types of submicroscopic representations (e.g., Lewis structures, space-filling models, ball-and-stick figures).

The larger goal of our project is to develop assessments that place students along a learning progression (LP) for the nature of matter, which focuses on the structure, properties and behavior of matter (Stevens, Delgado, & Krajcik, in press). In order to create validated assessments, it is critical that students understand the item, which includes correctly interpreting the meaning of the question, the answers and any associated representations. Extensive learning research has focused on how students use and translate between the three types of representations required to explain phenomena using a particulate model (e.g., Keig & Rubba; Kozma & Russell, 1997). We extend this work by investigating students' ability to translate among different submicroscopic representations and how those interpretations affect their thinking. This work will inform assessment and curriculum materials development linked to students developing a particulate model of matter.

Methods

We developed assessment items to measure how well students apply ideas within and across topics to explain phenomena involving transformations of matter following the Construct-Centered Design process (Stevens et al., in press). The items were validated through rounds of internal and external review, followed by collection of student data. To ensure that students interpret the questions and representations as intended, the items were each accompanied by a set of questions (e.g., Was the question clear? Were there any words that were confusing? What does the picture represent? DeBoer, et al., 2008). Each item will be piloted with students of grades 6-14. Semi-structured interviews with a subset of students supplemented this data. We will also investigate the range of representations students connect with atoms and molecules over grades 6–14 using a written survey.

Results and Discussion

Tests and textbooks often use multiple submicroscopic representations for atoms and molecules, and we questioned whether students can readily shift between them. To this end, we created four versions of an item designed to measure students' submicroscopic models of the solid, liquid and gas states of water. The four versions contain the same four answer choices that are represented differently (version **1**–molecules as spheres and ice represented as a close-packed lattice [CPL]; version **2**–molecules as spheres, and ice represented as a hexagonal patterned lattice [HPL]; version **3**–molecules as three-lobed structures and ice as a CPL; version **4**–molecules as three-lobed structures and ice as a HPL). The HPL is a more scientifically accurate representation for the structure of ice than the CPL; distinguishing between the two models will help separate students at the higher levels of the LP. In addition, the set of models associated with response A is consistent with amorphous solids (e.g., wax) in which the molecules do not arrange in a regular pattern, potentially providing another way of measuring students' understanding of the structure of matter in the upper levels of the progression.

Middle school students appeared to favor the traditional representation of a solid (CPL) with either form for the water molecules (versions **1** and **3**; see Figure 1), as only slightly over 11-12% of students did not provide a response to the item. Not unexpectedly, the middle school students struggled with the hexagonal representations of solid water. Approximately 25% of the students did not provide an answer to either version **2** or **4**. Ten percent of students answering version **2** considered response A and response D to be equivalent, perhaps not recognizing the hexagonal pattern or its meaning in the representation of ice.

The different versions of the item seem to draw out different alternate conceptions from the students. Slightly over 50% of the middle school students responded correctly to version **1**. Approximately twice the number of students with versions **1** and **3** chose response B (no water molecules in the gas phase, much more space between molecules in liquid as compared to solid form–two common alternative conceptions; Harrison & Treagust, 2002) relative to the other incorrect answers. This result suggests that the alternate idea that ‘the space between molecules in liquid form is significantly greater than that in the solid form’ dominates students’ reasoning leading to the observed preference for choice of response B. The hexagonal arrangement of water molecules in the solid form elicited a different proportion of responses. Students with version **2** exhibited a very strong preference for response B (2-3-fold greater than for response A or C). In contrast, very few students with version **4** chose response B (2-3-fold less than for response A or C), while the other incorrect answers were chosen with fairly even distribution. Thus, the relative amount of space between the molecules in the solid and liquid form do not seem to dominate students’ thinking with the version **4** set of representations. Further investigation through interviews will help explain the observed change in students’ responses. These results also suggest that using different representations of a solid in assessments will help assign students’ location on a LP for the nature of matter. Piloting the four versions of the items with more advanced students will provide information on the effectiveness of this strategy. While we only focused on results related to students’ interpretation of models of water molecules and their arrangement in representations of different phases here, in the final poster, we will discuss students’ interpretation of representations in multiple contexts for students throughout the LP (grades 6-14).

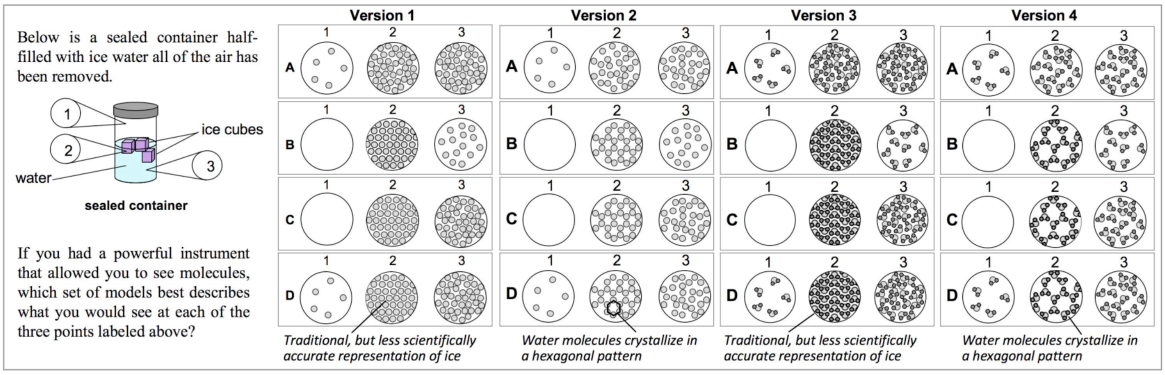

Figure 1. Item requiring students to choose appropriate models to represent water in various states.

References

Stevens, S.Y., Delgado, C., & Krajcik, J. S. (in press). *Journal of Research in Science Teaching.*

DeBoer, G.E., Abell, C.H., Gogos, A., Michield, A., Regan, T., & Wilson, P., (2008) J. Coffey, R. Douglas, & C. Stearns (Eds) Assessing Science Learning: Perspectives from research and practice. National Science Teachers Association, Arlington, VA.

Griffiths, A. K., & Preston, K. R. (1992). Grade-12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching*. 29(6), 611-628.

Harrison, A. G., & Treagust, D. F. (2002). The particulate nature of matter: Challenges in understanding the submicroscopoic world. In Gilbert, J. K., Jong, O. D., Justi, R., Treagust, D. F. & Van Driel, J. H. (Eds.), Chemical Education: Towards Research-Based Practice (pp. 189-212). Dordrecht, Netherlands: Kluwer Academic Publishers.

Keig, P. F. & Rubba, P. A. (1993). Translation of representations of the structure of matter and its relationship to reasoning, gender, spatial reasoning, and specific prior knowledge. *Journal of Research in Science Teaching*. 30(8), 883-903.

Kozma, R. B. & Russell, J. (1997). Multimedia and understanding: expert and novice responses to different representations of chemical phenomena. *Journal of Research in Science Teaching,* 34(9), 949-968.

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The "Other" curriculum: Constructing success and failure in a game-based learning environment

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Abstract: We examined after-school classroom practices to understand how a game based curriculum based on American standards is taken up in Singapore schools. The Singapore educational system privileges a certain model of success and failure, which led students and teachers to adopt roles and practices which ran counter to the intended outcomes of the curriculum. Despite this, emergent student-oriented activities presented opportunities for successful implementations of the curriculum.

Introduction

Video games are immersive environments that engage learners in experiences that have personal, epistemological, cultural connections and potentially transformative. (Shaffer, Squire, Halverson & Gee, 2005) Unsurprisingly, schools have forayed into video games in order to promote learning among students. While game-based curriculum has its advantages, the impact of a multi-disciplinary curriculum within a classroom framework and what it means to learn in an informal school environment is less apparent. In the water quality unit in Quest Atlantis (QA), a learning environment, students adopt the role of a field investigator to explore why fishes were dying in Taiga national park (Barab, Sadler, Heiselt, Hickey & Zuiker, 2006). We examine how the unit normalized by both students and teachers in order to ensure its relevance to school. Additionally, we focus on how the models of success and failure can be re-constituted through student oriented activities.

Theoretical Framework

The classroom is a site of competing discourses; certain actions legitimize dominant discourse while silencing other forms (Delpit, 1988). It is a site where the techniques of surveillance and self-discipline occurs and where power is not acted upon the individual but is exercised through relationships and actions of free individuals who can either accept or resist (Foucault, 1982). Luke (1995) argued that classrooms are sites in which teachers and students construct what success and failure means, thereby producing "'versions' of successful and failing students" (p.12). Based on the notion that power is central to an analysis of competing discourses in the classroom, we identified identity and world building situations (Gee & Green, 1998) that helped us analyze how students and teachers constructed the various models of success and failure.

Context and environment

The Singapore educational system consists of primary, secondary, college, polytechnic and tertiary level education. Secondary education is targeted for 13 to 16 year olds and students are placed in three academic tracks, Special, Normal and Express. Students placed in the Special and Express track complete their secondary education in 4 years whereas the Normal track students complete theirs in 5. These students are placed in these academic tracks based on the Primary School Leaving Examination (PSLE), a major examination undertaken by all students to progress to secondary education. Due to the perceived differences in student abilities, Express track students are believed to be better students, both in terms of academics and behavior, thus shaping student and teacher attitudes.

Design and methodology

Students from two Express and Normal classes participated in an after-school program using QA for four weeks. Two teachers were in charge of each class and given guides which gave suggestions on how to structure classroom activities. Participation in the Express class was constant; at least 40 students were engaged in Taiga every week. In contrast, participation in the Normal class averaged 10 students or less per week.

Two pairs of same sex dyads from each class were selected and videotaped for the duration of each two-hour session. These pairs were present during most of the implementations, which meant that we could observe their participation and trajectory. Whole classroom and group discussions were also videotaped and teachers were interviewed after the implementation. Dyad, group and whole classroom interactions were then transcribed and through emergent coding, we initially identified episodes of acceptance or resistance, in which students and teachers would accept, challenge or impose assumptions on the game-based curriculum and other individuals. Building on these set of initial codes, we framed these episodes as identity and world building episodes (Gee & Green, 1998). The former refers to situations in which students and teachers projected their identity to others while the latter included how they constructed success and failure in the classroom.

Findings

The Taiga curriculum was positioned as a Geography subject, although the unit included Science, Geography and English Language topics. As a result of this alignment, teachers in this implementation did not engage formal concepts unrelated to Geography, treating unfamiliar concepts such as eutrophiction as an "Other". The lack of take up was possibly due to time constraints and lack of expertise. For instance, when students in the Express class expressed confusion over concepts such as phosphate and nitrates, Wendy, the teacher, chose not to explicate further. In that same discussion, Wendy also summarized students' impressions on the relevance and amount of learning gleaned by going through the Taiga curriculum. She concluded that "you (the students) have not learnt as much things as compared to class". As a person of authority, she noted the lack of relevance of the curriculum therefore positioning it as a less useful learning environment for students.

Despite the lack of curricular connection, Wendy characterized Taiga as "serious work". Since students were engaged in Taiga as an extra-curricular involvement, the curriculum needed *features* of schooling, such as outcomes that encourage analytical skills and criticality in assessing information. Being a good learner from the teacher's perspective meant that students had to take notes in their log book, being able to "look through all the answers before you (the students) come to a conclusion" and knowing the "proper etiquette" of how to interact with others in the chat space. Teachers in both tracks adopted a surveillance stance, walking around to make sure students were on task and not "playing". Students had to ensure that they were successful in features of Taiga that featured testing and assessment, such as taking a non-player character's test to gain power cells. Nic, an Express student, voiced concern over the possibility of failing the test and panicked when he thought he had missed an opportunity to get a power cell. Tanya and Joy, from the Normal track, on the other hand, ensured that they were prepared mentally and in terms of copious note-taking before attempting a different test. To students, passing tests was representative being successful in class.

The two teachers from the Normal track mainly ensured that students remained on task (procedural and behavior) and/or understood the vocabulary in the curriculum. However, the Normal track students resisted the notion of unsuccessful learners and were able to articulate and synthesize information gathered from interviewing characters just as well as their Express peers. In a student produced video, one of the students, Pingying, adopted the role of a teacher and facilitated the interview process with her peers. She pushed other students to critically assess information that was presented to them, rather than reading from their notes. This student's negotiation of her role as a knowledgeable person however, remained unnoticed by teachers. Activities that reflected the abilities of the Normal students were mostly invisible; while the curriculum encouraged students to take up legitimate roles that empower them; their public identities remain that of mediocre learners.

Discussion and implications

Since the Taiga curriculum content was not taken up by the teachers, students were unable to see the relevance of their activities. As the curriculum was implemented as an after school activity, the informal setting was immediately framed by discourses surrounding what success and failure meant in schools. Thus, both students and teachers were engaged in performing what they thought the classroom should look like, instead of enlisting the opportunities that the Taiga curriculum offered. However, student oriented activities such as making group videos, provide opportunities for students to reconstitute a narrative of their own, based on the experiences afforded by the game based curriculum and through peer interactions. Teachers expressed the need for units aligned to Singapore's standards so that the content can be better leveraged. However, this does not address the invisibility of certain students, although in other implementations, activity structures have demonstrated that it is possible to empower such students.

References

Barab, S. A., Sadler, T., Heiselt, C., Hickey, D., & Zuiker, S. (2007). Relating narrative, inquiry, and inscriptions: A framework for socio-scientific inquiry. *Journal of Science Education and Technology*, *16*(1), 59-82.

Delpit, L. (2001). The silenced dialogue: Power and pedagogy in educating other people's children. *Landmark Essays on Basic Writing*, 83-101.

Foucault, M. (1982). The subject and power. *Critical inquiry* 8(4), 777-795.

Gee, J., & Green, J. (1998). Discourse analysis, learning, and social practice: A methodological study. *Review of research in education*, 23(1), 119-163.

Luke, A. (1995). Text and discourse in education: An introduction to critical discourse analysis. *Review of research in education, 21*, 3-48.

Shaffer, D., Squire, K., Halverson, R., & Gee, J. (2005). Video games and the future of learning. *Phi Delta Kappan* 87(2), 104-111.

Knowledge Building For Historical Reasoning in Grade 4

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This study examined the historical reasoning of Grade 4 students exploring medieval times using a Knowledge Building approach and Knowledge Forum technology. Discursive analysis of student contributions was conducted according to six attributes of historical reasoning: *contextualization, using substantive concepts, asking historical questions, using meta-concepts, using historical sources, and argumentation.* Results show student engagement with the first two attributes in particular, and pinpoint components of less developed attributes that require further pedagogical support.

Introduction

Theoretical explanations are central to historical inquiry. The ability to create coherent explanations, which demonstrate how well a particular theoretical proposition explains a set of established facts, becomes especially critical for addressing historical questions with no "right answer" (Thagard, 2006). Thus, the objective of this study was to explore what attributes of historical reasoning help to develop coherent explanations and under what conditions these attributes could be developed in students. Van Drie and Van Boxtel (2008) propose a framework for conducting empirical analysis of historical reasoning that includes six critical attributes: (1) *asking historical questions*—a core competency in the domain that "drives" historical reasoning; (2) *contextualization*—required to interpret and make sense of historical phenomena; (3*) argumentation*—supporting claims with valid reasons, (4) *using substantive concepts*—those that name and organize historical phenomena (e.g. 'serf' or 'Middle Ages'); (5) *using meta-concepts*—those that deal with broader historical phenomena (6) *using historical sources*—which involves interpretation, evaluation and comparison of primary and secondary sources. These aspects are fundamental to high-level historical reasoning and a provide basis for developing students' capacities to produce coherent explanations.

So what are the pedagogical practices that would help to develop these six attributes of historical reasoning in students? In this study, we choose to focus on a Knowledge Building pedagogical approach (Scardamalia & Bereiter, 2003) to historical inquiry. This approach is defined as '*the production and continual improvement of ideas of value to a community'* (Scardamalia & Bereiter, 2003: p. 1370). Knowledge Building is expected to be particularly conducive to the development of historical reasoning because it requires students to propose and improve their own working theories, a pedagogical practice that is central to genuine historical inquiry. Knowledge Building is supported by Knowledge Forum (KF), a multi-media space where students contribute ideas, questions, evidence, and so on, as multimedia notes into a collective knowledge space.

Benefits of engaging in Knowledge Building discourse associated with gains in explanation-based inquiry have been demonstrated (Zhang et al., 2007), but this study will be the first to address the following questions: Does sustained engagement in Knowledge Building help young students develop sophisticated historical reasoning? What critical attributes of historical reasoning were fostered in the setting under investigation? Which attributes remain unaddressed or underdeveloped, and thus require additional support?

Methods

Participants

Participants included 21 Grade 4 students (9-10 years) attending a primary school located in downtown Toronto. Knowledge Building and KF were introduced to students as early as junior kindergarten.

Classroom Structure

The Grade 4 teacher was new to both Knowledge Building and KF prior to this unit of study, which spanned approximately three months. During this time the class engaged in Knowledge Building (KB) for three hours a week for 45-60 minutes at a time. Students used KF in tandem with "KB talks" and active research. During this time, students discussed their ideas, questions, theories, and research on medieval times. The teacher allowed the study to grow organically, situating herself as a co-learner with the students. Responsibility for advancing individual and collective knowledge remained with the students as they worked to produce and improve their own ideas about medieval history. At the end of every KB session, students were given 10-15 minutes to enter any new information or knowledge generated during in-class discussion and research into the KF database.

Knowledge Forum Environment

In the KF online environment, students contributed ideas, questions, evidence, and so on, as multimedia *notes* into a shared knowledge space. Students could organize notes thematically into *views,* which served as workspaces for various inquiry goals. Students could *build on*, *annotate*, and *co-author* notes, make *reference* links to other notes, and create *rise-above* notes, which represented higher-level conceptualizations.

Plan of Analysis

A total of 445 notes were generated in the database, distributed over 13 views. The most complex view, entitled "Medieval Times" and containing 92 notes, was chosen for data analysis. To guide the analysis, we created a coding scheme that included the attributes of historical reasoning as outlined by Van Drie and Van Boxtel (2008) and adapted it to our research study. More precisely, we examined whether each note falls into one or more of the following categories: (1) *asking historical questions*—category that included explanation-seeking, fact-seeking, or evaluative questions; (2) *contextualizing*—category that situated historical phenomena in a spatial, temporal or social context; (3) *arguing*—category where claims or theories were supported with arguments, or refuted with counter-arguments; (4) *using substantive concepts*—category that included unique, inclusive and colligatory concepts; (5) *using meta-concepts*—category that dealt with cause and consequence, change and continuity, historical significance, moral judgment, and historical perspective; and (6) *using historical sources*—category where new facts were introduced or described, references were sought or used to support or refute an idea, and sources were evaluated or compared. In addition to these six categories, already identified by Van Drie and Van Boxtel (2008), we added a seventh—*theorizing*. This category allowed us to detect how often students proposed theories to explain historical phenomena, how often they worked to improve these theories, or sought alternative theories. Two raters independently coded the notes with a result of 80% agreement. To resolve the 20% disparity, raters discussed the discrepancies and thereby attained full agreement.

Results

The analysis of KF notes produced in the Knowledge-Building classroom showed that historical *theorizing* was present in 18% of the notes. Close examination of these notes demonstrated that with help of Knowledge Building pedagogy, 9-10 year old students were not only able to develop their own theories to explain historical phenomenon, but also to perform substantial work on *theory improvement.*

So, what attributes of historical reasoning helped students to develop historical theories at this young age? Analysis indicated that the most apparent attributes of historical reasoning were *contextualizing* (which was present in 63% of student notes), and *use of substantive concepts* (present in 47% of student notes). Students repeatedly introduced familiar historical concepts into the collaborative dialogue in an explicit effort to advance their knowledge about these concepts and to construct meaningful historical contexts around them. For example, S1 writes, "*Was Shakespeare in Medival Times? I think he was because he wore those goofy clothes*." S2 builds onto this comment in an effort to improve his classmate's ideas: "*Actually back then they were very stylish clothes so I wouldn't call them goofy. also I think that he wasn't in the medieval times but in fact in the elizabithen era*."

Other aspects of historical reasoning, such as *using historical sources, historical questions* and *using meta-concepts,* were detected in 28%, 27 % and 25% of the notes respectively. Sources were most often used to introduce or describe new facts, historical questions were extensively of an evaluative nature (e.g. "*why back then they painted so much?"*), and finally, meta-concepts referred mostly to historical continuity and change (e.g. "*How were the Elizabethan times different from medieval times*?"). These findings demonstrate that Knowledge Building pedagogy allows engagement with history in a much more exploratory manner than traditional texts, and encourages students to discuss historical events from different perspectives.

Less present, but still quite high for this age is the number of notes demonstrating *argumentation* (18% in total). This attribute is among the most difficult for students to master, as it requires sophisticated use of historical evidence. Future pedagogical intervention would involve additional work on the evaluation and comparison of historical sources, which represent important processes but were lacking in students discussions.

References

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Eds.), *Liberal education in a knowledge society* (pp. 76-98). Chicago: Open Court.

Scardamalia, M., & Bereiter, C. (2003). Knowledge building. *Encyclopedia of education*, (2), 1370-1373.

Thagard, P. (2006). *Hot thought: Mechanisms and applications of emotional cognition*. Cambridge: MIT Press.

Van Drie, J., & Van Boxtel, C. (2008). Historical reasoning: towards a framework for analyzing students' reasoning about the past. *Educational Psychological Review*, *20*, 87–110.

Zhang, J., Scardamalia, M., Lamon, M., Messina, R., & Reeve, R. (2007). Socio-cognitive dynamics of knowledge building in the work of nine and ten year-olds. *Educational Technology Research and Development,* 55:2, 117– 145.

Learning inter-related concepts in mathematics from videogames

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Abstract: If students learn multiple inter-definable relational concepts, their resulting knowledge will be more stable, flexible, and likely to be applied on transfer tasks. A videogame has been developed to teach fractions. Based on analysis of Asian curricula in mathematics, the favored instructional sequence and relative emphasis on various topics have been incorporated into the game design. Through the game, students interact with different numbers and operations. Their performance on pre- and post-test are compared.

Objective

Learning mathematics involves recognizing relationships between different pieces of information including mathematical facts, ideas, and procedures, constructing new relationships between previously disconnected information or reorganizing already connected information, and finally building a network of representations (Brownell, 1935; Hiebert & Carpenter, 1992). To achieve this goal, most attempts to use games to teach mathematics have focused on practicing procedures. Some games have focused on teaching understanding of specific concepts (e.g., why the denominators cannot be added when adding fractions). Our approach is to use games to teach an inter-related set of concepts by helping students recognize relationships between different number systems and different operations. Our hypothesis is that if students learn a number of relational concepts, their resulting knowledge will be more stable, more flexible, and more likely to be applied on transfer tasks. Skemp (1976) distinguishes relational understanding from instrumental understanding in mathematics learning, and argues that relational understanding is more adaptable to new tasks and easier to remember because learners can remember inter-related concepts as parts of a connected whole, rather than as disconnected pieces of information.

Method

We have analyzed curricula of Asian countries that have shown high achievement levels in mathematics (Japan, Singapore, and South Korea), and defined what kinds of experiences enable students to acquire conceptual understanding of fractions. Based on our analysis, we provided game designers with the instructional sequence and relative emphasis on various topics related to operations with fractions.

Instructional game design and content goals

A videogame has been developed to teach fractions intending to be played by students who already have some prior experience with fractions (i.e., not a substitute for an introductory course). In this project, three major connections have been emphasized and incorporated into the game design process. First, students should be able to see relationships between concrete representations they manipulate and conceptual representation to be taught. Many teachers use concrete examples (e.g., visual diagrams, physical manipulatives) to help students understand abstract mathematical concepts and symbolic notations. Use of concrete materials, however, does not guarantee their effectiveness. Concrete materials seem to be useful in teaching only if learners recognize "the correspondence between the structure of the materials and the structure of the concept" (Boulton-Lewis, 1992, p. 10). Also, for an analogy between a concrete representation and a conceptual representation to be effective, the relations found in one representation should be clearly mapped to the relations present in the other representation (English & Halford, 1995). To achieve this goal, two distinct workspaces have been developed to teach fractions in the game: a realistic problem space which includes a concrete visual representation, and a symbolic number representation space. Players are allowed to manipulate simple visual forms of quantities using operator tools in the realistic problem space to test their hypotheses.

A potential issue with physical representations of quantities is that students may attend to superficial features of the representation rather than to the concept embodied by the representation. To address this issue, we have incorporated a design element into the game in which the intermediate visual representation fades out as players encounter "night-time" gameplay. Players learn early on in the game that night-time looms, and thus they must pay attention to the quantities being represented as well as to the visual representations of the quantities. Also, in a later phase of the game, the aid from the visual representation space fades out altogether so that students must work directly on the symbolic number representation. By having each manipulation tool in the visual representation space clearly correspond to one of the mathematical operations, students should be able to map unambiguously between different representations.

Second, students should be able to see relationships between different operations. Students should understand the way in which different operations are related, and how each operation works to change a quantity from one state to another. For example, students should understand that multiplication and division have an inverse relation to one another. Students will use the inverse relationship in two ways. One way is to reverse or undo an action and the other way is to use division to find an unknown scalar operator. By ensuring that students are exposed to problems that have the same structure but a different goal, inverse relations can be understood.

Third, students should be able to see relationships between different number systems. In most U.S. classrooms, operations with different types of numbers are taught separately. For example, after mastering operations with whole numbers, students move on to operations with decimal numbers or fractions. However, connections between different types of numbers, and subsequently operations with these different types, are not emphasized. When these number systems and operations with them are taught as distinct concepts, students may construct separate mental models for each of different number systems. This hypothesis is supported by the finding that students often treat the same word problems differently depending on the type of the numbers (Sowder, 1995). To prevent students from developing separate mental models, in this game, a common visual representation is used across different types of numbers. The main concepts common across different number systems include units, decomposing and recomposing numbers, and different operations and their inverse relations. For example, any number can be understood as a collection of units: whole numbers as a collection of 1's, fractions as a collection of 1/n's, and decimals as a collection of 0.1's. Besides emphasizing common mental models across different types of numbers, problem situations with different number systems were inter-mixed in the game sequence. Rather than mastering one number system with all kinds of operations and moving on to another number system, students have to operate with several different types of numbers together from a very early phase of the game.

In each level of the game, players are challenged to solve a problem involving lengths. This challenge makes students reflect on their own knowledge and strategies, and focuses their effort on construction of rich relationships among different representations and mathematical concepts. Students are not encouraged to simply memorize demonstrated rules or principles.

Results

To test the effectiveness of the video game for teaching fractions, the game is played by a group of sixth- through ninth-grade students. Students' performances on a pre-test and on a post-test of fraction operations are compared. Players are tested in terms of both conceptual understanding and procedural fluency with materials learned directly from the videogame, and with transfer tasks. Additional data are collected during game play, allowing evaluation of students' mistakes and their hypothesis testing throughout game play. The findings will be discussed in terms of advantages of teaching inter-related concepts, and the possibility of constructing a videogame-playing experience that results in increased relational understanding of mathematics.

References

Boulton-Lewis, G. (1992). The processing loads of young children's and teachers' representations of place value and implications for teaching. *Mathematics Education Research Journal, 4,* 1-23.

Brownell, W. A. (1935). Psychological considerations in the learning and teaching of arithmetic. In W.D. Reeve (Ed.), *The teaching of arithmetic: Tenth yearbook of the National Council of Teachers of Mathematics* (pp. 1-31). New York: Teachers College, Columbia University.

English, L., & Halford, G. (1995). *Mathematics education: Models and processes* Mahwah, NJ: Erlbaum.

Hiebert, J., & Carpenter, T. P. (1992). Learning and teaching with understanding. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 65-97). New York: Macmillan.

Skemp, R. R. (1976). Relational understanding and instrumental understanding. *Arithmetic Teacher, 26*, 9-15.

Sowder, L. (1995). Addressing the story-problem problem. In J. T. Sowder & B. P. Schapelle (Eds.), *Providing a foundation for teaching mathematics in the middle grades* (pp. 121-142). Albany: SUNY Press.

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Robotics and environmental sensing for low-income populations: design principles, impact, technology, and results

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Abstract: Programmable devices have become very popular in schools, for robotics, environmental sensing, and even interactive art. However, in developing countries, their penetration has been limited due either to unavailability or high cost. In this paper, we discuss recent work on an open-source, low-cost platform mainly designed for developing countries. We discuss its design principles, based on extensive fieldwork, as well as the learning implications, use of low-cost materials, and local construction of boards.

Robotics and probeware in school environments

The use of probeware, robotics and sensors has a long history in education (Tinker, 2000, Papert, 1971). But it was not until the early nineties that designers succeeded in creating viable robotics and probeware products for educational settings (the Handy Cricket and the Lego Mindstorms kit, Martin & Resnick, 1993; Sargent, 1995). In recent years, the Lego NXT kit, the Pico Cricket, the MIT Tower (Lyon, 2003) and the Arduino platform have incorporated new features based on advanced sensing and modular design.

However, despite the potential of these technologies (Sargent, 1995; Tinker, 2000), their educational use has been limited to well-funded schools and organizations due to their cost and limited availability, in special outside the developed world. In low-income areas, even when the equipment was made available, we observed students who would not engage in the activities for fear of breaking it, and teachers who would vocally criticize the spending of thousands of dollars to benefit just a small number of students. We present a technology design to address those difficulties: the GoGo Board (see figure 1), a low-cost, open-source platform for probeware and robotics, tailored for educational use in developing nations. The platform is composed of the main board, add-ons mini-boards (such as displays, sound recorders, amplifiers, and wireless communication), libraries and APIs for most programming environments, and a collaborative website with documentation and sample projects from the user community. We discuss the design choices that made the board low-cost, multi-purpose, easy to assemble, and easy to be used with scrap electronics and simple materials.

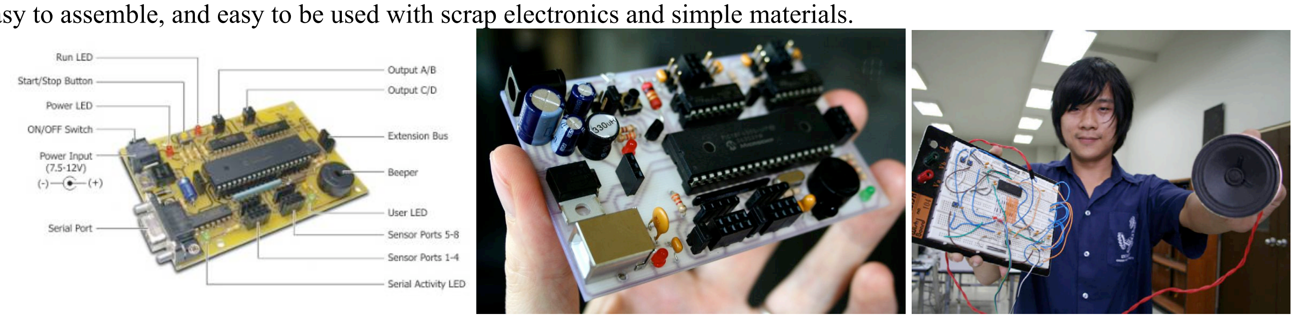

Figure 1: (Left to right) The original GoGo Board, the new USB GoGo, and a prototype of a sound recorder plug-in board.

Design Principles

Low-cost and local construction: Our field work indicated that importing equipment from the US or Europe more than doubles the local cost in many countries. This applies even for open-source hardware such as Arduino boards, which components are hard to find in many countries. Therefore, we designed the platform to be assembled locally, if needed, after extensive research for component availability in Brazil, Mexico, Thailand, and Malaysia. Also, the platform has been designed to make its construction process as simple as possible (see Results section). Differently from most commercial and open-source platforms, it does not incorporate the most cutting-edge features, but instead focus on ease of construction. It uses human-sized components, wide traces, a single-sided printed circuit board, and simple, inexpensive sensor connectors. While the Lego Mindstorms kit can reach as much as US$ 500 in developing countries, the GoGo Board costs US$ 25.

Dual mode: Our field observations in several schools revealed that probeware and robotics have traditionally employed different hardware (Sipitakiat, Blikstein, & Cavallo, 2004). One important design decision was to integrate both functions into one single platform. In the autonomous mode, the student writes a program and downloads it to the board's memory, which can then operate disconnected from the computer (to control robots or gather environmental data, for example). In the tethered mode, the board remains connected to the computer at all times, providing high speed sensing and control capabilities. As a result, students can develop scientific experiments or sophisticated interactive systems which rely on the higher processing power of the computer (see, for example, Blikstein & Wilensky, 2006).

Documentation: Another concern about the dissemination of the board was multi-lingual documentation. Most young children outside of English-speaking countries can only communicate in their native language. As a result, we developed a customized website engine to allow for easy, decentralized translation of the content, and set up a wiki and code repositories where multiple authors could contribute with localized documentation and code.

Results

For the past years we have collected usage data across several countries. There are over 2,000 GoGo Boards being used worldwide, two international foundations adopting it, and a growing user community of students and hobbyists in more than 10 countries. In many locations, middle- and high-students themselves build their own boards, using improvised equipment (Figure 2, top and bottom left) – and our data indicates that assembling the boards had a significant impact on their sense of technological competence and self-efficacy. Additionally, being an open-source project, users customize the board to their own use: undergraduate students in Brazil created their own version of the board (BR-GoGo) with different connectors better adapted to their use (see Figure 2, bottom, center). This group of students also developed their own multi-platform block-based visual programming environment (see Figure 2, bottom right), created a website for the project, and started to conduct projects in local schools. Students in Mexico managed to assemble a board with components almost exclusively scavenged from broken electronics.

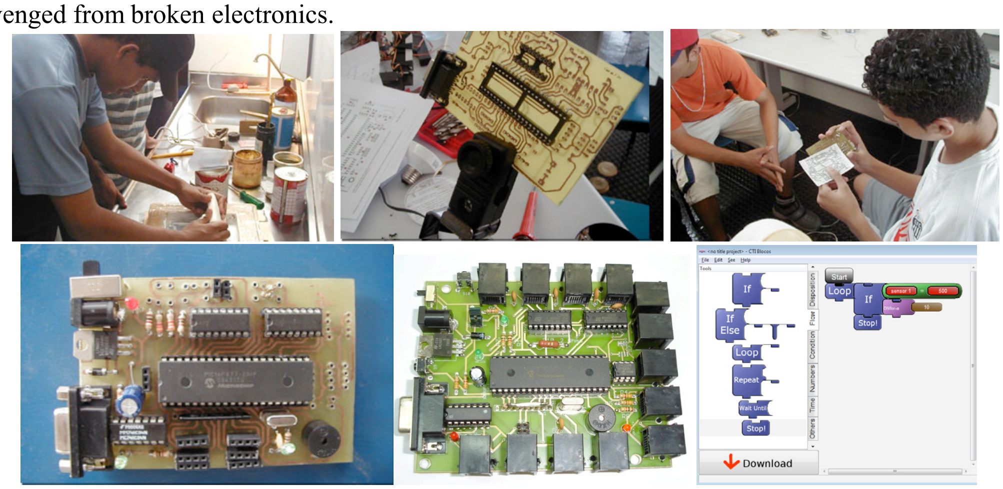

Figure 2: High-school students creating boards, the Brazilian version of the board, and the programming environment create by undergraduate students in Brazil (lower right).

Conclusion

Although the educational benefits of computational tools for robotics and environmental sensing have been acknowledged, their widespread sustainable use in low-income areas has been uncommon. The GoGo Board framework allows for sustainable, cost-effective, and appropriate implementation of these technologies in schools, especially in locations where accessibility, support, and economical limitations are an issue. Our results show that designing for low-cost, local assembly, local customization, and open-source had a significant impact on adoption, sustainability, and use.

References

Blikstein, P., & Wilensky, U. (2006). The Missing Link: A Case Study of Sensing-and-Modeling Toolkits for Constructionist Scientific Investigation. Proceedings of the 6th IEEE ICALT, pp. 980-982.

Lyon, C. (2003), Encouraging Innovation by Engineering the Learning Curve. Cambridge, MA: Department of Electrical Engineering and Computer Science Master's Thesis, MIT.

Martin F., and Resnick M. (1993). "LEGO/Logo and Electronic Bricks: Creating a Scienceland for Children", Advanced Educational Technologies for Mathematics and Science. Springer.

Papert, S. (1971). "Teaching children thinking". MIT Artificial Laboratory Memo #247, MIT, Cambridge.

Sargent, R. (1995), The Programmable LEGO Brick: Ubiquitous Computing for Kids. Cambridge, MA: Media Laboratory Master's Thesis, MIT.

Sipitakiat, A., Blikstein, P., & Cavallo, D. Moving towards highly available computational tools in learning environments. Proceedings of ICLS 2004, USA.

Tinker, R. (2000). A History of Probeware. Retrieved from http://www.concord.org/publications/detail.

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Model-Evidence Link Diagrams: A Scaffold for Model-Based Reasoning

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Abstract: This poster explores the ways in which students participating in a scientific modeling curriculum engaged with a specific scaffold, the 'Model-Evidence Link' (MEL) diagram, designed to reduce cognitive load and facilitate modeling literacy. Completed MEL diagrams, along with the small-group argumentation sessions they supported, represent rich sources of data on students' norms for model-evidence coordination, both before and after the scaffold's introduction. We consider various approaches to coding these data and present preliminary results.

Objectives & Theoretical Framework

This poster presents ongoing results from the PRACCIS (Promoting Reasoning And Conceptual Change in Science) project, a microgenetic investigation of the effectiveness of classroom argumentation around scientific modeling for promoting learning and reasoning in middle school life-science classes. PRACCIS has explored ways in which the challenges of developing sophisticated model-based inquiry might be met in instruction. The effectiveness of scaffolds in promoting authentic, reflective inquiry suggests that they might be the kind of instructional tool for engendering model-evidence fluency among science students (Hmelo-Silver et al., 2007).

Previous research by the project team has identified the central evaluative modeling and argumentation criteria used by students engaged in the PRACCIS research project has and tracked changing patterns of criteria use over the course of the school year (Pluta et al., 2009). Here we investigate the ways in a specific modeling scaffold served to facilitate and constrain the reasoning and argumentation practices of students.

A goal of the analyses presented in this brief paper is to critically assess students' use of a scaffold used prominently in the PRACCIS curriculum—the model-evidence link (MEL) diagram (see Figure 1). This scaffold is a graphical representational and reasoning tool designed to facilitate the coordination of multiple pieces of evidence in the evaluation of one or more models. When using the MEL diagram, students use different kinds of arrows to denote different kinds of relationships between evidence and models: *supports*; *strongly supports*; *is irrelevant to*; or *contradicts* a model. The scaffold encourages students to present reasons for particular model-evidence relations and to consider how model-evidence relationships can vary not only in direction (support versus contradict) but also in strength (e.g., strongly support versus support). The scaffold allows students to consider multiple models against multiple pieces of evidence, each of varying relative strength. Accomplishing this kind of reasoning presents multiple difficulties for students unaccustomed to modeling practices, not least due to the cognitive load involved.

Methods and Data Sources

Data are drawn from a yearlong microgenetic study of 16 classes taught by 7 teachers, including a full school year of class video and small-group audio recordings. Our analyses focused on the use of the scaffold in written pretest and posttest assessments in the classes of four teachers. Additional data are drawn from written work and from class and group discourse sampled (a) several weeks before, (b) during and (c) several weeks after the introduction of the MEL diagrams.

The data analyzed in this paper come from two separate inquiry investigations in which MEL diagrams were embedded, allowing for counterbalanced assessment of students reasoning. For reasons of space we shall briefly describe one of these—a problem in which students used evidence to determine which of two explanations of the cause of gastrointestinal ulcers should be preferred. Students considered two models: (a) a stress model, on which increased tension leads to overproduction of stomach acid which damages the stomach lining; and (b) a bacteria model, in which bacterial infection results in damage to the stomach lining. After deciding which model they initially considered better, students were presented with three pieces of evidence: (1) the pain produced by the action of stomach acid on wounds in the stomach lining; (2) associations between stressful jobs and ulcers; and (3) the effectiveness of antibiotics (which kill bacteria) on alleviating ulcers. Students then completed a MEL diagram that presented the models and evidence in a perspicuous form, and students justified their choice of links they considered to be the most important for comparative model evaluation.

Completed scaffolds provide a concise, justified summary of a student's reasoning. In our analyses, we coded students' completed diagrams to capture the particular pattern of weighted links for each student, as well as the argumentation strategies revealed in their justifications. Students' patterns of link judgments were initially assessed against those generated by domain experts solving the same problems.

Results and Significance

Students' justifications were coded in several ways. First, according to their degree of elaboration, specifically in terms of the nature of the link between the model and evidence they coordinated. *Highly elaborated justifications*, e.g. "… because ulcers are commonly found in dangerous jobs, like firefighter, or coal miners… jobs [that] can be hard on the body causing stress that lead to excessive body acid which causes ulcers" typically introduced a new element or perspective which served to fit some feature(s) of the evidence with the model. *Low elaboration answers* merely asserted the presence of a substantive link, without taking steps to integrate them in unifying explanation, or simply restated the characteristics of the model and/or evidence. This coding scheme provides a useful way of delineating high and low quality of reasoning in student responses, as high levels of creative elaboration is needed to bring apparently disparate models and evidence together in successful explanation. Creativity and narrative fluency appeared to play an important role in students' reasoning.

Additional coding categories included various classes of factual and inferential error, including responses in which the relevance of evidence for a model was missed (e.g., many students judged the antibiotic evidence as irrelevant to the bacterial model, as it only dealt with the healing of ulcers and not explicitly with their causation). Students appear to need to learn strategies that can help them recognize the relevance of such evidence.

More sophisticated strategies such as 'exclusion' (e.g. "the evidence supports the stress model, because it contradicts the bacteria model") were also documented, as was 'meta-modeling' facility, in which different criteria for good and bad models were expressed in their justifications. Less sophisticated strategies were also evident, including 'non-justificatory' responses, in which model-evidence judgments were defended in ways that failed to provide genuine reasons (e.g. "…because that is what I think").

The MEL diagrams provided students with an intuitive and simplifying means of representing complex sets of model-evidence relations, and they supported collaborative argumentation about issues such as the strength of evidence. However, the impact of the diagrams varied somewhat between teachers. Gains in the quality of students' justifications were mixed. Differences were noted in the frequency of non-justificatory responses between two groups of teachers demonstrating quite different styles of classroom inquiry and argumentation management. The students in classes taught by the teachers who were considered to most effectively balance teacher-scaffolded instruction and feedback with student-led inquiry and discussion exhibited a decrease in the non-justificatory responses (that is, responses that failed to provide substantive reasons for claims). However, the students of teachers who provided less clear scaffolding or dominating the inquiry discourse in their classrooms increased slightly in their tendency to give non-justificatory responses. It appears that in the context of this learning scaffold, the instructional styles of teachers may substantively impact students' justificatory practices.

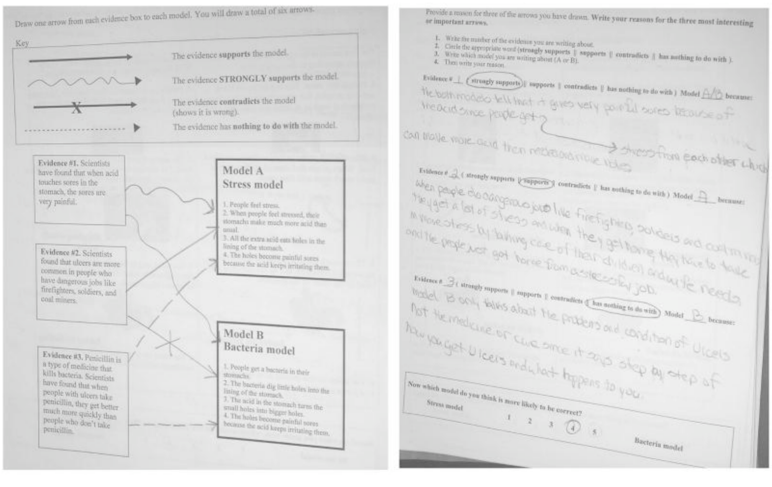

Figure 1. A completed Model-Evidence Link Diagram.

References

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42,* 99-107.

Pluta, W. J., Buckland, L. A., Chinn, C. A., Duschl, R. A., & Duncan, R. G. (2008). Learning to evaluate scientific models. In *ICLS 2008: Proceedings of International Society of the Learning Sciences*. Lulu.

Rhythm Games and Learning

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Abstract: This paper extends studies of music cognition to the genre of video games known as "rhythm games" – a popular, understudied video game genre. In this study, eight Guitar Hero II songs were analyzed and six participants were asked to perform a listening and tapping task. Results suggest that players do not exhibit knowledge of underlying metrical structure.

Introduction

Contemporary research on video games and education argues that the social, authentic and engaging activities that games encourage provide players with learning environments that outstrip traditional schooling (e.g. Gee, 2004). While this perspective has produced compelling evidence in support of the theory that games encourage exemplary educational activities, difficult questions have begun to arise from pragmatic issues of implementation and from structural issues of formal educational settings (Van Eck, 2006), not to mention the inherent (and non-trivial) issue of figuring out how one goes about designing an educational game that engages a player and promotes learning specific content (Gaydos & Squire, in press). Specifically, new methods still need to be explored to investigate and interpret the complex player behaviors and measurable changes that result from play.

The purpose of this investigation was to specifically investigate the nature of meter learning in the popular music game Guitar Hero 2. It re-appropriates methods used in the study of music cognition to the genre of rhythm video games – a genre of video games that has only in the past ten years or so, achieved market prominence and widespread popularity.

This paper presents preliminary results of a study that examined the rhythm game Guitar Hero for the way that it conveys meter, and explored whether Guitar Hero players were leveraging musical resources similar to those of trained musicians. Discussion of the potential for the design of rhythmic interactive environments and performance-based assessment is provided.

Guitar Hero, Meter, and Music Cognition

Recently, rhythm/music games have exploded in popularity. For example, the Guitar Hero franchise, for example, has become the third franchise ever to break the billion-dollar mark (Carless, 2009). Despite this success, rhythm games have received relatively little attention from researchers. In a recent study by Miller (2009), a survey and interviews suggests that Guitar Hero is like lip-syncing, in that it is a hybrid of traditional music and performance. Miller describes the satisfaction that results from Guitar Hero as arising from the players re-assembling of the recorded music that the game designers took apart. Miller argues that, rather than evaluating Guitar Hero as a bastardized form of music performance, a tension often found within game communities, the game should be considered for its own merits and for the experiences it provides players. Nevertheless, investigating the nature (musical or not) of Guitar Hero play is interesting from the perspective of music cognition, where a robust corpus of research has been developed to explain musical mechanisms such as timing, tone, and rhythm.

According to Lerdahl and Jackendoff's *Generative theory of tonal music* (Lerdahl & Jackendoff, 1996) meter is comprised of beats, or zero-duration points in time, and is structured hierarchically, with lower equivalence classes comprising higher equivalence classes. The beat is said to be *strong* where coordination is high amongst these classes and *weak* where coordination is low amongst these classes. Meter is thus defined as the hierarchically organized structure of beats. Within Guitar Hero, players are forced to synchronize their actions in time with musical, structured stimuli.

Over the course of game play, players may be learning the structure, or meter, of the stimuli, and that this learning might result in behavioral differences between expert guitar hero players and guitar hero novices.

Methods

This study is comprised of two components, an analysis of Guitar Hero II (GHII) songs and an experiment on players. One song from each of the eight song sets within the game Guitar Hero II was randomly selected and, similar to Palmer & Krumhansl (1990), the frequency of notes with respect to their location in the "measure" were recorded for the first twenty measures of each song on all four difficulties (easy, medium, hard, and expert), starting with the first measure that contained notes.

In the experimental portion of the study, three expert GHII players (age 21 – 37, all male) and three non-GHII players (age 25 – 33, 1 male) who did not regularly play music were recruited from the local university community. GHII expertise was verified at the end of each study session by asking participants to play a song on progressively harder difficulties. All GHII experts could complete at least two songs on the hardest difficulty level. No non-GHII players could complete a song on either the hard or expert level. Participants performed a listening task in which they provided goodness of fit ratings on a 7-point likert scale for the timing of tones within a 4/4 meter. Participants also performed a tapping task in which they synchronized taps in time with a metronome, which sounded at inter-stimuli-intervals (ISIs) of 250, 500, 750, and 1000 ms. They continued tapping once the metronome was removed. Results for the tapping task were analyzed in light of the Wing Kristofferson model (1973), which posits that for ISIs greater than 250 ms, time-keeper variance can be thought of as originating from a stochastic wait process in which an internal time keeper and motor control processes account for tap variances.

Results

The GHII song analysis suggests that increasingly metrical as difficulty increased from easy to expert. Results from the listening task were unclear. A 4 (ISI Times) x 2 (Synchronization/Continuation) x 2 (Level) ANOVA was conducted on the inter-response intervals and a significant 3-way interaction effect ($F = 3.32$, $p = .019$) was found for Player Level*Times*Synchronization/Continuation, results that align with previous findings in the literature. A significant effect for player level was found at the shortest inter-stimulus interval ($F = 10.087$, $p < .01$).

Discussion and Conclusion

Though rhythm games may appeal specifically to the already musically inclined as Miller's (2009) survey suggests, it is interesting to note that, even in spite of GHII's distinctly non-traditional musical form, this study does not support the theory that players are improving their sensitivity to meter, rather suggests expertise entails improved performance at the fastest levels of perception and action. It is important to consider that the primary purpose of the game is entertainment and the primary goal of the company is revenue; the game is not designed for music education. In some ways, these results are unsurprising considering the difficulty in associating language learning with merely exposure frequency. The results suggest that frequent structured actions may not be sufficient for adopting specific mental representations.

The line demarcating where perception stops and cognition begins is not easily determined and theories that highlight the active nature of "seeing" (e.g. Noe, 2005) suggest a connection between perception, action and thought. Reconsidering the role of perception may be important for theories that emphasize the meaningful experiences that games can provide for education (e.g. Squire, 2005) as experiences that change how we see the world may lay the groundwork for future learning (diSessa, 2000).

References

Carless, S. (2009). Kotick: Guitar Hero Now $2 Billion Franchise. *Gamasutra*. Retreived 10/09 from <http://www.gamasutra.com/php-bin/news_index.php?story=23537>

diSessa, A. (2000). *Changing Minds.* The MIT Press: Boston.

Gaydos M.J. & Squire, K (in press). Citizen Science: Designing a game for the 21st century. *In Interdisciplinary Models and Tools for Serious Games: Emerging Concepts and Future Directions*, Richard Van Eck, Editor. Hershey, PA: IGI Global.

Gee, J.P., (2004). *Situated Language and Learning.* Routledge: UK

Honing, H., & Ladinig, O. (2007). Exposure influences expressive timing judgments in music. *JEP:HPP.*

Lerdahl, F., & Jackendoff, R. (1983). *A Generative Theory of Tonal Music*. The MIT Press: Boston.

Miller, Kiri. (2009). Schizophonic Performance: Guitar Hero, Rock Band, and Virtual Virtuosity. *Journal of the Society for American Music.* 3(4):395-429.

Noe, A. (2005). *Perception in Action*. The MIT Press: Boston.

Palmer, C. & Krumhansl C. (1990). Mental Representations for Musical Meter. *JEP:HPP* 16(4) 728-741.

Squire, K.D., (2006). From content to context: Video games as designed experiences. Education Researcher. 35(8): 19-29.

Van Eck, R. (2006). Digital game based learning. *Educause.* 41(2). 16-30.

Wing A., & Kristofferson, A., (1973). The timing if interresponse intervals. *Perception & Psychophysics.* 13(3), 455-460.

Yee, Wm., Holleran, S. & Jones, M. (1994). Sensitivity to event timing in regular and irregular sequences: Influences of musical skill. *Perception & Psychophysics*, 56 , 461 - 471.

Building Creativity: Collaborative Learning and Creativity in a Virtual Gaming Environment

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Abstract: Using a systems-based approach to creativity and situated approach to learning, this study is a pilot exploration into how creative ideas emerge within a community and are spread amongst its members. This study takes place within the Multi-User Virtual Environment, Quest Atlantis, and uses chat data, screenshots, and offline conversation to explore creativity and collaborative learning in the context of virtual 3D architectural building.

21st century Internet culture has produced a growing number of public forums in the digital realm geared toward the sharing of creative ideas. Blogs, wikis and chatrooms are all spaces where millions of dispersed members create community around new or shared ideas from within simulated environments. A more elaborate form of social interaction in online spaces is the Multi-User Virtual Environment (MUVE), where players contribute to virtual communities by putting forth original ideas, actions or physical objects that, in turn, shape the aesthetic/philosophical landscape of the community. If other community members engage and value these contributions, the contributions then become recognized as meaningful expressions of creativity. A creative idea, object, or action is thus in part a socially-determined process, consistent with Csikszentmihalyi's (1996) systems model of creativity. In this model, a system is composed of individuals, knowledge domains, and the related social contexts that form a field. An individual builds on culturally valued meanings, practices and designs to produce new variations of the domain, which, if deemed valuable by the community (field) become part of what constitutes the evolving domain. This field component implies that colleagues and domain norms are essential to the realization of individual creativity (Schneiderman, 2000). Such a view removes the aura of mystery around creativity and, instead, emphasizes the importance of sustained discussion with peers and the need for appreciation of the constraints that one is augmenting or violating while producing a creative contribution.

Central to this model is the relation of creativity to a system, with the idea that how one's social group takes up the work ultimately defines its value as a creative act. Our study takes place within the MUVE, Quest Atlantis (QA), an educational virtual world that engages players with educational content while supporting dynamic interaction between a live community of players (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005). The reflexive relationship between users and the environment makes this an ideal setting to study how creative ideas emerge within a community and are spread amongst its members. For these purposes, we created an architectural world within QA based on Ayn Rand's novel, *The Fountainhead*, to explore how communities take up the themes of creativity and constraint within their 3D virtual building. Our questions for this study are: Using a systems-based approach to creativity, what ideas are seen as creative and taken up by the field? Further, how do learners collaboratively engage in the learning process to enable the spread of such ideas?

Methods

Quest Atlantis is a 3D MUVE that immerses players in educational tasks, combining commercial gaming elements and educational lessons. Players engage in socially and academically meaningful activities, being part of stories, interacting, and developing social and academic skills. 124 elementary- and middle-school students from several countries around the world participated in this study, engaging in the architecture mission in schools, afterschool centers or at home. Our architecture mission, following the themes of the Rand novel, has players join an architecture firm where they must chose whether to align with individualistic head Architect, Howard Roark, which guarantees members complete freedom over their 3D building in the virtual world, or align with the more capitalistic architect, Peter Keating, which guarantees the member lots of city contracts but under the condition that they adhere to strict building restrictions. Regardless of their choice, players have the opportunity to rent real estate and practice their creative ideas.

Data was collected from multiple sources throughout the architecture trajectory, including submitted review reports throughout the gaming missions, screenshots from Questers' buildings, chat and messages, as well as online interviews from the researchers' online interactions with several players. We extracted

Questers' architectural review reports, the chat logs in all the relevant worlds, as well as the chat logs for specific Questers whose creations were of special interest. Using a qualitative approach to data analysis, we used a top-down approach to coding derived from our theoretical frame to code and analyze chat data, log files, artifacts and player responses. Coded events were then further analyzed to better understand how players learn about such "spreadable" ideas and collaborate with one another to learn about how to build their own architectural structures.

Findings

Using a systems-based approach to creativity, we identified architectural ideas that were seen as creative by the larger field of Questers. In other words, creative ideas were those that new builders wanted to appropriate and the field of participant observers (those without a building license spent time discussing and highly valued for one reason or another). After the thematic analysis of our categories, we have focused on the following "creative" ideas within the community: fire textures, mushroom shaped houses, glass, bright colors/aesthetics, and animated objects. Further analyses of each of these ideas are presented below as well as insights are shared about how a community learns to adopt creative innovations through shared collaborative learning. Further analysis of how Questers learned to take up these ideas is presented in our poster. One of the creative ideas is presented below in further detail.

Playing with Fire

A number of Questers found changing the specific texture of objects challenging but a key space for creativity in their buildings. At the start of August 2008, several buildings began to have fire textures on their walls and on some of the objects. Questers seemed to like the particular texture because of its animated fire image. They also seemed to associate it with the feelings they had viewing the buildings and some Questers also link the fire texture to their real life experiences. Jath554mse observed a house and reported: *"It makes me feel cool and very warm inside. It is this way because of its fiery color and the way the color moves…. I like what it looks like on the inside when you are in it because it looks like you are in a fire."* However, learning to change the textures was difficult. As a result, several of the Questers built tutorials for others to follow and a flurry of chat activity (both an and offline) resulted around this activity. Chat records, screenshots, and interviews were further analyzed to better understand how creative ideas evolved over time within the community and how knowledge of these practices were spread within the community.

Discussion

Implications for creativity and collaborative learning are discussed. While the use of video games as an educational medium continues to entail issues of deep concern, we are seeing more and more games that are gender-neutral, have pro-social narratives at their core, and that support collaborative inquiry and deep learning. Moreover, the utility or even indispensability of creativity in meeting this need is evident but even less well understood, and this poster brings together two domains to harness and foster children's creativity: Spreadable ideas and collaborative learning. Indeed, the social dimension involves not simply the presentation of the building artifacts, but the critical reception and discussion around the work, contributing to the legitimacy and caliber of the work and, in turn, to the community and their engagement in practices relating to computer programming and interactive narrative composition.

References

Barab, S. A., Dodge, T., Thomas, M., Jackson, C., & Tuzun, H. (2007). Our designs and the social agendas they carry. *Journal of the Learning Sciences*, 16(2), 263–305.

Csikszentmihalyi, M. (1996). *Creativity: Flow and the psychology of discovery and invention*. New York: HarperCollins.

Schneiderman, B. (2000). *Creating creativity: User interfaces for supporting innovation*. ACM Transactions on Computer-Human Interaction, 7(1), pp. 114–138.

Predicting Social Influence and Project Influence in Online Communities of Creators

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Abstract: This paper introduces Online Communities of Creators, the subset of social networking sites in which the focus is sharing, developing and understanding personal creations. It proposes that two kinds of influence are important in these communities: social influence and project influence. Using multiple linear regressions the factors that predict each type of influence were identified for one Online Community of Creators called the Scratch Community web site.

Introduction

As more of our time is spent online, more opportunities for learning and creating are available in virtual spaces. The sites that offer the richest communities engage participants in a range of ways. These sites may support establishing an online identity, making small talk that leads to common ground, developing a dialogue about personal creations, and presenting, trying-out and critiquing projects.

In this paper I define a subset of SNS called *Online Communities of Creators* (OCOCs). OCOCs are the online communities in which the core activity is sharing personal creations. In these communities, a network of people is brought together by the projects they create and share. These sites provide features that emphasize:

- the sharing their own original creations (such as photographs, music, writing, or computer programs);
- the discussion of one another's work;
- the association of particular contributions with the people who make them.

When members post projects, they reveal themselves and create a public self for others to reflect upon. Thus, they are conscious of what they share, the attention it might garner, and how they hope others will react. To be accepted by their community, they develop relevant skills and perspectives that stimulate the community. Through their public persona and supported by their creations, they build online relationships with other members.

Online communities of creators must find a balance between supporting the social system and project sharing. If the design and use of the community focuses too much on the social system and not enough on projects, it risks losing its core mission. If the community focuses upon the projects without allowing for personal recognition and social interaction, it can seem a dry, undesirable place. In a community in which people are making different kinds of contributions, understanding the factors that bring these contributions recognition is also important.

One way to approach understanding influence in OCOCs is to examine their most important features, specifically, the social system and the original creations. I propose that in OCOC two kinds of influence are key (Sylvan, 2007). The first, *social influence*, is how much a member is a social bridge between otherwise unconnected members. Social influence can be measured by betweenness centrality. Betweenness centrality is defined as how much a particular member is part of the shortest path between two other members in a given community (Brandes, 2001). The second, *project influence*, is a measure of the degree to which the community recognizes members' work. Members who exhibit this trait are influential because of the work they create. Project influence can be defined as how much a particular member's work is cited by other members.

The Current Investigation

This paper investigates an Online Community of Creators called the Scratch Online Community (Monroy-Hernandez & Resnick, 2008). Scratch is a visual programming environment that lets users create their own animations, games, and interactive art (Maloney et al, 2008). To program in Scratch, users run the software locally on their machines. Once their project is ready, they can upload it to the Scratch Online Community.

This data was gathered from February to June 2007. During this time Scratch had over 16,000 users who created over 10,000 projects. Members' mean age was 25.61 and fifty-two percent report they were 21 or younger. Twenty-nine percent of users described themselves as female. Forty-six percent of were from the United States. (For greater description of methods and sample, see Sylvan, 2010).

Results

Social Influence

In the Scratch Online Community members can request to be listed as each other's friends on their profile pages. In the current multiple linear regression social influence was measured by members' betweenness centrality in this friendship network. This means that people who commonly are the shortest path between other members in the network would have higher social influence than those who rarely acted as bridges.

Betweenness centrality values in the friendship network were regressed on four factors: number of comments made, number of galleries the user participated in, number of "love-its" received, and number of tags added to people's projects. These four predictors accounted for over one-third of the variance in the betweenness values (R^2 = .37), which was highly significant, $F(5050) = 755.01$, $p<.0001$. All of the relationships were positive ones, except for tagging, which was a negative relationship. All measures demonstrated significant effects on the betweenness centrality of the friendship network. Two factors had the most sizable impacts participating in galleries (T=26.65) and writing comments (T=29.42) while the other effects were smaller.

Project Influence

In the Scratch Online Community people can run other people's projects in the browser, but to see how they are built, they must download the source code. When someone downloads another person's work in this community, they are likely to be interested in the inner workings of the project. As a result, the number of times someone's work is downloaded is used to measure of project influence in this community.

Project download counts were regressed on eight factors: number of friends, number of comments, number of times a user's project was featured, days since first project, days since last project, number of projects, date the user joined, and date of last login. These eight predictors accounted for a little more than half of the variance in the project influence values (R^2 = .53), which was significant, $F(2781) = 392.73$, $p<.0001$. All measures demonstrated significant effects on project download counts. By far the biggest predictor of having one's project downloaded was being featured by administrators (T=38.30).

Discussion

When the variables that were predictive of project influence were added to the social influence regression, none, except number of comments, was found to predict social influence. Additionally when the variables that were predictive of social influence were added to the project influence regression, none, except number of comments, was found to be predictive. This evidence suggests that these two types of influence may be distinct constructs. On the site comments are used for both social and project-related reasons. Future work will discriminate between different kinds of comments.

Conclusions

This paper introduces Online Communities of Creators, the subset of social networking sites in which the focus is sharing, developing and understanding personal creations. It proposes that two kinds of influence are important in these communities: social influence and project influence. In the Scratch Community web site social influence was predicted in a multiple linear regression by number of comments made, number of galleries the user participated in, number of "love-its" received, and number of tags added to people's projects. Project influence was predicted in a multiple linear regression by number of friends, number of comments, number of times a user's project was featured, days since first project, days since last project, number of projects, date the user joined, and date of last login. Other than number of comments, the factors that predicted these two kinds of influence were distinct from one another. Thus, in this community, these two concepts seem to be distinct constructs. The current work provides concepts and measures that, with further study, may be applicable, and valuable, to understanding and designing other communities.

References

Brandes, U. (2001). Faster Algorithm for Betweenness Centrality. *J Math Sociol., 25, 2,* 163-177.

Maloney, J., et al. (2008). Programming by Choice: Urban Youth Learning Programming with Scratch. *Proc. SIGCSE 2008* (pp 367-371), AMC Press.

Monroy-Hernández, A. and Resnick, M. (2008). Empowering kids to create and share programmable media. *Interactions 15*, 50-53.

Sylvan, E. (2007). The sharing of wonderful ideas: Influence and interaction in online communities of creators. *Doctoral dissertation,* (2007), MIT Cambridge, MA. http://hdl.handle.net/1721.1/42404

Sylvan, E. (2010). Predicting Influence in an Online Community of Creators. To be included in the *Proc. of CHI 2010*, ACM Press.

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Neighborhood Investigations and Game Design Using Mobile Media

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Abstract: This poster presents a design-based research study aimed at exploring the use of commercial mobile devices to support guided, yet open-ended and emergent explorations of place. As part of our study we explore the potential of a design studio model to support students' ability to investigate, analyze and report on contested issues and places in and around their school and guide their design of place-based Augmented Reality simulations and games.

Introduction

Mobile devices allow for new forms of learning that challenge the traditional culture of schools. While some schools have chosen to focus on the potentially negative consequences of these devices, others have begun to more seriously consider the growing disconnect between school policies and practices and the way that learning takes place outside of school (Squire, 2009; Norris & Soloway, 2009). The study presented here seeks to address this disconnect by exploring the potential of commercial mobile devices (particularly iPhones and similar smart phones) and "off-the-shelf" software to support guided, yet open-ended investigations of place. As such, it builds on previous research highlighting the potential of mobile media to support inquiry-based and constructivist learning environments (Rogers & Price, 2009; Sharples, Taylor, & Vavoula, 2005), as well as research related to critical, place-based learning (Gruenewald, 2003; Hull & James, 2007).

Study Design and Methods

Neighborhood Investigations and Game Design is a studio-based design curriculum piloted with two groups (N=10 and N=12) of 11th and 12th-grade students over a period of twenty days. Both of the implementations took place in a suburban high school and included *a place-based inquiry workshop*, where students used mobile devices to identify and investigate contested issues in their city and *a mobile game design workshop*, where students collaboratively designed place-based Augmented Reality games using mobile devices. We utilized a design studio model during both of these workshops as a way to simultaneously scaffold the students' designs and teach them about the design process (Cox, Harrison & Hoadley, 2009). A normal class period (90-minute block) included the following: (1) *Large-group check-in* at the start of class. This usually occurred at the school, but on occasion took place at a location outside of the school (e.g., we used a local coffee shop and the city hall as meeting locations). This time was used for full-group presentations, critiques and discussions related to the concepts we were studying (e.g., game design, contested places) and as an avenue for checking in on individual and group progress; (2) *Community-based independent and small group research and investigation*. During this time students left the school building to conduct field work that was relevant to their design(s) (e.g., conducting interviews, taking photos, making observations, testing prototypes). During these field excursions, students either selected from pre-scripted design quests or developed their own design tasks to guide their investigation. In addition, they used mobile devices (both their own and ones supplied by the researchers) to receive additional quests, collaborate, gather data and share their progress; and (3) *Large-group debrief sessions* where students reported on their field and design experiences, shared works in progress and participated in formal critiques. During the AR game design workshop the students also used studio time to play several pre-designed Augmented Reality games, design and prototype "micro-AR games", and collaboratively design their own Augmented Reality simulation aimed at teaching other students and staff at the school about a controversial issue in their local community.

Because we were interested in exploring the curriculum and the overall learning environment as an integrated system we employed a design-based research methodology. As such, a major goal was to iteratively redesign the curriculum and intervention strategies *in situ* in order to ground our questions, findings and re-designs in both the existing theory surrounding mobile and place-based learning and the issues, challenges and questions that emerged from our unique context (Cobb, diSessa, Lehrer & Schauble, 2003). The data we analyzed to make (re)design decisions included: observations, students' design journals, small group and individual interviews and student generated artifacts. Because of space constraints we chose to limit our discussion of the data/data analysis in this short paper, however, as part of our presentation we will share photographic evidence, excerpts from interviews and design journals, and student generated artifacts (e.g., design documents, media assets and final games) that both, exemplify the key components of the intervention, and support our findings.

Findings

Our preliminary findings suggest that framing the students' investigation around the concept of contested issues and places served as a conduit for developing their understanding of the multiple perspectives surrounding contentious issues in their community. Not surprisingly, students' positionality shaped the way they initially perceived and discussed the issues, people and places they chose to study. However, each student's understanding of the issues became more complex as their investigations advanced and they developed a greater capacity for empathetic thinking. Studying issues within their local community increased students' engagement and challenged them to think more complexly about these issues, while also providing opportunities for them to perform and explore a range of identities (e.g., game designer, researcher, community activist). Similarly, the AR design experience also provided a space for students to share their own perspectives on the places where they live their daily lives. For many students a highlight of the design experience was seeing their voices and perspectives represented in the final AR design/simulation.

The studio model, in conjunction with the use of mobile devices, helped cultivate a hybrid-learning environment where students fluidly moved between the classroom and the broader community in order to complete investigatory and design tasks. The mobile devices allowed us to maintain contact with students as they explored the broader community, while providing them space to semi-autonomously and flexibly manage their own research, social interactions, and progress. We maintained contact with the students as they worked in the community via mobile-to-mobile (text messaging, emails, phone calls) and face-to-face conversations. It was common practice for us to setup in a central location, where we were in close proximity to the students as they worked in the field. If a question came up or we wanted to check-in with a student or a group, we would communicate with them via cell phones and/or arrange a meeting place. These "in the field" meetings provided opportunities to connect with individuals or small groups to offer feedback or just in time instruction. Despite our emphasis on the use of mobile devices, a central design space (e.g., a shared work space and physical design board where students posted and collectively organized their work) and consistent design rituals or practices (e.g., journaling, group discussion, critiques) also proved critical to the studio/learning experience. The physical design space provided opportunities for students to share their work informally and often became the site of emergent design conversations. Similarly, the design journals provided an opportunity to gauge students' conceptual understanding and general reactions to particular activities and/or the overall design process.

Finally, consistent with previous research around the use of a studio model for designing and learning about design, our study found that: (1) Developing AR games recruited students' digital media skills, tools, and Web-based communities that were not ordinarily used in school to complete tasks; (2) Creating games for an authentic audience deepened the design experience and increased engagement; (3) The complex, distributed nature of the design task led to the development of particular areas of expertise (related to both content, design and technology use) within the groups and allowed students to select design tasks that met their interests and skill levels. Overall these factors provided an avenue for differentiating the learning experience, which in turn, led to increased engagement, more autonomous learning behaviors, and increased feelings of self-efficacy.

References

Cobb, P., diSessa, A., Lehrer, R., Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9–13.

Cox, Harrison & Hoadley (2009). Applying the "studio model" to learning technology design. In C. DiGano, S. Goldman, M. Chorost (Eds.), *Educating learning technology designers* (pp. 145-164). New York: Routledge.

Gruenewald, D. (2003). The best of both worlds: a critical pedagogy of place. *Educational Researcher*, 32(4), 3-12.

Hull, G. and James, M. (2007). Geographies of hope: A study of urban landscapes, digital media and children's representations of place. In P. O'Neill (Ed.), *Blurring Boundaries: Developing Writers, Researchers and Teachers* (pp. 255–89). Cresskill, NJ: Hampton Press.

Norris, C. & Soloway, E. (2009). A disruption is coming: A primer for educators on the mobile technology revolution. In A. Durin (Ed.), *Mobile technology for children: Designing for interaction and learning* (pp. 83-98). Burlington, MA: Morgan Kaufman.

Rogers, Y. & Price, S. (2009). How mobile technologies are changing the way children learn. In A. Durin (Ed.), *Mobile technology for children: Designing for interaction and learning* (3-22). Burlington, MA: Morgan Kaufman.

Sharples, M., Taylor, J., and Vavoula, G. (2005). Towards a theory of mobile learning. *Paper presented at mLearn 2005.* Cape Town, South Africa.

Squire, K. (2009). Mobile media learning: multiplicities of place. *On The Horizon*, 17(1), 70-80.

Student Understandings of Solutions

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Abstract: This poster will present research about student understandings of solutions while observing dissolution and reactions first qualitatively and then quantitatively using ion-selective probeware. Preliminary data show that students have difficulty describing dissolutions symbolically and have difficulty choosing products in a double displacement reaction. The addition of quantification helps students reason about the identity of the substance in the beaker and the reaction that occurred.

Introduction

Solutions chemistry is important because it pertains to life, environmental and earth sciences as well as the field of chemistry itself. In chemistry, solutions imperative to reactions, concentration, and identity of chemicals. For example, cell biology studies the flow of solutions inside the cell through a semi-permeable membrane. One reason that students have difficulty learning to describe chemical phenomena is the use of different qualitative representation of matter by scientists (Johnstone 1982). Johnstone identified the different qualitative representations as submicroscopic, macroscopic, and symbolic. He defined macroscopic descriptions as the tangible and what can be seen, touched and smelt; submicroscopic as atoms, molecules, ions and structures; and the representational (symbolic) as symbols, formulae, equations, molarity, mathematical manipulation and graphs (Johnstone 2000).

There are three conceptual issues involved in solutions chemistry. They are Identity, Concentration, and Reaction. Identity is *what* is in the solution, Concentration is *how much* of it is in there, and Reactions occur in solution forming new substances. Reactions are different conceptually than Identity and Concentration because something new has been formed in this case. The three qualitative representations can be used to describe all three of the conceptual issues. A vast majority of the studies involving solutions chemistry looked at students' qualitative understandings (Johnstone 1982; Liu & Lesniak 2006; Nakhleh et al 2005; Mattox, Reisner, & Rickey 2006) concluding that students showed difficulty moving between the three representations of matter (symbolic, macroscopic, and sub-microscopic). These and other studies have a gap in that they do not address the use of number specifically within the concepts.

One review article (Çalỳk et al., 2005) discussed sixteen studies only one of which dealt with students reasoning about solutions (Gennaro, 1981). Three other studies point to the problems that arise when students are given numerical data in the context of solutions (Eliam 2004; Sanger & Greenbowe 1997, Calyk 2005). As seen in the literature, quantification is an aspect of solutions chemistry that experts seem to move effortlessly through in descriptions of phenomena. We believe that quantification is a 4th vertex to Johnstone's triangle, creating a tetrahedron of descriptions (Figure 1).

Methods

Nine students from a general chemistry course at an urban public institution in the Midwest were interviewed while they experienced different chemical phenomena. The tasks included: dissolution of copper(II) nitrate, reaction of copper (II) nitrate with sodium carbonate, reaction of copper(II) nitrate with sodium hydroxide solution, training with probeware, reaction of calcium chloride and potassium carbonate with probeware, and the reaction of calcium chloride with silver acetate. Students were video and audio taped and their drawings were collected. Students were encouraged to represent symbolically, macroscopically, submicroscopically, and quantitatively. The videotapes were transcribed and coded using NVIVO.

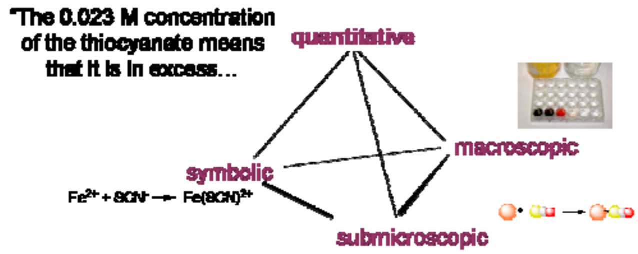

Figure 1: Tetrahedron of descriptions

Preliminary Results

Preliminary results yield several interesting findings. Two of nine students in the first part of the study forced a reaction of copper(II) nitrate with water for the dissolution of copper(II) nitrate in water when asked to represent it symbolically (Figure 2).

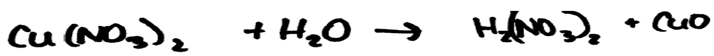

Figure 2: Student forcing a reaction when prompted to symbolically represent the dissolution of copper(II) nitrate

Several students were unable to predict the products for double displacement reactions using the probeware. This resulted in incorrect "flipping and switching" (two cations together) or in super-molecules that contained all of the ions involved in the reaction (Figure 3). Others chose the correct products but had difficulty reasoning with the concentration number for calcium to change or support their predictions.

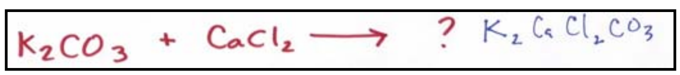

Figure 3: Example of a "super-molecule"

We have preliminary evidence showing that especially in the reaction task where potassium carbonate is added to calcium chloride to form a precipitate, students are able to reason using the number output from the probeware. Because the calcium ion concentration falls drastically toward zero as it is no longer in ion form, students are able to reason that the precipitate must involve calcium.

Conclusions and Implications

Preliminary data show that students have difficulty describing dissolutions symbolically and have difficulty choosing products in a double displacement reaction. This is consistent with the literature reviewed earlier. Students have difficulty moving between the different representations. The addition of quantification helps students reason about the identity of the substance in the beaker and the reaction that occurred. With the revised protocol that emphasizes on probeware training, quantification has the potential to help students reason through their misconceptions of solubility, identity and reactions.

References

Bodner, G.M. & Domin, D.S. (2000) Mental Models: The Role of Representations in Problem Solving in Chemistry. University Chemistry Education, 4(1) , 24-30.

Çalẏk, M. (2005). A cross-age study of different perspectives in solution chemistry from junior to senior high school. *International Journal of Science and Mathematics Education*, 3, 671-696.

Çalẏk, M., Ayas, A., & Ebenezer, J.V. (2005). A review of solutions chemistry studies: insights into students' conceptions. *Journal of Science Education and Technology*, 14, 29-50.

Gennaro, E. D. (1981). Assessing junior high students' understanding of density and solubility. *School Science and Mathematics*, 81, 399-404.

Johnstone, A.H. (1982). Macro-and microchemistry. *School Science Review*, 64, 377-379.

Liu, X., & Lesniak, K. (2006). Progression in children's understanding of the matter concept from elementary to high school. Journal of Research in Science Teaching, 43, (320-347).

Mattox, A.C., Reisner, B.A., & Rickey, D. (2006). What happens when chemical compounds are added to water? An introduction to the model-observe-reflect- explain (MORE) thinking frame. *Journal of Chemical Education,* 83, 622-624.

Nakhleh, M.B., Samarapungavan, A., & Saglam, Y. (2005). Middle school students' beliefs about matter. Journal of Research in Science Teaching, 42, 581-612

Sanger, M.J., & Greenbowe, T.J. (1997). Students' misconceptions in electrochemistry: current flow in the electrolyte solution and the salt bridge. *Journal of Chemical Education*, 74, 819-823.

Connecting Brain and Learning Sciences: An Optical Brain Imaging Approach to Monitoring Development of Expertise in UAV Piloting

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Abstract: In this paper we present our ongoing research project on UAV operator training and cognitive workload assessment for safe piloting to exemplify the potential for conducting interdisciplinary research that incorporates insights from learning sciences and cognitive neuroscience. The goal of the project is to devise cognitive neuromarkers to assess the cognitive workload experienced by UAV operators and to monitor their development of expertise through analysis of optical brain imaging data and flight-training videos.

The past decade has seen an increasing interest towards connecting research on learning sciences and cognitive neuroscience around various topics of common interest such as language learning, creative problem solving, learning disabilities and development of expertise (de Jong et al., 2009). Although the mind, brain and education movement has recently gained considerable momentum, initial findings of neuroscience on learning were received with reservations by educational researchers and practitioners (Bruer, 1997; Varma, Schwartz & McCandliss, 2006). This was largely due to lack of practical applications of neuroscientific findings to the design of real-life learning activities and environments. Earlier neuroscientific research in learning was confined to highly controlled laboratory settings and relied on protocols limited in scope due to the constraints imposed by the instruments used for monitoring brain activity. However, this body of research has brought important findings with regard to the correlations between brain activation patterns and basic cognitive processes such as attention, memory and visual/auditory perception that are fundamental to understanding the biological basis of higher order cognitive processes like learning. Different neuroimaging modalities such as positron emission tomography (PET), functional magnetic resonance imaging (fMRI), and electroencephalography (EEG) studies have consistently found correlations between specific brain activation patterns and underlying cognitive processes. Moreover, recent advances in brain imaging technology have led to the design of more portable instruments that afford new ways to study learning in real life settings. Therefore, recent developments have opened up new and exciting possibilities for collaboration across learning sciences and cognitive neuroscience, which may shed further light on our collective quest for better understanding the nature of learning.

This paper introduces an ongoing research study where we aim to identify cognitive indices related to Unmanned Aerial Vehicles (UAV) operations by using an emerging optical brain imaging technique called functional near-infrared (fNIR) spectroscopy. We brought together an interdisciplinary team of researchers with backgrounds in cognitive neuroscience, biomedical engineering, signal processing, and learning sciences to study the correlation between increasingly competent performance demonstrated by novice pilots during simulated missions and brain activation data obtained from subjects' prefrontal cortices that correspond to an area known to be associated with executive functions (e.g. judgment, decision making, planning).

fNIR is a neuroimaging modality that enables continuous, noninvasive, and portable monitoring of changes in blood oxygenation and blood volume related to human brain function. fNIR technology uses specific wavelengths of light, introduced at the scalp, to enable the noninvasive measurement of changes in the relative ratios of deoxygenated hemoglobin (deoxy-Hb) and oxygenated hemoglobin (oxy-Hb) in the capillary beds during brain activity. Over the last decade, studies in the laboratory have established that fNIR spectroscopy provides a veridical measure of oxygenation in the brain. Our recent findings indicate that fNIR can effectively monitor cognitive tasks such as attention, working memory, target categorization, and problem solving (Izzetoglu et al., 2007). These experimental outcomes compare favorably with fMRI studies, and in particular, with the blood oxygenation level dependent signal. Since fNIR can be implemented in the form of a wearable and minimally intrusive device, it has the capacity to monitor brain activity under real life conditions and in everyday environments. Moreover, the fNIR system is amenable to integration with other established physiological and neurobehavioral measures, including EEG, eye tracking, pupil reflex, heart rate variability, respiration, and electrodermal activity.

Research on human factors of UAV flight has identified several reasons underlying mishaps in UAV operations (Cooke et al., 2006). Firstly, UAV operators have limited situational awareness due to the disembodied nature of UAV flight where operators need to fly UAVs by relying on limited camera angles. Since commands are transmitted over satellite links, UAVs are less responsive to operator input as compared to manned aircraft. In addition to this, typical UAV missions take long durations of time that require transitions from long periods of dull flight mode to critical moments where operators need to stay alert to engage with a target or to attend to a contingency. In short, physically and cognitively taxing aspects of UAV flight have resulted in a large number of mishaps during military and civilian use. Therefore, devising reliable indices for assessing cognitive load and level of expertise are of critical importance for evaluating training regiments and interface designs, and ultimately for improving the safety and success of UAV operations.

We are currently in the data collection phase of our research project. Our initial pilot study includes 10 adults who have no prior experience with UAV flight. The simulation platform is based on Microsoft's Flight Simulator X with the Predator UAV add-on by Firstclass Simulations. Using a complete joystick, throttle, and rudder pedal controller set, this simulation environment approximates an actual MQ-1 Predator user interface (Figure 1). After completing a demo session, each subject completed a total of 8 two-hour long training missions within three weeks. During each session subjects fly variants of the same mission, where they are asked to successfully take off, locate a submarine in a specified geographical area, pass over it to allow identification photographs to be taken, navigate back to an airfield with given coordinates, fly within 500ft of the ground en route to the airfield over mountainous terrain, and successfully land after following a contingency maneuver revealed towards the end of the mission. These aspects, as well as other factors such as crosswinds, are added to the simulation to create realistic cognitive and physical demands, similar to those experienced by a real UAV pilot. The simulation environment allows us to replay each session. In addition to the flight video, we collect brain activation data, as well as additional parameters such as pitch, roll, yaw, altitude, longitude, latitude and air speed from within the simulation to aid in the assessment of performance.

We employ both quantitative and qualitative methods to monitor the progress of each subject. Critical aspects of the mission that are likely to increase or decrease cognitive load (e.g. actively searching for a target, navigating towards a set of coordinates, etc.), are identified through video analysis and the flight data. Once critical moments are identified and sampled, fNIR data collected at those moments will be correlated with operator performance to identify cognitive markers indicating expertise development and cognitive workload.

Our preliminary analysis has focused on the moment when two pilots reported that they have detected the submarine by pressing a button during 16 missions. In an effort to measure the effect of sub sighting on the change in oxygenation levels in the prefrontal cortex, we have compared 100-second blocks before and after the subjects located the submarine. For preprocessing the signals, a linear phase, finite impulse response (FIR) low pass filter with cut-off frequency of 0.1Hz is applied to the raw fNIR data to eliminate high frequency noise. Next, for oxygenation calculations, modified Beer Lambert Law is applied to the filtered data to calculate oxy-hemoglobin and deoxy-hemoglobin concentration changes for 16 measurement locations (voxels). The averages of total hemoglobin concentration changes were calculated for pre- and post- blocks, and then normalized by calculating z-scores for each pair independently. Repeated measures analyses of variance, with the Geiser-Greenhouse correction, indicated that the decrease in oxygenation only at voxel 2 is significant in both subjects $F(1,28)=794.73$, $p<0.023$. This result is in-line with our previous findings (Izzetoglu et al., 2007) and can be interpreted as a sign of relief where cognitive resources corresponding to voxel 2 become less active once the search task is complete. Therefore, voxel 2 seems to be highly associated with the search process.

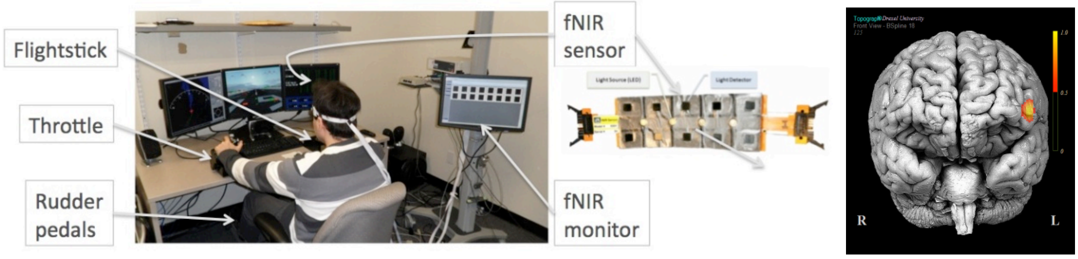

Figure 1: The Experimental Setup for the UAV study and the location of voxel 2

References

Cooke, N. J., Pringle, H., Pederson, H., Connor, O., & Salas, E. (2006). *Human Factors of Remotely Operated Vehicles*. The Netherlands: Elsevier.

de Jong, T., van Gog, T., Jenks, K., Manlove, S. et al. (2009). *Explorations in Learning and the Brain: On the Potential of Cognitive Neuroscience for Educational Science*. New York, NY: Springer.

Izzetoglu M, Bunce S, Izzetoglu K, Onaral B, Pourrezaei K, (2007). Functional Brain Imaging Using Near Infrared Technology for Cognitive Activity Assessment. *IEEE Engineering in Medicine and Biology Magazine, Special issue on the Role of Optical Imaging in Augmented Cognition, 26(4):*38-46.

Szucs, D. & Goswami, U. (2007). Educational Neuroscience: Defining a New Discipline for the Study of Mental Representations. *Mind, Brain, and Education, 1 (3)*, 114- 127.

Varma, S., Schwartz, D. L., & McCandliss, B. (2006). Is Neuroscience a Learning Science? In Barab, S. A., Hay, K. E., and Hickey, D. T. (Eds) *Proceedings of ICLS2006*. Bloomington, IN: LEA. pp 792-798.

Reasoning about the Seasons: Middle School Students' Use of Evidence in Explanations

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Abstract: This study examines the ways in which middle school students (N=39) approach problems which require scientific reasoning about seasonal change and how this relates to their overall improvement across the domain. Students' limited use of observable evidence in reasoning about observational astronomy concepts indicates the need for further instruction on scientific reasoning in this domain.

Introduction

Recent research syntheses, such as *Taking Science to School* (NRC, 2007), promote the importance of both understanding the challenges in changing children's conceptual frameworks but also in the importance of providing opportunities to further develop their abilities in scientific reasoning. Given that "scientific reasoning is intimately intertwined with conceptual knowledge" of natural phenomena imply that research must be designed to investigate this interplay within different disciplines (NRC, 2007, p. 129). This article examines students' use of evidence in explanations about the reasons for the seasons to assess how their growth in conceptual knowledge influences their reasoning strategies.

Theoretical Framework

We locate this study of children learning about the seasons in a learning progression framework. Learning progressions (LP) are hypothetical descriptions of how students understanding of big ideas in science become more sophisticated through targeted instruction across time (e.g. NRC, 2007). Big ideas hold broad explanatory power in the domain, make connections across isolated concepts, and are developed over time as learners understanding them in increasingly sophisticated ways (e.g. NRC, 2007). One of the central concepts of astronomy experienced by humans is the changing of the seasons; yet extensive research has shown the prevalence of alternative ideas about this conceptual area (e.g. Sharp, 1996) and the resistance learners have towards developing full understanding (e.g. Schneps & Sadler, 1988). The seasons, in itself is not a big idea but rather a manifestation of the more generalized concept of *celestial motion* that unifies this with other related concepts in astronomy (Plummer & Krajcik, 2010). We do not present a full learning progression, across multiple grade-bands in this study; rather we focus on aspect of the progression in more detail and the ways in which these connect to earlier conceptual development on the progression (Plummer & Slagle, 2009). Songer et al. (2009) have laid out the argument for integrating content and inquiry reasoning into learning progressions, rather than focusing on content alone. Their learning progression is developed around dual strands: the big ideas of *biodiversity* and *evidence-based explanations*. The results of this preliminary research on children reasoning about the seasons will allow us to take a critical first step towards developing an integrated learning progression hypothesis and plan for further instruction to test our theories in celestial motion. We are guided by following questions: 1. Do students provide explanations that make connections to evidence when reasoning about celestial motion and the season? 2. How does increased understanding of the content impact students' use of observable evidence when reasoning about the seasons?

Research Design

Participants were students in five of Lori Agan's 8th grade science classes (N=39). The 10-day curriculum was based on published curricula and teacher-created materials. The pre/post assessment consisted of six multiple-choice questions and seven open-responses questions. The open response questions were assigned codes for scoring. Inter-rater reliability for the pre and post open response questions for 15 students (38% of the set) was 94% (by scores) and 89% (by individual codes). Student responses to both the multiple-choice items and the open-ended prompts were aligned to levels on a 4-level scoring guide to examine change in understanding.

Results

The results of a paired samples t-test indicates that there was significant improvement from the pretest to the posttest ($t= -7.458$; $p<0.001$). However, only eight students (21%; compared to 1 student prior to instruction) were able to provide scientifically accurate responses (which did not also include alternative ideas) on at least 6 out of 7 seasons-concept questions. We present three cases in our analysis of students' reasoning about the seasons, from different levels of the learning progression. <u>First</u>, we analyzed student reasoning on a lower level of the learning progression: use of the earth's rotation. Students were given an image showing the sun's location and a pole casting its shadow in the morning; they were asked to draw the location of a shadow cast by a pole in the afternoon and then to explain this apparent motion. Table 1 shows the change in use of the earth's rotation and our examination of students' reasoning. After instruction, students were significantly less likely to make a clear connection between observation and explanation (students did not provide evidence or gave a reason that did not logically correspond to the evidence they presented). Second, Table 1 shows the results of Scenario A (temperature changes with latitude in water along Atlantic Coast) and Scenario B (temperature changes in water between summer and winter at a set location), where students were specifically prompted to reason with what they know about *light from the sun*. This type of reasoning is an important step in the progression towards scientific sophistication on the seasons (Plummer & Agan, 2010). Note that this analysis is not looking at scientifically accurate uses of light and explanations but rather how they attempt to reason in these situations (change in number of accurate responses is also reported in Table 1). Significant change was only found for understanding in Scenario A and increased use of explanation for Scenario B.

Table 1: Three cases of students connecting explanations with evidence in the seasons (N=39)

	Pre	Post
Earth's rotation - Accurate use to explain observations	14 (36%)	22 (56%)
Earth's rotation - Explanation logically corresponds to evidence***	39 (100%)	27 (69%)
Scenario A – Use of light	19 (49%)	21 (54%)
Scenario A – Explanation for change in light	12 (31%)	16 (41%)
Scenario A – Scientific response to question*	3 (8%)	11 (28%)
Scenario B - Use of light	13 (33%)	19 (49%)
Scenario B - Explanation for change in light*	3 (8%)	11 (28%)
Scenario B - Scientific response to question	9 (23%)	13 (33%)

X^2 test - $p<0.05$: *; $p<0.001$: ***

Discussion and Implications

Learning to explain the seasons involves the ability to explain observable evidence relating to patterns of change in sunlight with rotational and orbital motion of the earth on its tilted axis. Student responses indicate that additional guidance in using observational evidence will be necessary to advance their ability to reason scientifically about the seasons. First, students' attempts to reason about the earth's rotation suggests that because many students did not have a strong understanding of this concept initially, instruction on the tilt model may have "distracted" students from applying appropriate reasoning strategies. Students' difficulty in this lower level of sophistication on the learning progression may have inhibited progress in the more sophisticated levels (Plummer & Agan, 2010). Second, students showed some improvement in scientific knowledge of how changes in sunlight across the seasons and across locations on the earth affect seasonal temperature changes. But many students did not attempt to use sunlight to reason about changes in temperature or to attempt to explain changes in sunlight. In our poster, we will consider how instruction in this intervention may have supported some but not all students in moving forward in their reasoning about the seasons and the implications for future curriculum interventions and research. Our results suggest that successful instruction along the celestial motion progression will first support students in use of the earth's rotation on daily apparent motion; then provide students with experience in applying the observable seasonal change to temperature pattern; and finally support students in constructing explanations that use the tilt model in a way that uses reasoning between frames of reference. Without the observational knowledge, the use of the "tilt model" is meaningless.

References

National Research Council (2007). *Taking Science to School*. Duschl, R. Schweingruber, H. and Shouse, A. Eds. Washington, DC, National Academy Press.

Plummer, J. & Agan, L. (2010). Towards a Learning Progression Addressing the Seasons. *National Association for Research in Science Teaching*, March 21-24, Philadelphia, PA.

Plummer, J. & Krajcik, J. (2010). Building a Learning Progression for Celestial Motion: Elementary Levels from an Earth-Based Perspective. *Journal of Research in Science Teaching*.doi:726 10.1002/tea.20355

Plummer, J. & Slagle, C. (2009). Children Explaining Celestial Motion: Development of a Learning Progression. *National Association for Research in Science Teaching*, April 20, Garden Grove, CA.

Schneps, M.H. & Sadler, P. (1988). A private universe [Vido]. Pyramid Film and Video, http://learner.org.

Sharp, J. G. (1996). Children's astronomical beliefs: a preliminary study of Year 6 children in south-west England. *International Journal of Science Education*, 18(6): 685-712.

Songer, N., Kelcey, B., & Gotwals, A.W. (2009). How and when does complex reasoning occur? *Journal of Research in Science Teaching*, 46(6): 610-631.

Activating childhood expertise to engage with disciplinary concepts

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Abstract: Child experts in museums have demonstrated their ability to rehearse well organized dinosaur knowledge in conversation with their parents that distinguishes them from novice children and parents (Palmquist & Crowley, 2007). This study builds on research about parent-child learning conversations and considers the potential opportunities made possible when prior knowledge can be activated in museum exhibitions to support learning conversations that include ecological and evolutionary relationships.

Research on early childhood expertise has found that child experts distinguish themselves from novices in their ability to organize dinosaur knowledge, reason hierarchically, generate inferences about behaviors, and categorize novel dinosaur examples (Chi, Hutchinson, and Robin, 1989; Gobbo & Chi, 1986). The *islands of expertise* concept suggests that this level of childhood knowledge can emerge through the convergence of parent child activity and engagement with learning resources around a topic like dinosaurs (Crowley & Jacobs, 2002). Parents are often well positioned to provide explanations during conversations with their children across contexts that have the potential to support early science learning and the development of scientific literacy (Callanan & Jipson, 2001; Callanan & Oakes, 1992; Crowley et. al, 2001). Museums provide opportunities for intergenerational learning through conversation where children and adults are more equitably empowered to adopt the roles of knowledge presentation and reception (Hilke, 1989). Child experts in museums have demonstrated their ability to rehearse well organized dinosaur knowledge in conversation with their parents that distinguishes them from novice children and parents (Palmquist & Crowley, 2007). This study considered whether parents and children in a dinosaur exhibition could use islands of expertise as a knowledge resource to support learning conversations that include ecological and evolutionary relationships. This analysis describes patterns of parent-child learning conversations observed among expert and novice families and considers the implications for disciplinary engagement and the design of learning environments.

Research Context

The redesigned *Dinosaur in Their Time* exhibition highlights the Carnegie collection of Mesozoic fossils. Dinosaurs are displayed in ecological and temporal contexts that suggest a narrative of interactions that may have occurred between different species including pterosaurs, early mammals, and birds. The layout and design of the information mediation (printed labels, touch screen labels, videos, and murals) was intended to support conversations about ecological and evolutionary relationships.

Methods

A total of 50 families with children between the ages of 5-8 years old participated in this study. Target children included 30 boys and 20 girls with a mean age of 6 years, 9 months. A dinosaur knowledge assessment was completed by all children that measured ability to identify dinosaurs, familiarity with causal relationship between features and behaviors, awareness of extinction theories, familiarity with paleontology practices, and temporal relationships between dinosaurs. Parents and children completed a pre and post visit task in which they discussed images of the exhibition and were encouraged to engage with ecological and evolutionary themes.

Through a combination of emergent and deductive approaches, three coding categories were developed to explore patterns of topic and thematic engagement in parent-child conversations: object focused talk, ecology talk, and evolutionary talk. Object focused talk captured four types of conversations about the specimens and features of the exhibition. These include: identification, dinosaur comparisons, form & function, and affective talk. Ecology talk captured levels of connection between species that parents and children noticed and discussed. Evolution talk captured the themes of change over time and common ancestry.

Preliminary Findings

Novice and expert children and their families produced different patterns of learning during visits to this exhibition. Consistent with previous research, expert children consistently labeled species with their scientific names (both dinosaur and non dinosaur), made comparisons between dinosaurs, highlighted examples of form and function and often commented on their favorite species and features. Novice children also engaged in conversations across these categories but more often referred to dinosaurs through descriptive labels and followed the lead of their parents when they engaged in dinosaur comparisons and recognized form and function relationships between dinosaur features. Patterns of disciplinary talk captured by ecological and evolutionary coding categories suggested that experts and their parents engaged in more explanatory depth than novices.

Conclusions

This study builds on research about parent-child learning conversations and considers the potential opportunities made possible when prior knowledge can be activated in museum exhibitions. Examining how islands of expertise in a topic like dinosaurs might facilitate early engagement with disciplinary thinking and reasoning providesa model for exploring this kind of interest driven learning pathway across contexts.

References

Callanan, M. A., & Jipson, J. (2001). Explanatory conversations and young children's developing scientific literacy. In K. Crowley, C. D. Schunn, & T. Okada (Eds.), *Designing for science: Implications from everyday, classroom, and professional science*. Mahwah, NJ: Lawrence Erlbaum Associates.

Callanan, M. A., & Oakes, L. A. (1992). Preschoolers' questions and parent's explanations: Causal thinking in everyday activity. *Cognitive Development, 7*, 231-233.

Chi, M.T.H., Hutchinson, J. & Robin, A. F. (1989) How inferences about novel domain-related concepts can be constrained by structural knowledge. *Merrill-Palmer Quarterly* 35, 27-62.

Crowley, K., Callanan, M., Jipson, J., Galco, J., Topping, K., & Shrager, J. (2001). Shared scientific thinking in everyday parent-child activity. *Science Education,* 85*, 712-732.*

Crowley, K. & Jacobs, M. (2002). Islands of expertise and the development of family scientific literacy. In G. Leinhardt, K. Crowley, & K. Knutson (Eds.) *Learning conversations in museums* (pp. 333-356). Mahwah, NJ: Lawrence Erlbaum Associates.

Gobbo, C., & Chi, M. T. H. (1986). How knowledge is structured and used by expert and novice children. *Cognitive Development*, 1, 221-237

Palmquist, S. & Crowley, K. (2007). From teachers to testers: How parents talk to novice and expert children in a natural history museum. *Science Education*, 91(5), 783-804.

Facilitation, Teaching, and Assistance at the Intersection of the Learning Sciences and Informal Science Education

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Abstract: This poster focuses on approaches and strategies tied to pedagogy, facilitation, and assistance employed by members of the Informal Science Education (ISE) and Learning Sciences (LS) communities working toward informing understanding of teaching that accounts for the challenges and unique affordances particular to informal learning contexts.

Intersections

This poster is part of a collaborative effort[1] among Learning Sciences (LS) and Informal Science Education (ISE) researchers and practitioners. The authors discuss principles that apply across diverse settings compared to facilitation within constrained settings whose dimensions are more easily described, how "good" pedagogy outside of schools may be defined, what informal facilitator content knowledge might look like, and productive researcher/practitioner partnerships that can help advance practice, using four research studies as examples that characterize the application of these principles.

Research Studies

Study #1: Sharing spaces: Examining the continuum of self-managed and community-managed learning and engagement in informal science environments

As state and federal agencies in the U.S. increase their commitment to informal science, technology, engineering, and math (STEM) learning, the role of outreach in STEM learning has come under increasing scrutiny. LS approaches, including design experimentation, can highlight important aspects of the interplay between self-managed learning and community-managed learning in STEM outreach programs. However, it is important to highlight the effect that stakeholder involvement in STEM outreach has on participants' experiences, not only concerning STEM content learning, but regarding overall satisfaction with the outreach experience, including outcomes that may not be considered central to learning sciences approaches to STEM learning. Questions addressed by this study include: How is the viability of a design experimentation approach to improving STEM outreach affected by programs with an increasing numbers and kinds of stakeholders, including local, state, and federal agencies?; Does the nature of self-managed learning change when more (and more powerful) stakeholders are involved?; and Can we adapt best practices from both ends of the continuum despite the complexities and difficulties of meeting stakeholder interests?

Study #2: Nonformal Science Learning within a Framework of 4-H Positive Youth Development

This study focuses on pedagogical opportunities and challenges related to nonformal science learning within 4-H programs. 4-H programs are delivered through the extension offices of land-grant universities across the United States and serve over 6 million youth ages 8-18. In 2008, National 4-H announced a commitment to engage 1 million new youth within science, engineering and technology (SET). A recent report from year five of a longitudinal study by Lerner and colleagues (2009) found that 4-H youth are more than twice as likely as other youth to be in the highest trajectories of contribution to their communities and 41% lower on the risk behavior measure than youth who participated in other out-of-school activities. The study includes a review of abilities targeted within the 4-H program and how these are situated within the pedagogical structures of positive youth development. The analysis of abilities presented considers opportunities and challenges of nonformal science learning within the 4-H model and highlights affordances for learning in the interactions linking youth, adults and educative materials. Case examples are shared in domains of robotics, GIS/GPS mapping, alternative energy and veterinary science.

Study #3: Astronomical Concepts and Audience Self-Perceptions of Learning and Understanding

Researchers and informal science education practitioners can work together to identify research questions and design appropriate tools to measure and assess STEM learning, with learning defined as a process of knowledge acquisition that is constructive in nature. Understanding informal science learning and tapping into cognitive processes at play during informal educational programs is challenging because of space and time constraints, but it is known that even brief interactions have had demonstrated impacts (Dunlop, 2000; Sunal, 1973). This study focuses on informal science learning during 55-minute planetarium shows and audiences' acquisition of content knowledge, understanding of concepts, and visitors' perceptions of their own learning. Findings include that, in general, audiences tend to be overly optimistic in their self-reporting, and more specifically, while visitors wanted most to learn how to identify constellations, they felt that finding constellations was the hardest idea discussed. Implications for practice relative to identified correlations across demonstrated ability, self-perceptions, and demographic information, are discussed.

Study #4: Parent Pedagogy: Digging into Disciplinary Talk

Scientific practices such as observation are disciplinary specific rather than domain general in nature (Eberbach & Crowley, 2009), and this paper examines how parent disciplinary talk mediates family scientific observations of biological phenomena. In a controlled study, 79 parent-child pairs observed and talked about pollination during a visit to a botanical garden. In order to help parents elaborate upon children's observations, parents in the treatment groups were instructed in the use of four naturally occurring conversational strategies. To detect evidence of disciplinary talk, a Disciplinary Model that drew upon philosophy of science (Machamer, Darden, & Craver, 2000), disciplinary content, and emergent parent-child disciplinary talk was developed. The findings revealed that parents and children who knew more about pollination at the start of the study had higher levels of disciplinary talk in the garden, as expected. However, the use of the conversational strategies also increased the amount of disciplinary talk in the garden, independent of what families knew about pollination. In effect, the use of the four conversational strategies enabled parents to support more disciplinary talk whether they knew a lot or knew a little about pollination. These results provide new insights into how parent talk may support science learning in informal learning environments.

Importance of This Work

This work on pedagogy, facilitation, and assistance builds upon recent work that summarizes what we know about learning outside of school in science-related fields. The authors, both researchers and practitioners, apply what we know about teaching in informal science environments to the building of more inclusive models of STEM learning in the Learning Sciences and the connecting of methods of research and methods of informal learning practice.

Endnotes

(1) Collaborative Research: *Building Capacity and Collaboration at the Intersection of the Learning Sciences and Informal Science Education* (Intersection project); National Science Foundation ISE awards: 0813874 and 0814831. Sandra Toro Martell, Heather Toomey Zimmerman, and Leslie Rupert Herrenkohl lead the Intersection project. Opinions expressed do not necessarily reflect the National Science Foundation.

References

Dunlop, J. (2000). How children observe the Universe. *Publications of the Astronomical Society of Australia 17*, 194-206.

Eberbach, C. & Crowley, K. (2009). From everyday to scientific: How children learn to observe the biologist's world. *Review of Educational Research*, *79*(1), 39-68.

Lerner, R.M., Lerner, J.V., Phelps, E. and Colleagues (2009). Waves of the future: The first five years of the 4-H study of positive youth development. Medford:MA. Institute for Applied Research in Youth Development. Tufts University. http://ase.tufts.edu/iaryd/researchPositive4H.htm

Machamer, P., Darden, L., & Craver, C. F. (2000). Thinking about mechanisms. *Philosophy of Science, 67*(1), 1-25.

Sunal, D. W. (1973). The Planetarium in Education: An Experimental Study of the Attainment of Perceived Goals. Doctoral dissertation. University of Michigan.

Unpacking the Design Process in Design-based Research

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Abstract: Characterizing the design process is critical for design-based research as a research method. In this study, we propose that the design process of design-based research may be perceived as a dialogic process among four major design components—frameworks for learning, the affordances of the chosen instructional tools, domain knowledge presentation, and contextual limitations. It is essential for researchers to align these design components based on the frameworks for learning.

Developing Design-based Research as a Research Method

Designing and studying a learning context is an emerging method employed by many learning scientists in transforming learning practices with new approaches of learning. This method in studying how learning occurs in *designed* environments is often coined as design experiment (Brown, 1992; diSessa & Cobb, 2004), design research (Edelson, 2002), or design-based research (Barab & Squire, 2004).

As an emerging research method, design-based research has yet developed itself as a comprehensive research method like ethnography or case studies. Though there are some key features many design-based researchers would identify as core elements of design-based research, researchers have not reached general agreements on certain key constructs of design-based research, such as issues of validity, appropriate units of analysis, and the concept of context (Sandoval & Bell, 2004).

Examining the design-based research literature, we find that efforts in developing design-based research as a research methodology contribute mostly to (1) how theoretical constructs may inform design (e.g., diSessa & Cobb, 2004), (2) what the design-based research method may contribute to in terms of theory development (e.g., Edelson, 2002), and (3) how design-based research differs from other research approaches that investigate learning (e.g., Sandoval & Bell, 2004). Based on the research literature, we argue that the following features are key constructs for design-based research as a research method:

1. The design in design-based research is informed and guided by theoretical constructs of learning.
2. Design-based research engineers the learning context in order to transform current learning practice.
3. Design-based research studies learning in the *designed* context, which is also shaped by the local social-cultural-material environment.
4. Design-based research seeks to improve design and develop context-laden theories via iterative design and enactment.

Such broad strokes about design-based research not only help us identify the major research orientations toward developing design-based research as a method, but also help us articulate the missing pieces in the puzzle. In this puzzle, little has been argued about the design *process* through which a design-based research project takes shape. Arguments have been made mostly on the theories that inform design, designing and engineering the learning context, and the theories to be developed. Little, however, is theorized when it comes to the process that shapes design-based research. We maintain that the design process in a design-based research demands more attentions than it is currently receiving. Characterizing the design process constitutes an important step toward the development of design-based research as a research methodology.

Research Method

One way to explore how the design process may be characterized is to build cases along design challenges. Design challenges reflect the gaps unforeseen by researchers and issues hard to resolve using conventional methods. Situating the analytic primacy in design challenges provides a pragmatic approach in understanding a key aspect of the design process in design-based research.

We employ a method akin to participatory action research (Kemmis & McTaggart, 2000) to examine the design challenges of a game-based learning project *The Legends of Alkhimia,* an inquiry curriculum designed for secondary Chemistry in Singapore. To clarify what, when and how major design challenges turn into design decisions and curricular activities, we analyze the following data: (1) major design documents such as the game design narratives and flow charts, (2) finalized game products, and (3) a reflective account of the design process among key project participants.

Design of the Legends of Alkhimia Game

In a ten-day chemistry curriculum (20 hours), young people role-play as teams of four apprentice chemists to solve six levels of game challenges presented in the *Legends of Alkhimia* game. The game engage young people in cycles of scientific inquiry. In order to defeat monsters made of unknown substances, players propose hypotheses, conduct virtual experiments and test the effectiveness of their hypotheses and weapons in virtual combats. The scientific inquiry is situated in a personal narrative in which young people describe their experiences in the *Legends of Alkhimia* curriculum.

Findings and Discussion

Our efforts in unpacking the design process suggests four major design challenges in this game-based learning project: (1) conceptualizing theoretical constructs that informs learning, (2) reframing chemistry domain knowledge, (3) transforming theoretical constructs as game design features and curricular activities, and (4) situating curricular design in local school culture. The following describes how these challenges emerge in the design process.

We initiated the design process with the goal to transform the content-mastery learning paradigm with game-based learning approaches. Therefore, we asked what it means to learn and why learning chemistry is important to young people. Our questions eventually boiled down to the mantra "situating the inquiry of self in the inquiry of science." We drew from Dewey (1938) and scientific inquiry literature (White & Frederiksen, 1998) as our orienting frameworks for learning, but these frameworks do not inform game and activity design as directly as domain-specific instructional theories (diSessa & Cobb, 2004). The situation was further complicated by the need to rethink how chemistry might be learned without foregrounding chemistry contents. We classify the above challenges as "theoretical challenges" in design-based research. The other two major challenges fall into design category. Not only did we have to transform the orienting frameworks into concrete game and activity design decisions, but also situate the design decisions within the constraints of local school culture and curricular structure. We classify such challenges as "practical challenges."

The theoretical and practical challenges above are the major stumbling blocks in the design process of this design-based research project. To further thematize these design challenges, we conclude that a design-based research project aiming to transform learning with technologies requires appropriate alignment of four major design components: *frameworks for learning*, *the affordances of the chosen instructional tools*, *domain knowledge presentation*, and *contextual limitations*. In our design practice, these design components are deeply intertwined. Ideally, *frameworks for learning* is the core based on which the other components of design are aligned with in a dialogic process. In reality, however, the *contextual limitations*, such as the underlying culture and structure of schooling, often dominate the other design components.

Conclusion

In this paper, we argue that it is critical to unpack the design process in design-based research in order to develop design-based research as a research method for learning. This explorative study is our initial attempt at characterizing the design process in a game-based learning project. We maintain that depicting design process along design challenges affords researchers a beneficial way to unpack the design process in a design-based research. We present two types of challenges that emerge in the *Legends of Alkhimia* game-based learning project: theoretical challenges and practical challenges. Four core design components are derived from the design challenges. We believe that these are also core design components shared by many other design-based research projects. The success of a design-based research depends largely on the alignment of these core design components and it is critical to align the design based on the *frameworks of learning*.

References

Barab, S. A. & Squire, K. D. (2004). Design-based research: Putting a stake in the ground. *The Journal of Learning Sciences*, *13*(1), 1-14.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of Learning Sciences*, *2*(2), 141–178.

Dewey, J. (1938). *Logic: the theory of inquiry*. New York: Holt and Co.

diSessa, A. A., & Cobb, P. (2004). Ontological innovation and the role of theory in design experiments. *The Journal of Learning Sciences*, *13*(1), 77-103.

Edelson, D.C. (2002). Design research: What we learn when we engage in design. *The Journal of Learning Sciences, 11*(1), 105-121.

Kemmis, S., & McTaggart, R. (2000). Participatory action research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research* (2nd ed., pp. 567-605). Thousand Oaks, CA: Sage.

Sandoval, W. A. & Bell, P. (2004). Design-Based Research Methods for Studying Learning in Context: Introduction. *Educational Psychologist, 39*(4), 199–201.

White, B., & Frederiksen, J. (1998). Inquiry, Modeling, and Metacognition: Making Science Accessible to All Students. *Cognition and Instruction, 16*(1), 3-118.

Knowledge eCommons: Merging Computer Conferencing and Wikis

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Abstract: Asynchronous computer mediated conferencing (CMC) is widely employed as a medium for collaborative discourse in distance education courses. However, one frequently cited problem with CMC is the lack of coherence in many online discussions. To address this problem, we have developed a new technology called "Knowledge eCommons" that uses wiki functionality to provide representational guidance for online discourse. Our poster presentation describes the results of our initial Knowledge eCommons design experiments.

Introduction

Despite the tremendous promise of CMC, the educational benefits of online discourse are uncertain. While students in online courses frequently interact with one another and exchange information, there is little empirical evidence that they are engaged in the sophisticated processes of joint meaning-making and social negotiation (Wallace, 2003). In fact, conventional threaded discussions have been characterized as lacking coherence (Herring, 1999; Thomas, 2002), and are thought to offer relatively weak support for online collaborative knowledge construction (Hewitt, 2001; Suthers et al., 2008). Hewitt (2001) argues that the source of the coherence problem is the intrinsically divergent nature of threaded discourse. Over time, online discussions tend to branch into dozens of sub-discussions. It is not uncommon for participants to be engaged in many parallel conversations, not all of which are necessarily germane to the original purpose of the thread. While branching is often useful for drawing out a broad range of ideas and perspectives, the resulting lack of coherence makes it difficult to ascertain whether or not the group is making progress. Moreover, it is often unclear which direction the discourse is taking, what conclusions the group has reached, or whether particular issues warrant further inquiry.

A promising solution to the coherence problem involves augmenting conventional threaded discourse with a shared meta-level representation of the group's progress. For example, this might involve displaying an online discussion on one part of a computer screen, and a discussion summary on another part of the screen. As the discussion unfolds, the jointly-owned summary is updated. Shared, explicit representations of this sort are advantageous because they encourage participants to clarify their thinking, identify areas of disagreement, and help learner's monitor the group's growing understanding (Brna, Cox, & Good, 2001). Past efforts to provide representational guidance for CMC have used various discussion visualization tools as an adjunct technology (e.g., Reyes & Tchounikine, 2003; Suthers, 2003; Suthers et al., 2008). For example, in one experiment (Suthers et al., 2008), students were asked to continually update a group concept map as they engaged in online discussion with a partner. This produced promising results. In line with expectations, it was discovered that the small groups (dyads) who maintained a shared concept map during their discussion were more likely to converge to similar conclusions, and score higher on post-tests than dyads in the control condition (i.e., discussion-only). However, the authors of the study questioned the practicality of this approach with larger groups, or over longer periods of time.

Wiki Supports for the Synthesis of Ideas

The current study is also concerned with discourse coherence, but it approaches the problem from a new direction. Rather than use concept maps, we explore how wiki-style supports might provide representational guidance. Wikis offer several advantages in this regard. As the success of Wikipedia illustrates, wikis are useful technologies for creating complex, cohesive artifacts authored by many individuals (Wheeler, Yeomans, & Wheeler, 2008). The ability of wikis to support group coherence is grounded in three different design elements: 1) The existence of a single group-owned document that necessitates negotiation among participants; 2) The preservation of all previous versions of the group-owned document, which prevents the loss of data and permits backtracking; and 3) The provision of meta-level communication supports in which participants can identify problems, resolve disagreements and negotiate consensus. Since a wiki page is a single, jointly owned construct, it can serve as an up-to-date summary of the discussion that can guide further discursive activity.

Knowledge eCommons

The current program of research is being carried out using a new open-source learning environment called Knowledge eCommons (KeC), which has been specifically designed to investigate the coherence problem. While conventional threaded discourse environments are powerful for promoting a diversity of ideas, they tend to be weak at encouraging the collapsing of messages into one larger idea, or the creation of a collective summary. To address this shortcoming, KeC encourages the interplay between the expansion of ideas in the discussion mode and the synthesis of ideas in the wiki mode. To illustrate: In one of the current trials, graduate students discussed the educational potential of handheld computers in a KeC forum on the left side of the screen. As their discussion progressed, they periodically updated a wiki page summary on the right side of the screen. After some discussion, one of the students added a new sentence to the wiki page, "We still need to answer the big question, 'Do handhelds offer any advantages over laptops beyond cost? This inspired new discussion. This process continued to repeat, with an ongoing interplay between discussion messages on the left side of the screen, and summary statements and new ideas on the right side.

Method

We are currently conducting a series of design experiments (Brown, 1992) crafted to explore how to optimize the interplay between the idea expanding nature of the asynchronous discourse forum and the idea condensing nature of the wiki. Our first trial was conducted in an online graduate course in September-December 2009 (n=17). Our poster presentation will focus on this initial experiment. A second trial is currently underway. The online wiki pages, students interviews and a questionnaire serve as our primary data sources.

Results

The results of the initial trial suggest that the summary wiki page offers promise as a tool for representational guidance. The final wiki pages were judged to be excellent summaries of the course material. Interview data reveal that the high level of visibility associated with the wiki page's construction (i.e., people could easily see who made contributions, and the nature of those contributions) produced a heightened sense of accountability among students, which encouraged participation. However, some students felt that this visibility made people more reluctant to edit or delete the text of their classmates. Students were also cautious about making large-scale organizational changes to the wiki page, worrying that their actions might be viewed as presumptuous.

To move students beyond the construction of simple summaries, a number of scaffold labels were added to the wiki pages in December 2009. These scaffolds include: "Big ideas from this week", "Unresolved issues", "New ideas that move us ahead", and "What we don't understand yet". The goal of these scaffolds was to foster a deeper and more reflective collective analysis of the group's progress.

The full poster presentation will provide a more detailed account of the completed research and a demonstration of the Knowledge eCommons environment (if facilities for a demonstration are available).

References

Brna, P., Cox, R., & Good, J. (2001). Learning to think and communicate with diagrams: 14 questions to consider. *Artificial Intelligence Review, 15*(1–2), 115–134.

Brown, A.L. (1992) Design Experiments: Theoretical and methodological challenges in evaluating complex interventions in classroom settings. *The Journal of the Learning Sciences, 2*(2), 141-178.

Gunawardena, C.N., Lowe, C.A. and Anderson, T. (1997). Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing. *Journal of Educational Computing Research, 17*, 397 – 431.

Herring, S. C. (1999). Interactional coherence in CMC. Journal of Computer-Mediated Communication, 4(4). Retrieved on Sept 30, 2009 from http://www3.interscience.wiley.com/journal/120837770/abstract

Hewitt, J. (2001). Beyond threaded discourse. *International Journal of Educational Telecommunications, 7*(3), 207-221.

Kear, K. (2001). Following the thread in computer conferences. *Computers & Education, 37*, 81–99.

Reyes, P & Tchounikine, P. (2003). Supporting emergence of threaded learning conversations through augmenting interactional and sequential coherenence. In B. Wasson, S. Ludvigsen & U. Hoppe (Eds). *Designing for change* (pp. 83-92). The Netherlands: Kluwer Academic Publishers.

Suthers, D. (2003). Representational guidance for collaborative inquiry. In J. Andriessen, M. Baker & D. Suthers (Eds.) *Arguing to learn: Confronting cognitions in computer-supported learning environments* (pp. 27-46). AA Dordrecht, The Netherlands: Kluwer Academic Publishers.

Suthers, D. D., Vatrapu, R., Medina, R., Joseph, S., & Dwyer, N. (2008). Beyond Threaded Discussion: Representational Guidance in Asynchronous Collaborative Learning Environments. *Computers & Education 50*(4), 1103-1127.

Thomas, M. J. W. (2002). Learning within incoherent structures: the space of online discussion forums. *Journal of Computer Assisted Learning, 18*, 351-366.

Wallace, R. (2003). Online learning in higher education: A review of research on interactions among teachers and students. *Education, Communication & Information, 3*(2), 241-280.

Wheeler, S., Yeomans, P., & Wheeler, D. (2008). The good, the bad and the wiki: Evaluating student-generated content for collaborative learning. *British Journal of Educational Technology, 39*(6), 987-995.

21st Century Assessment: Redesigning to Optimize Learning

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Abstract: This poster presents design implications related to findings from research on the development of Interactive Learning Assessments (ILAs). Standardized assessments using multiple choice questions cannot measure the most critical aspects of learning for the 21st century. ILAs place students in advisory roles, leveraging a place-based metaphor to navigate, learn, then give counsel in situations in which they do not already know how to solve the problem; we assess how students learn to learn.

"I think it was because it's like it's a real thing, like genetic counseling is a real thing in the world and then if you know that what you're learning in class can actually help somebody it just gives you more of a reason to learn it."

Introduction

The above quote highlights the potential for successful integration of learning and assessment in the 21st century context. Rather than emphasizing facts and fragmenting the curriculum, students should see connections to their everyday and professional future selves. Preparing students for diverse and technologically demanding lives requires a substantively different skill set than has been traditionally in school curricula (Partnership for 21st Century Skills, 2002). Towards this goal, we have been designing assessments and related curriculum practices. Our work builds on theories of teaching, learning, transfer and assessment (Bransford, Brown, & Cocking, 2000; Bransford & Schwartz, 1999). While being assessed, students should have the opportunity not only to demonstrate what they already know, but also how prepared they are to learn in the future. Learning should pause while students are assessed. Though strides have been made with respect to teaching practices and the use of formative assessments to improve teaching and learning (Black & Wiliam, 1998), we envision major changes in *what* we assess. Most assessments emphasize factual knowledge rather than problem solving and thinking skills, or attempt to measure these skills in the absence of content, leaving out key elements of what is known about the development of expertise (e.g., Ericsson, 2006). Therefore, if the assessment of 21st century learning is to reveal and drive meaningful learning, it must be authentic and occur at the nexus of skills and content.

Learning Assessment Design Principles

With these issues in mind, we have engaged in design-research, iteratively designing Interactive Learning Assessments (ILAs). As an illustration, the learning assessment we designed for the domain of human genetics has three cases that relate to a common scenario, in which students assume the role of an intern genetic counselor (Svihla, et al., 2009). Each case involves a simulated meeting between the student-as-intern, a virtual mentor and client(s) seeking genetics counseling. Clients have authentic presenting circumstances—for example, in one case the clients, a Mr. and Mrs. Jones, wish to start a family but are concerned about the risk of their children inheriting sickle cell disease. To successfully counsel these virtual clients, students need to understand and be able to apply a set of core genetics concepts and skills and to communicate with their clients in ways that are professional and appropriate to the role of genetics counselor. Sickle cell disease was chosen because it is frequently included in high-school biology curricula and is sufficiently nuanced, providing many layers for exploration: inheritance, evolution, gene-environment interactions, protein structure-function, political policy and bioethics. Each of the cases is organized into three phases: *preparation*, in which students familiarize themselves with the case and conduct research prior to counseling their virtual clients; *formative assessment plus feedback* in which students interact with a virtual mentor to review their preparation, and as needed, further prepare for meeting their clients; and *performance and reflection*, in which students counsel their clients and reflect on their learning.

Findings from Design Cycles

Design cycles have been conducted in high school biology classrooms in a rural North Carolina community and in a suburban, high-SES Washington state community. Our research with this learning assessment shows that this approach provides a rich source of information about students' learning related to content and ability to synthesize across resources, especially as compared to traditional assessments (Gawel, Philips, et al., 2008; Gawel, Phillips, Svihla, Vye, & Bransford, 2008; Svihla, et al., 2009). Teachers appreciated that it changed their perspective of how they interacted with students.

Although pleased with aspects of the design, classroom iterations highlighted redesign opportunities, presented in Table 1. The most significant change involved moving from linear, programmed instruction to a place-based metaphor, which provides virtual locations for types of activities and allows the student to make decisions about when she or he is prepared to counsel clients. The place-based metaphor includes the *Lobby*, where students can learn about general aspects or get a new case, *Mentor's office*, where students can be mentored, an *Intern room*, where students can interact and give and get peer feedback, and a *Consultation room*, where students can answer questions from their virtual clients. Also provided are tools to scaffold students in making effective and responsible use of internet resources, and for professional writing. This place-based metaphor requires that students take greater control of their learning, allowing assessment of metacognitive aspects in addition to contextualized problem solving.

Table 1. Emergent design needs and directions

Needs	**Design directions**
Students did not do initial research to prepare themselves to meet with their clients.	Provide more explicit scaffolding and expectations; Block access to client if student has not prepared; Show "final product" example to hint at scope of expectations.
Students did not use internet to revise answers.	Provide case report tool to scaffold writing; Include opportunity for peer review; Add bibliographic tool to store notes, rate reliability of sources, tag with key words, and cite sources.
Students didn't understand what an internship is.	Provide explicit introduction to what an internship is.
Students wanted to be told what to do.	Provide guidance that puts students in control, leveraging game-like atmosphere; Allow time for implementation dip.
Linear structure limited ability to assess students' judgments about their preparedness	Shift to place-based metaphor.
Teachers were uncertain about placement in curriculum.	Provide teacher guide showing options (e.g., as formative introduction or summative conclusion to a unit).

References

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education, 5*(1), 7-74.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How People Learn: Brain, Mind, Experience, and School. Expanded Edition.* Washington, D.C.: National Academy Press.

Bransford, J. D., & Schwartz, D. L. (1999). Rethinking Transfer: A Simple Proposal with Multiple Implications. *Review of Research in Education, 24*, 61-100.

Ericsson, K. A. (2006). *The Cambridge Handbook of Expertise and Expert Performance*: Cambridge University Press.

Gawel, D. J., Philips, J. L., Svihla, V., Vye, N. J., Brown, M., & Meyers, E. (2008). *New approaches to 21st century schooling: Preparation for future learning assessments and their instructional implications.* Paper presented at the CAESL 2008: International Conference on Assessment for Learning in Science, San Francisco, CA.

Gawel, D. J., Phillips, R., Svihla, V., Vye, N. J., & Bransford, J. D. (2008). *Considerations for the development of a Preparation for Future Learning Assessment.* Paper presented at the ICLS, Utrecht, Netherlands.

Partnership for 21st Century Skills (2002). *Learning for the 21st Century: a Report and Mile Guide for 21st Century Skills*.

Svihla, V., Vye, N. J., Brown, M., Phillips, R., Gawel, D. J., & Bransford, J. D. (2009). Interactive Learning Assessments for the 21st Century *Education Canada.*

Development of Engineering Design Modules for Middle School Students: Design principles and Some initial Results

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This paper reports on the initial development of a program that uses engineering design challenges with middle school students to facilitate STEM learning and interest. We present the goals and design features of the modules and compare them to other successful approaches. We also present data showing differences in how students who worked with the modules perceive engineering. The results are discussed as they relate to the continued successful design and development of the modules.

Major issues Addressed

Education in science, technology, engineering, and mathematics (STEM fields) is often discussed as important to economic growth. The project described here emerged from such a community concern for workforce development in a medium size city. The work was spearheaded by the local education foundation. Before the foundation began its work, the focus on engineering was initially was sparked by a high school that developed an engineering themed curriculum to boost enrollment. The foundation started by developing engineering clubs and camps for elementary school students. Then the project moved into middle schools to help build opportunities for theses students. Along with this expansion has come funding to pursue further design and development.

The centerpiece of the project is a set of modules that use engineering design challenges. Students work on these design challenges each quarter during their middle school years. The goal of the modules is provide students with experiences that help them learn and motivate their interests in STEM. There are many potential benefits to the design challenges that suggest that they may enhance STEM learning and motivation. First, they provide a meaningful context for learning of science and mathematics. Second, given that the challenges involve meaningful applications, students are more likely to see the value of math and science. Third, students often have misconceptions about how engineers work. Practice working in collaborative groups to solve engineering problems provides a context that mimics the actual practice of engineers and may reduce student misconceptions.

Potential significance of the work

While in the past engineering challenges have been used in k-12, most of the time they have not been required in the curriculum (Brophy, Klein, Portsmore, & Rogers, 2008). So, one potential significance element is that the project involves the design of engineering challenges for all students. A second significant element is that the modules involve work in both mathematics and science classes. Thus, as we study the modules, we can potentially learn about how to integrate these engineering related themes across the two content domains. A third significant element of this project is that the modules are being developed so that students get a glimpse of the communities of practice of engineers. Finally, a fourth significant element is that the long term goal of this project is motivation and interest in STEM fields, not just student learning that occurs in the modules. Thus, there are potential insights that might be gleaned concerning the building long-term motivation and interest.

Theoretical Approach

As the modules are being designed and revised we are using elements of design from anchored instruction (CTGV, 1997), Learning by Design (Kolodner, et al., 2003), and the How People Learn Model to guide our work (Bransford, Brown, & Cocking 1999). Also, since one of our goals is motivational, we also are designing the modules with theories of interest and motivation in mind (e.g., Hidi & Harackiewicz, 2000). Our goal is to explore how we can develop and improve modules from these existing models.

Methodological Approach

The project is designed to examine both the development of the modules, and outcomes for students, teachers, and parents. For this poster, we focus on two different elements. First, we report quantitative data showing differences in student perceptions of engineering from the school that was used to develop the preliminary versions of the modules. Second, we analyze the currently designed modules in light of classroom observations, and through comparing them to other successful programs.

Major Findings and Conclusions

First, in analyzing the modules in comparison to other initiatives, we learned that our modules are not as thematically tight nor are the units as long as those of other programs. The concepts covered across the different challenges involve different types of engineering and different aspects of science, and typically do not last more than one week or two. However, they all have the in common idea of designing something in a collaborative group to solve a problem. The diversity of topics is intentional. First it was done to fit within current math and science standards (the modules were meant to enhance not replace the curriculum). Second it was done to provide students with evidence of the diversity within fields of engineering. Third, an important element of design for the modules is that the modules are set up so that the work takes place in science and math class. We believe that this feature has potential for helping students recognize the value of mathematics. If they just worked in science class they might not as easily see the importance of mathematics to these challenges. An initial analysis of a videotape of the implementation of the first module suggests that one issue that needs to be considered is whether the math class involves a continuation of the design process or whether the goal of activities in math class is to expand the concepts and facilitate transfer. For example, in a wind-turbine module, the science part of the activity involved working in groups to design and test the turbines, whereas the mathematics part of the activity involved working with a computer-based simulation of wind turbines. The teacher reviewed turbine concepts, and then the students and the teacher filled out a worksheet that asked students to make estimates from graphs, fill in charts, and do other calculations.

An additional feature of this project is that it has a strong community–based focus. We use the community focus in ways suggested by Bransford et al. (1999). First, engineers in the community have volunteered to help with the modules and visit classrooms. For example, an aerospace engineer was present for part of the wind turbine challenge. He told the students about his career and helped the students work on developing their turbines. Hence, there is involvement of the professional community in supporting the work. Second, the issues addressed by the modules are ones that are important to the community. For example, the community is located along a coastal area so a soil erosion challenge was built. Third, there is a pathway to continuing the emphasis on STEM fields in specialty high schools.

Finally, as noted earlier, an important element to the modules is an emphasis on the design process each time students engage in working on a module. The "design" rituals are reinforced and time is taken to help them focus on how the design process is present throughout the modules. This focus on the design process along with the connection to engineers of different types from the community provides students who work on the modules the opportunity to learn that engineering is a collaborative process. Part of the data for the project involves examining ideas students have about engineering. We asked students whether they agreed, disagreed, or did not know about statements concerning what engineers do. Students from the school that worked on the modules were more likely to believe that engineers mainly worked with other people to solve problems, were more likely to believe that engineers designed things that helped the world, and were more likely to know that engineers can choose different kinds of jobs than students from a matched comparison school. They were more likely to disagree with the statement, "engineers work on things that have nothing to do with me." Hence, there is some initial evidence that the beliefs of students may be influenced by the modules.

References

Bransford, J. D., Cocking, R.R., & Brown, A.L. (1999). How people learn. Washington, DC: National Academies.

Brophy, S., Klein, S., Portsmore, M., & Roger, C. (2008). Advancing engineering in p-12 classrooms. *Journal of Engineering Education 97,* 369-387.

Cognition & Technology Group at Vanderbilt (1990). Anchored instruction and its relationship to situated cognition. Educational Researcher, 19 (5), 2-10.

Hidi, S., Harackiewicz, J. M. (2000). Motivating the Academically Unmotivated: A Critical Issue for the 21st Century. *Review of Educational Research 70*, 151-179

Kolodner, J. L., Camp, P.J., Crismond, D., Fasse, B., Gray, J., Holbrook, K., Puntambekar, S., & Ryan, M. (2003). Problem-based learning meets case-based reasoning in the middle-school science classroom: Putting learning by design into practice. *The Journal of the Learning Sciences*, *12,* 495-547.

Coordination and contextuality: Revealing the nature of emergent mathematical understanding by means of a clinical interview

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Abstract: Clinical interviews provide a rich source of data about the nature of student understanding. We use the "knowledge in pieces" (diSessa, 1993) epistemological framework to analyze a clinical interview of a sixth-grade student's knowledge of fraction equivalence. We focus on the coordination of his knowledge across representational contexts. Our analysis reveals a local understanding of "fraction as quantity" that we hypothesize could be leveraged in helping the student build a more coordinated understanding of fraction equivalence.

Introduction

In March of 2004, Deborah Loewenberg Ball conducted a public, ninety-minute clinical interview with one sixth-grade student, Brandon, at the first MSRI "Critical Issues in Mathematics Education" Workshop on Assessment. The purpose of the interview was to give a vivid demonstration of what clinical interviews reveal about student understanding. Over the course of 90 minutes, Ball and Brandon explored a variety of fraction concepts, using several different representational forms (e.g. area models, number lines, Hindu-Arabic notation, the physical activity of paper folding, and "real world" contexts). Schoenfeld's (2007) discussion of this interview illustrates the complex nature of what it means to learn and understand by highlighting various aspects of Brandon's emergent knowledge of fractions. In this poster, we develop a complementary line of analysis and explore what we can conclude about Brandon's understanding of fractions through the lens of a particular epistemological frame.

Theoretical perspective

The "knowledge in pieces" (KiP) epistemological framework starts from the assumption that it is productive to think about emergent knowledge of a domain as a complex system of diverse and loosely organized pieces (as opposed to an integrated, coherent system) (diSessa, 1993, 2004). Two central ideas of KiP are *coordination* and *contextuality*. One of the indications of deep conceptual understanding from this framework is "seeing" and coordinating relevant knowledge across a broad range of contexts. Furthermore, KiP highlights the productive role of prior knowledge in building deeper understandings of a domain.

Focus of inquiry

To illustrate the nature of our analysis, we share here a summary of one striking example of a "coordination issue" across three representational contexts in which he explores fraction equivalence: Hindu-arabic notation, area model, and number line. In order to get traction on why the lack of coordination across contexts is not salient to Brandon, we focus on the question of how Brandon attends to features of the representational forms and what this reveals about his understanding of fraction equivalence.

A summary of an exemplar preliminary analysis

Table 1: Contextuality and coordination in the case of Brandon's knowledge of fraction equivalence

Hindu-Arabic Notation Context	In the context of working with fraction notation, Ball asks Brandon if he can write another fraction for one-fourth. **Brandon writes down 2/8 as another fraction for 1/4** and explains "Umm, two-eights 'cause it takes four—it takes four two's to equal eight, so two would be 25 percent—or one-fourth."
Area Model Context	Later in the interview, Ball and Brandon are working together with area models. Ball asks Brandon to draw area models of 1/4 and 2/8. She then asks him which one he thinks is bigger. In this context, **Brandon answers that 1/4 is larger than 2/8** and reasons that it is the denominator alone that determines the size of a fraction: fourths are "bigger chunks" than eighths and so 1/4 is bigger than 2/8. This is despite having just constructed area models for 1/4 and 2/8 that suggest visually that 1/4 and 2/8 represent the same amount of shaded area. When Ball re-directs Brandon to the fraction notation context and his previous assertion, **Brandon sees no conflict with his previous assertion that 2/8 is another fraction for 1/4 and his new assertion that 1/4 is greater than 2/8.**
Number	After Ball and Brandon finish discussing area models, they turn to working on fraction

Line Context	equivalence using number lines. Brandon has labeled 1/4 and 2/8 at the same position on a number line. **In this context, Brandon again concludes that 1/4 is greater than 2/8** and reveals an understanding that is similar in nature to what he shows in the area model context. Specifically, he reasons that it is the length of the line segments that determine the size of the fraction: since fourths are longer segments than eighths, 1/4 is bigger than 2/8. This is despite having constructed a number line on which 1/4 and 2/8 label the same position that suggests visually that 1/4 and 2/8 represent the same distance from zero. When Ball re-directs Brandon to the location of 1/4 and 2/8 on the number line, **Brandon sees no conflict with the noticing that 1/4 and 2/8 label the same position on the number line juxtaposed with his statement that 1/4 is greater than 2/8.**

Discussion

In this poster, we used the "knowledge in pieces" epistemological perspective to frame the phenomenon of a student reasoning about fraction equivalence across a range of representational contexts. In the example discussed above, we see that Brandon has different ways of comparing fractions and determining "sameness" across the different representational contexts. When he works with area models and number lines, he cues up a rule involving the denominator in order to compare fractions. He can specify the logic of his rule locally in terms of features of the representational form at hand (i.e. chunks of pieces or lengths of segments).

We hypothesize that in order to understand equivalence of fractions, Brandon must first develop a coordinated understanding of fractions as quantities. That is, he must come to see a fraction as a relationship between the numerator and denominator that represents an amount (Mack, 1990). When reasoning about fraction equivalence, "quantity" is not salient to Brandon in his interpretations of area model and number line representations. Without recognizing fractions as quantities, it makes little sense to ask whether two fractions are equivalent or whether one fraction is bigger than another. We see resolving this issue as deeper than merely learning the conventions about how to properly express fractions as quantities in whatever representational system (number line, area model, etc) he is working with. We see the kernel of a "fraction as a quantity" understanding in his talk about the fraction notation 1/4 and 2/8 as both representing 25% of the whole. We hypothesize that this idea could be leveraged in helping Brandon build a more coordinated understanding of fraction equivalence.

Conclusions

The preliminary analysis discussed in this poster raises issues about how we interpret the nature of student reasoning revealed through clinical interviews. On one hand, probes across representational contexts can paint a complex picture of student understanding of mathematical ideas like equivalence of fractions. However, our analysis makes us aware that we cannot consider various representational forms as neutral windows into student thought about underlying mathematical ideas. Rather, expanding our focus to include the ways that students themselves understand the purpose of representation can help us give a more accurate characterization of how they understand underlying mathematical ideas.

References

Ball, D. & Peoples, B. (2007). Assessing a Student's Mathematical Knowledge by Way of Interview. In Alan H. Schoenfeld (Ed.) (2007). *Assessing mathematical proficiency.* Cambridge University Press. Streaming video available at http://www.msri.org/communications/vmath/VMathVideos/VideoInfo/2653/show_video

diSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and Instruction, 10* (2–3), 105–225; responses to commentary, 261–280.

diSessa, A. A. (2004). Contextuality and coordination in conceptual change. In E. Redish and M. Vicentini (eds.), *Proceedings of the International School of Physics "Enrico Fermi:" Research on physics education* (pp. 137-156). Amsterdam: ISO Press/Italian Physics Society.

Mack, N. (1990). Learning fractions with understanding: Building on informal knowledge. *Journal for Research in Mathematics Education, 21*, 16-32.

Schoenfeld, A. H. (2007). Reflections on an Assessment Interview: What a Close Look at Student Understanding Can Reveal. In Alan H. Schoenfeld (Ed.) (2007). *Assessing mathematical proficiency.* Cambridge University Press.

Student Progress in Understanding Energy Concepts in Photosynthesis using Interactive Visualizations

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Abstract: This study explores student progress in understanding energy flow in photosynthesis while studying a technology-enhanced inquiry science project using interactive visualizations. Eight classes of 7th grade students (N=220) completed the project. Students generated narrative explanations and visual representations of their ideas. Students made significant gains in understanding of energy source, energy transformation, and energy transfer in photosynthesis.

Introduction

Although energy is a unifying concept across all science domains, it is often neglected in current science curricula (Van Huis & Van Der Berg, 1993; Solbes, Guisasola & Tarin, 2009). Energy has received little attention in photosynthesis instruction, although energy plays complex roles in this process. Learning about photosynthesis requires students to distinguish different forms of energy, understand how energy is transformed from one form to another, and explain how energy flows from place to place. However, science textbooks mainly focus on the mechanism of photosynthesis, such as reactants and products of photosynthesis. To help students build a coherent understanding of energy concepts in photosynthesis, we designed the photosynthesis project (1) for Cumulative Learning using Embedded Assessment Results (CLEAR), using the Web-based Inquiry Science Environment (WISE, Slotta & Linn, 2009). In this study, we explored student progress in understanding energy source, energy transformation, energy storage, and energy transfer in photosynthesis as a result of using the CLEAR project.

The CLEAR Photosynthesis Project

The CLEAR Photosynthesis project was created in partnership with 7th grade science teachers, discipline experts, and educational researchers. Teachers helped develop the activities and figure how to support cumulative learning over the middle school years. Using a series of powerful interactive visualizations developed by the first author, the project consists of three activities to help students understand how energy is involved in photosynthesis (see Figure 1). The first activity introduces the overall process of photosynthesis showing how the sun serves as the energy source for plants through animated instruction. The second activity teaches how light energy is converted into chemical energy in the chloroplast using animations and simulation. Students observe animations that visualize how light energy breaks up CO2 and H2O molecules and they combine as glucose. The third activity shows students how plants use the chemical energy produced in the chloroplast and how the energy is transferred to other animals in the form of food through virtual experiments. For example, students conduct virtual experiments to explore how the amount of light affects the plants' growth and draw conclusions from their investigations.

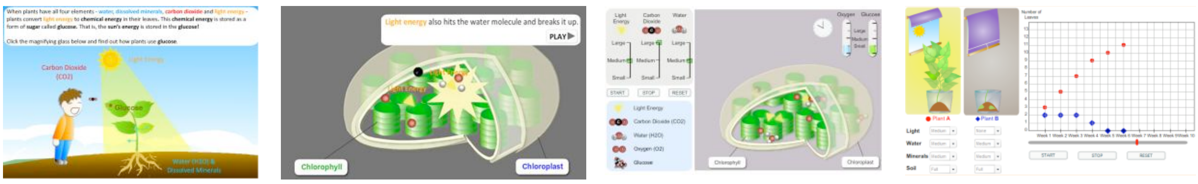

Figure 1. Examples of Interactive Visualizations Used in the Project

Assessments and Methods

The CLEAR Photosynthesis project developed new assessment types, Energy Stories and MySystem, to measure students' growing repertoire of energy ideas in photosynthesis. Energy Stories ask students to provide narrative explanations about how energy is involved in photosynthesis, and MySystem, a computer-based diagramming environment, asks students to visually relate energy concepts.

Seventh-grade students from eight classes (N=220) at a middle school completed the project. Before the project, students took the pretest that elicited students' initial ideas about energy in photosynthesis using Energy Stories and MySystem diagrams. After completing the project, students reflected on what they learned and responded to the posttest. New Knowledge Integration rubrics were developed to score the Energy Stories and MySystem. The rubrics have additional levels including full link (one scientifically valid link between ideas), complex link (two scientifically valid links), and advanced complex link (three or more scientifically valid links).

Results and Discussions

For energy stories, paired t-tests reveal significant gains from the pretest to the posttest (M = 3.96, SD = 1.12 pretest; M = 5.02, SD = 0.78 posttest), $t(219) = 10.26$, $p<.001$, $d = 1.10$). On the pretest 28% of the students presented disconnected or alternative ideas about how energy is involved in photosynthesis. For example, some students were confused about different forms of energy (e.g., the plant grows by the sun giving off chemical energy")) and where energy ends up (e.g., "the energy ends up in the soil"). 44% of the students provided one scientifically valid link between ideas, but most students' ideas were limited to the role of sun as the energy source. After completing the CLEAR project, students not only provided a more broad range of energy concepts, but they also made more scientifically valid links between these concepts and told a more coherent story. In particular, 73% of the students identified both the sun as being the energy source and how light energy is converted into glucose in their post-Energy Stories (e.g., "First, the plants get the energy to grow from the sun. Second the energy from the sun goes into the leaf and it starts photosynthesis. Thirdly the energy in the plant is turned into glucose using CO2, sunlight, and water to make glucose which feeds the plant").

Consistent with their learning gains in the Energy Stories, students demonstrated an improved visual representation of their understanding about energy flow in photosynthesis using MySystem diagrams (M = 3.41, SD = 0.96 pretest; M = 4.86, SD = 1.13 posttest), $t(109) = 14.71$, $p<.001$, $d = 1.38$). Students initially presented a variety of often isolated ideas related to energy flow generally without any valid connections (see Figure 2). However, on the posttest, students created a more integrated representation of how energy source, energy transformation, energy storage, and energy transfer are involved in photosynthesis. They also provided more detailed descriptions of what each arrow indicated in their MySystem diagrams.

These results demonstrate how a technology-enhanced inquiry curriculum can help students integrate their abstract science ideas and show potential advantages of explanatory narrative and visual representation as assessment tool to document student progress in understanding energy concepts.

(a) (b)

Figure 2. Knowledge Integration Scores of Energy Stories and My System (a) and MySystem Examples (b)

Conclusions

This study explores the progress students make in developing an integrated understanding of energy source, energy transformation, energy storage, and energy transfer around photosynthesis using the CLEAR curriculum. The findings from students' responses to Energy Stories and MySystem show that students made significant gains of their understanding in energy concepts from using the project. They also indicate that instruction using powerful visualizations can clarify energy flows and improve students' understanding of the complex roles of energy in science. Additionally, it is critical to align the instruction and assessment to emphasize energy concepts in science if the goal is to enhance students' understanding of energy ideas.

Endnotes

(1) Project URL: http://wise4.telscenter.org/webapp/previewprojectlist.html

References

Slotta, J., & Linn, M. C. (2009). *WISE Science: Web-Based Inquiry in the Classroom*. New York: Teachers College Press.

Solbes, J., Guisasola, J., & Tarin, F. (2009). Teaching Energy Conservation as a Unifying Principle in Physics. *Journal of Science Education and Technology, 18*(3), 265-274.

Van Huis, C., & Van Der Berg, E. (1993). Teaching energy: A systems approach. *Physics Education*, *28*, 146-153.

A Photograph-Based Measure of Students' Beliefs About Math

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Abstract: While there is some consensus on the importance of students' beliefs about mathematics, it can be difficult to measure those beliefs. Thirty-five sixth-graders and 54 undergraduates completed a photo sort task that required them to make judgments about the extent to which activities depicted in a series of photographs "involved math." Results show the measure had some desirable properties, thus providing a proof of concept for non-verbal, photograph-based measures of students' views of mathematics.

Introduction

Students' beliefs about what is and is not mathematical are associated with a number of important problem-solving and motivational outcomes (Muis, 2004). In particular, studies have shown that the belief that mathematics is largely computational and meaningless outside of the classroom context can be a significant barrier to flexibility in problem solving (e.g., Schoenfeld, 1991). Despite widespread interest in students' beliefs about mathematics, they can be difficult to assess properly. Hammer and Elby (2002) note that, in spite of evidence to the contrary, many researchers tacitly assume that students' beliefs are coherent and consistent across context and across time. This mistaken assumption can lead to an over-reliance on verbal measures of beliefs, such as surveys and questionnaires, which can misrepresent these beliefs. As such, new, non-verbal measures of students' beliefs about mathematics may be particularly valuable to the field.

This paper reports on an exploratory effort to develop such a measure. As a part of a broader design study looking at students' views of mathematics in and out of school, a photo sort task was developed to help assess students' views of mathematics. As Schwartz, Chang, and Martin (2008) note, one of the most important contributions that design research can make is the development of new research instrumentation (i.e., measures) that can be shared with others. The photo sort task and its properties are the focus of the analysis here.

Method

Participants

Participants were 35 sixth-grade students (19 girls, 16 boys) from a diverse middle school in an urban area in California. Students participated as part of their math class. In addition, 54 undergraduates enrolled in an education course served as a comparison group.

Materials and Procedure

The photo sort task made use of a set of 25 photographs depicting everyday activities such as cooking, construction, dancing, and playing videogames (photos are available from the authors on request). Each student sorted the photographs into one of four categories based on whether they thought the activity "involved math": definitely math; probably math; probably not math; and definitely math. Students then categorized the photos based on their experience with the activities: things they had done themselves (personal experience), things they had not done but a family member had done (family experience), and things neither they nor a family member had done (no experience).

Following this initial photo sort, students completed a series of homework and in-class activities that gave them the opportunity to take their own photographs, share those photos with classmates, and participate in online and in-person discussions about what "counts" as mathematics. Students then completed a second set of ratings for the photo sort task.

In addition to the sixth-graders, a group of 54 undergraduates completed a modified version of the photo sort task. The instructions were the same, but they viewed digital projections of the photographs, rather than sorting physical prints. Their data served as an adult baseline.

Results

We present three pieces of evidence for the value of the photo sort task as a measure of students' beliefs about what "counts" as mathematical. First, sixth-grade students' ratings from the first and second photo sort were moderately highly correlated, $r = .62$. While this correlation is not as high as one would expect for a well-established measure, it is a reasonably good indication that students' responses were not random, but were related to an enduring underlying variable.

Second, students' ratings of activities were predicted by their experiences with those activities. There was a risk that a spurious association between experience and rating could arise from the choice of photographs (e.g., if photos showed only two activities, math class in school – high experience and high math – and writing novels – low experience and low math). To address this potential problem, we treated undergraduate data as an approximately normative guide to how mathematical each photograph was (results remain the same with or without this correction) . For each sixth-grade rating, we computed the deviation from the mean undergraduate rating for that photograph. For example, undergraduates rated the photograph of people playing chess as "probably math" and dancing as "probably not math." A sixth grader who rated both photographs as "probably not math" (as many did) would have deviation scores of -1 and 0, respectively, for those two items.

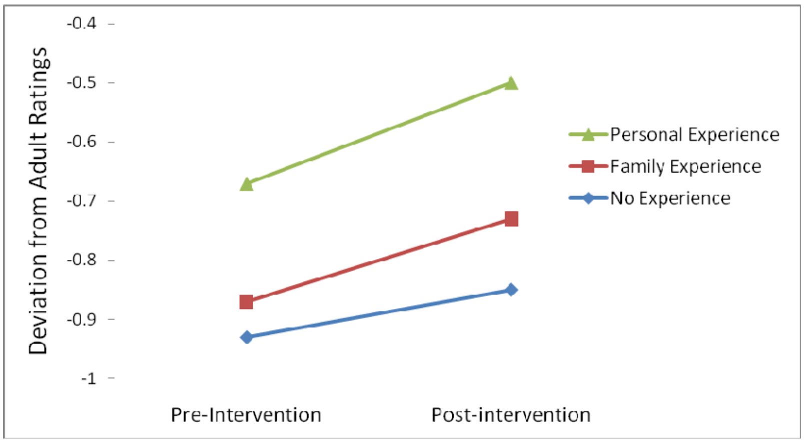

Figure 1. Sixth graders' deviation from adult ratings on the photo sort task.

We found that sixth-graders' personal experience with activities was predictive of their ratings for those activities. That is, students were the most adult-like in their ratings for activities with which they had personal experience, and the least adult like (and the least willing to call things mathematical) for activities with which they had little experience (see Figure 1). This result shows that the photo sort measure was sensitive, on an individual item level, to students' actual, real world experiences. Note that this improves upon measures of beliefs which treat them as independent of experience (Hammer & Elby, 2002).

Finally, as is evident in Figure 1, the measure was responsive to an intervention designed to have students reflect on the nature of what counts as mathematics in and out of school. Across all items, mean ratings increased about 0.15 points (about 0.4 standard deviations). The lack of control group requires caution in interpreting this result, as other factors may be responsible for the change. However, the change is in the anticipated direction, and it shows promise for the sensitivity of the measure to an intervention. Further analysis of the data will investigate the sensitivity of the measure at the individual item level.

Discussion and Conclusion

The photo sort task showed several promising properties. It was reasonably consistent from pre- to post-test, while still being responsive to an intervention. Most important, it was sensitive to students' real world experiences with the items depicted in the photographs. The analysis given here should not be taken to suggest that the photo sort task, as presented, should be widely adopted. Instead, the results provide a proof of concept that non-verbal, photograph-based tasks may provide a promising addition to researchers' arsenal of measures of students' beliefs about mathematics.

References

Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B.K. Hofer and P.R. Pintrich, (Eds.) *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 169 - 190). Mahwah, NJ: Erlbaum.

Muis, K. R. (2004). Personal epistemology and mathematics: A critical review and synthesis of research. *Review of Educational Research, 74*(3), 317-377.

Schoenfeld, A. H. (1991). On mathematics as sense-making: An informal attack on the unfortunate divorce of formal and informal mathematics. In J. F. Voss, & D. N. Perkins (Eds.), *Informal reasoning and education*. (pp. 311-343). Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Schwartz, D. L., Chang, J., & Martin, L. (2008). Innovation and instrumentation: Taking the turn to efficiency. In A. E. Kelly, R. A. Lesh, & J. Y. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching* (pp. 47-67). New York: Routledge.

Identity in Informal Game-based Learning Environments

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Abstract: In the learning sciences some scholarship investigating game-based learning environments has focused on studying large-scale identity transformations rather than describing the 'everyday' social processes. This paper investigates the specifics of the latter, arguing that relational identity resources may have be increasingly important for understanding identity formation and learning with games.

Introduction

'Identity' has become an increasingly important analytic construct in the learning sciences for understanding socio-technical learning practices. Learning is increasingly viewed as part a process of identity transformation – a change in the way a person recognizes herself relative to her mastery of a knowledgeable social practice (Wenger 1999).

In the learning sciences some scholarship has investigated the way that game-based learning environments help players take up new identities relative to a given knowledgeable practice (Barab et al., 2007). However, this scholarship has focused on studying large-scale identity transformations rather than describing the 'everyday' social processes that effect identity work. As part of a larger research project aimed at this end, this paper draws on methods from sociolinguistics to describe the micro-context of identity formation in game-based learning environments.

Theoretical Framework

This study utilizes both *interactionist* (Mead, 1934) and *sociocultural* perspectives on identity (Holland et al., 1998) that have arisen after it. Interactionist scholarship understands a person's identities and selves to develop primarily through interaction with and in the social world (Mead, 1934), and places import on how identity is negotiated through language. Sociocultural scholarship similarly emphasizes the dialogic and socially-enacted nature of identity, but distinguishes itself by emphasizing the importance of social resources in identity self-authorship (Holland et al., 1998).

Research Context & Method

This investigation grows out of a larger research initiative on game-based learning environments called *CivWorld*. Situated at an after-school center for adolescent working-class youth, CivWorld was a four year long research project that was focused on helping young people learn about history and geography (see Squire et al., 2008) using researcher-modified versions of the *Civilization* historical strategy game series. Data took the form of some two-hundred hours of program sessions that were audiovideo recorded along with supplemental field notes.

This investigation adopts tools of inquiry from *ethnographic discourse analysis*, a sociolinguistic method for studying how social identities are enacted through language and action over time (Gee & Green, 1998). After a thematic analysis of general content in the data corpus, both theoretical and representative sampling methods were used to select data so that the analysis would illuminate some larger research question while reflecting everyday activity in the space. The verbal data, transcribed in Jeffersonian notation, is presented in stanza form.

Results

Over the course of the analysis, it became evident that participants' identities relative to the CivWorld space were mediated as much by the club's structures for participation and relationships with other participants as they were by the game's semiotic system. Participants' trajectories of identity enactment in the space were very much dependent upon the social resources present during significant moments of identity work. Thes eries of interactions surrounding Salim one, a young newcomer who is the club illustrate this phenomena.

Example Interaction: Salim and Social Resources

Salim is an eight-year-old whose brother, Malik, age twelve, is a frequent and enthusiastic participant in the CivWorld club. Although he has frequently watched game sessions, Salim, who has a genial and deferential demeanor, has only played the game once some six weeks prior because he was intimidated by the typically older. As such, Salim is a very young and novice player of a game that can take hundreds of hours to master.

Salim has chosen to play in a competitive multiplayer game session - his second time playing the game – when his brother will arrive to the club late. Two more experienced players, Leo, age eleven, and Matt, age twelve, have secretly agreed to ally against Salim. They sit at the two computers to his right. Daniel, an adult, sits to Salim's left to help him with game play. At the start of game play, another sympathetic player attempts to trade to Salim in-game technologies, which might help him defend himself:

Daniel: The Persians wanna trade with you.

Salim: [Again?

Leo [turning]: DON'T DO IT!] NO! don't do it! >>don't do it! don't do it!<<

[Matt and Leo physically pull Salim away from his computer and whisper in his ear]

Salim [grinning]: [B-b-butt <Aaa.aaa.aaah.>

Daniel [smiling]: No coercion (.) only by talk (.)] no force.

During this exchange, Salim appears to relish the sudden attention and uninvited physical contact, rather than become upset by it. This attitude extended toward in-game play, where, with Daniel's constant advice and attention, Salim's non-aggressive civilization flourished despite the attempted in-game assaults by Leo and Matt. By the time his brother Malik arrives, Salim has by far the highest score in the game. Malik walks by Sami as he enters the room and greets a number of other participants, including Leo and Matt, with familiarity before turning to Sami's computer:

Malik: Who are you? You're <u>GREECE</u>? DAAAANG. See Salim? <u>see</u>? Good job Salim! <u>Good job!</u>

Salim became a regular and active participant in the CivWorld club over the next four months, and continued to participate frequently over the next three years. While his new interest in the game-based learning club cannot be attributed solely to his experiences that day, it certainly seemed to be a primary motivating factor. Salim seemed to enjoy the attention of older youth, even if it was hostile, and appeared to take great pleasure in his older brother's praise.

Discussion

Drawing on sociocultural research on identity (see Holland et al., 1998), Nasir & Cooks have recently argued that identity-linked social resources can be classified as *material*, *ideational* or *relational* – e.g. semiotic artifacts, cultural models or social relationships (2009). Learning sciences research has thus far placed primacy on the 'material' identity resources in game-based learning environments. By this I mean that researchers have emphasized the roles, values and dispositions for action that are 'designed into' the digital artifact for players to inhabit.

This analysis and evidence from other ongoing research suggests that the relational identity resources embedded in the social-discursive space of the game-based learning environment are important for understanding how identity formation takes place in these spaces. While the extent to which different types of social resources are leveraged in identity work is no doubt contextual, it seems that the relational identity resources may have be increasingly important for understanding identity in game-based learning environments.

References

Barab, S., Dodge, T., Thomas, M., Jackson, C., & Tuzun, H. (2007). Our designs and the social agendas they carry. *Journal of the Learning Sciences*, *16*(2), 263-305.

Gee, J., & Green, J. (1998). Discourse analysis, learning, and social practice: A methodological study. *Review of research in education*, *23*(1), 119-63.

Holland, D., Lachicotte,, W., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds.* Cambridge: Harvard University Press.

Mead, G. (1934). *Mind, self and society*. Chicago: University of Chicago Press.

Nasir, N., & Cooks, J. (2009). Becoming a Hurdler: How Learning Settings Afford Identities. *Anthropology &# 38; Education Quarterly*, *40*(1), 41-61.

Squire, K. D., DeVane, B., & Durga, S. (2008). Designing Centers of Expertise for Academic Learning Through Video Games. *Theory Into Practice*, *47*(3), 240-251.

Wenger, E. (1999). *Communities of Practice: Learning, Meaning, and Identity.* Cambridge: Cambridge University Press.

Exploring Intersections Between Online and Offline Affinity Space Participation

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Abstract: In order to examine the literacies involved with the digital media practices and affinity space involvement of a group of adolescent boys, multiple methods for data collection and analysis were adopted to supplement traditional case study methods. Longitudinal research crossing multiple sites from individual and group perspectives was essential to track development of literacies over time, and to mark the intersection of trajectories of interest-driven expertise development sparked by affinity space involvement individually and collectively.

Introduction

"New capitalism" (Gee, Hull &Lankshear, 1996) has caused many education-based tensions as workers at lower levels of the organization are being called upon for increasingly complex levels of critical thinking, decision making and higher levels of literacy skills, identified broadly as 21st century literacies. Today, unskilled positions have nearly disappeared and the modern workplace requires all students graduate from high school college ready, as the preponderance of jobs in the future will require at least some level of post secondary education incorporating broad based 21st century literacies, including traditional literacy areas (Wagner, 2008). Curtailing the trend of allowing boys, especially those from low income, minority and working class backgrounds, to opt out of literacy related activities has never been more urgent.

Research into boys' out of school literacies presents an optimistic picture of the kinds of literacy related activities they engage in using digital media. Affinity space involvement in conjunction with digital media offers a potentially rich area for the development of these productive practices. As Gee (2004) indicates, an affinity group is a space people congregate to share and forward a particular interest with participation ranging from *hanging out* to publishing artifacts, sharing knowledge or furthering the collective knowledge of the space. Participating in affinity spaces associated with massively multiplayer online games (MMOs) has been shown to host a veritable "constellation" of literacy practices (Steinkuehler, 2007), while also providing affiliation around interest driven learning (Hayes & King, 2009) immersed in popular culture. Supporting the development of broader 21st century literacies, other studies have highlighted the productivity of participatory culture (Jenkins, 1992), and affinity spaces associated with participating in online forums (Steinkuehler & Duncan, 2009) as well as writing and publishing fan fiction (Black, 2005) and taking part in "challenges" associated with The Sims games (Gee & Hayes, in-print).

Description of the Problem

While these studies have been useful in illuminating the kinds of affinity group practices "in the wild," (Hutchins, 1995), they focus on *visible* contributions published online. Unpublished practices of literacies shared between peers both online and offline have largely gone undetected. Therefore there is currently a somewhat limited picture of the kinds of literacy practices afforded by online participation, which omits discussion of the intersection between online and offline affinity group affiliation. This appears to be a relevant area to pursue especially concerning the literacy practices of males which, as research suggests is sparked by peer participation and shared as a social practice among the peer group (Newkirk, 2002).

Description and Discussion of the Research

My research is based on a longitudinal study (three years) of a racially mixed friendship group of eight teenage males from predominately working class backgrounds. Research was conducted in multiple locations in naturalistic face to face environments such as hanging out with friends, sleep overs and home settings, and online in settings such as in-game and hanging out on social networking sites. This was supplemented by activities in the *quasi-naturalistic* setting of the University of Wisconsin-Madison GLS Casual Learning Lab (see Steinkuehler & King, 2009 for program description). Data collection methods integrated participation in collaborative and parallel play, numerous interviews with participants and their parents, field notes from observations of individual and group play, survey administration and the collection of artifacts documenting literacy practices and digital media involvement.

Case study methodology (Stake, 1995) was effective for providing a basic framework for data collection and analysis however borrowing from other methodologies was essential (Steinkuehler, Black & Clinton, 2005). Incorporating methods associated with connective ethnography (Leander & McKim, 2003) to trace participation along trajectories of affinity space involvement and tease out cultural practices stemming from different affinity spaces ported into the friendship group provided necessary contextual underpinnings for understanding situated practices (Gee, 2004). Data analysis provided equally complex challenges and involved multiple perspectives as well. Being able to shift the lens of analysis from the individual to the group, as well as from specific incidents to group-enacted practice was essential. This was supported by a learning ecologies (Barron, 2006) framework to further explore trajectories of online involvement to illuminate patterns of affinity space involvement that seeded practices that were subsequently taken up or rejected by the friendship group. Adopting a phenomenological perspective to tease out how the boys learned to "be" experts in their game worlds (Thomas and Brown, 2009) and affinity spaces was also necessary in order to unpack how literacy practices impacted their online and offline identity. Adopting an orientation toward identifying and studying the development of individual areas of expertise, similar to Squire, DeVane & Durga (2008) as a way of identifying and tracking the dissemination of practices across the group was also beneficial.

Conclusion

The process of developing and adopting literacy practices across the group was a slow process marked by unanticipated activities, therefore a longitudinal study was essential to mark the dissemination of practices and knowledge over time. In addition, data collected from multiple settings, contexts and from both group and individual perspectives, online *and* offline appeared to provide a more complete picture of the breadth of literacy practices these boys engage in during the range of their affinity space involvement. Key challenges involved the continually evolving nature of the boys' gameplay as well as the complexities associated with collecting data from collective and parallel gaming practices both triggering the need for data analysis drawing upon multiple methods.

References

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development*, 49, 193-224.

Black, R.W. (2005). Online fan fiction: What technology and popular culture can teach us about writing and literacy instruction. *New Horizons for Learning Online Journal, XI* (2), Spring 2005.

Gee, J. P. (2004). *Situated Language and Learning: A Critique of Traditional Schooling*. New York: Routledge.

Gee, J. P., & Hayes, E.R. (in print). *Women and Gaming: The Sims and 21st Century Learning*. New York: Palgrave.

Gee, J. P., Hull, G. & Lankshear, C. (1996). The *New Work Order: Behind the Language of the New Capitalism*. Westview.

Hayes, E. R., & King, E. M. (2009). Not just a dollhouse: What the Sims2 can teach us about women's IT learning. *On the Horizon*, *17*(1), 60-69.

Hutchins, E. (1995). *Cognition in the Wild.* Cambridge MA: MIT Press.

Jenkins, H. (1992). *Textual Poachers: Television Fans and Participatory Culture*. New York: Routledge.

Leander, K. M., & McKim, K. K. (2003). Tracing the everyday 'sittings' of adolescents on the internet: A strategic adaptation of ethnography across online and offline spaces. *Education, Communication, Information, 3*(2), 211-240.

Newkirk, T. (2002). *Misreading Masculinity: Boys, Literacy and Popular Culture.* Portsmouth, NH: Heinemann.

Squire, K. D., DeVane, B., & Durga, S. (2008). Designing Centers of Expertise for Academic Learning Through Video Games. Theory Into Practice, 47(3), 240-251.

Stake, R. (1995). *The Art of Case Study Research.* Thousand Oaks, CA: Sage.

Steinkuehler, C. (2007). Massively multiplayer online gaming as a constellation of literacy practices. eLearning, 4(3), 297-318.

Steinkuehler, C. & Duncan, S. (2009). Informal scientific reasoning in online virtual worlds. *Journal of Science Education & Technology*, *17*(6), 530-543.

Steinkuehler, C., & King, E. M. (2009). Steinkuehler, C., & King, B. (2009). Digital literacies for the disengaged: Creating after school contexts to support boys' game-based literacy skills. *On the Horizon*, *17*(1), 47-59.

Steinkuehler, C. A., Black, R. W., & Clinton, K. A. (2005). Researching literacy as tool, place, and way of being. Reading Research Quarterly, 40(1), 7-12.

Thomas, D., & Brown, J. S. (2009). Why virtual worlds can matter. *International Journal of Learning and Media*, *1*(1), 37-49.

Wagner, T. (2008). *The Global Achievement Gap: Why Even Our Best Schools Don't Teach the New Survival Skills Our Children Need – And What We Can Do About It*. New York: Basic Books.

The Role of Explanations in Learning

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Abstract: This poster session brings together six perspectives on the role of explanations in learning. Each poster presents recent empirical and/or theoretical findings that address how, when or why explaining is beneficial for learning. This session will highlight the similarities and differences among how the term *explanation* is used in cognitive science, psychology, and science education with the aim of moving the field towards a better understanding of how explanations can support learning. By bringing together these researchers we aim to encourage communication around what constitutes an explanation and how the researchers from different communities are addressing similar issues, such as the nature of teacher's explanations, student's explanations, expert's explanations, and self-explanations and their role in learning.

Introduction

Explaining a phenomenon or why it occurs is viewed as a central element of science. Similarly, learning from scientific explanations is seen as an important goal of science education (National Research Council, 2007). A multi-disciplinary line of research from the science education community, cognitive psychology community and learning sciences community is interested in understanding the role of explanations in learning. In this symposium we bring together these different perspectives to highlight current research surrounding how and why explanations benefit learning, and identify similarities and differences among these approaches as to what constitutes an *explanation.*

Rationale

There is a great deal of evidence that the process of generating explanations can be beneficial to learning (e.g. Chi et al. 1994), and there is some evidence that explaining can promote conceptual change in young children (Amsterlaw & Wellman, 2006; Chi, 2000), but we do not know in detail how explaining helps learning (Lombrozo, 2006). Specifically we do not know what types of explanations are more or less beneficial for learning, what explanations look like in different disciplines, and what other factors might influence if and how explaining supports learning. This symposium has two main foci. First, we explore the relationship between the explanation and the type of learning being sought after, and second, we aim to identify variations within the term *explanation.*

The researchers in this symposium address the role of explanations in learning in a variety of ways. For example, one poster investigates how teachers' pedagogical content knowledge of scientific explanation and argumentation changes while they learn new practices in professional development. Another poster investigates the relative impact of explanation, exploration and observation on children's learning of underlying causal relationships and mechanisms. Across these posters there are differences in the populations being studied and how researchers operationalize *learning;* however, the common focus on explanations in learning will enable productive communication between the researchers from different perspectives, and should support a fruitful discussion with audience members.

Within the learning sciences community the term *explanation* is used in a variety of ways. The second goal of this symposium is to support a more precise understanding of the similarities and differences among these complementary perspectives. For example, one presenter views explanations as the "big ideas" or conceptual frameworks that are socially accepted by the professional science community, and aims to help students develop these kinds of complex understandings. Other posters view constructing explanations as a critical practice within the scientific community and present research that explores how both students and teachers develop epistemic understanding of scientific explanations. A poster from the cognitive science perspective builds upon the philosophy of science to view explaining as a constraint on learning that facilitates the interpretation of observations in terms of unifying patterns. One poster puts forth a comprehensive taxonomy of the possible components of a scientific explanation that can be used to characterize and better understand various types of novice and expert explanations (for a complete summary of posters, see Table 1). By bringing these perspectives together, we aim to encourage greater communication across fields and further our collective understanding of the nature and utility of explanations.

Table 1. Summaries of research focus, participants, and contributions for each poster.

Presenter	Focus	Participants	Research Contribution
Legare & Lombrozo	Compares self-explanation to exploration and attention	36 children aged 5 and 6	Explanations promote learning about mechanisms, but may have less benefit for memory of individual features
McNeill & Knight	Explores changes in teachers' pedagogical knowledge of scientific explanation and argumentation	24 grade 5-8 teachers	Teachers need to develop an awareness of the nature and importance of scientific explanation and argumentation as a key part of their pedagogical content knowledge
Sandoval et al.	Investigates relative influence of conceptual and epistemic understanding on biology students' ability to construct explanations	400 grade 6 and 7 students	Will clarify the degree to which conceptual knowledge and the understanding of epistemic requirements of a scientific explanation promotes learning
Williams & Lombrozo	Explores the effect of explanation on the ability to generalize to novel contexts	University undergraduates	Explaining constrains learners to interpret what they are learning in terms of general unifying patterns, driving the discovery of subtle generalizations that support transfer to novel problems and situations
White et al.	Presents a comprehensive taxonomy for the possible components of scientific explanations	Novice and expert explanations in physical and life science	Ability to characterize learners' existing and developing explanatory capabilities, as well as to characterize expert explanations that are generated by teachers and scientists
Zembal-Saul	Investigates how teachers' preparational experiences mediate their learning to teach science	Preservice K-5 teachers	Preservice teachers were able to adopt an increasing emphasis on evidence, explanation, and science content in addition to classroom discourse

Explanation as a guide to learning

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Although prior research with adolescents and adults has demonstrated that self-explanation benefits learning (Chi et al., 1994), little is known about the effect of self-explanation on learning in young children (but see Crowley & Siegler, 1999). The objective of the present study is to investigate the relationship between explanation and learning, and most importantly, to measure learning more directly by comparing self-explanation to other potential learning mechanisms such as exploration and attention. Does constructing a causal explanation benefit learning more than exploration or simple observation?

In order to test the differential effects of explanation on learning and to explore the relationship between explanation and learning experimentally we have constructed a novel problem-solving task that consists of a machine with five interlocking gears (see figure 1). When the gears are connected in the correct way a crank operates the machine and makes a fan turn. The three middle gears have peripheral pieces attached to them, which are used to differentially assess children's memory versus their understanding of the functional mechanism of the machine. Prior to participating in the test conditions children observe the intact machine. Using a between-subjects design, children will participate in one of four conditions: a control condition in which children attend to the machine but do not explain or explore (*attend condition*), exploration without constructing an explanation (*explore condition*), exploration after constructing an explanation (*explain plus explore condition*), and explanation without exploration (*explain condition*).

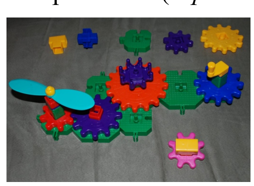

Figure 1. Gear machine. Shown with missing part and five candidate parts.

Following the experimental manipulation, children participate in three additional tasks. Two of the tasks are learning measures (presented first) followed by one procedural knowledge measure in which children are asked to reconstruct the machine. In each of the learning tasks the intact machine is presented to the child with one gear missing. In the *functional relationship learning task*, five candidate parts are presented to the child, none of which are identical to the missing part. The choices are: the correct size and shape but different color, a part of the correct shape but incorrect size, a part of the correct size but incorrect shape, a peripheral part they have seen before but is not the correct shape, and a distracter part. In the *memory learning task* another 5 candidate parts are presented to the child to assess the child's memory for the exact missing piece. All 5 pieces are the correct size and shape but only one is the same color as the missing piece. In each task the child is asked to select the part that will make the machine work. After completion of the learning tasks the machine is taken apart. All of the gears are removed from the base, and the peripheral parts are removed from the 3 middle gears. Participants are asked to reconstruct the machine in exactly the same way they saw it before and make it work.

Preliminary analyses with 32 children ages 5 to 6, in two key conditions, indicate that engaging in explanation leads to greater success in recreating the functional relationships within the machine (14 of 16 children) than simply attending to the machine (6 out of 16 children). Conversely, children who attend to the machine but do not engage in explanation are more successful in correctly matching peripheral parts to individual gears. Preliminary analyses also support a benefit for explaining in the learning measures. For the functional relationship learning measure only, children were more likely to select the correct functional part after engaging in explanation than merely attending, $t(31)=2.45$, $p<.05$. This suggests that explanation promotes learning about underlying causal relationships and mechanisms, but may have less of a benefit for memory of individual features. In sum, our data provide preliminary evidence that the process of constructing an explanation differentially promotes causal learning and suggest that explanation plays a role in young children's learning by highlighting functional and causal relationships and helping them integrate elements along a causal pathway.

The role of explanation in discovery and generalization: evidence from category learning

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A convergence of theory and data in education research, cognitive development, and cognitive psychology provides evidence for the significant role explanation plays in learning. Research in education (Chi et al, 1994) and cognitive development (Siegler, 2002) suggests that generating explanations drives the acquisition of knowledge that is retained in the long term and produces a depth of understanding that gives learners the basis to transfer and generalize to new situations. Explanation also plays a key role in theories of how conceptual knowledge is represented (Murphy & Medin, 1985) and explaining can even promote conceptual change in young children (Amsterlaw & Wellman, 2006).

Although explanation's effect on generalization is well-established in real-world contexts, less is known about the mechanisms that underlie explanation's privileged effect on generalization, possibly because of the complexity of these domains. We used three experiments on how people learn artificial categories in order to rigorously test a specific hypothesis: that explaining drives people to interpret what they are learning in terms of unifying patterns, which drives the discovery of underlying regularities that provide the basis to generalize. This hypothesis is motivated by theories in philosophy of science about what properties explanations possess, which we use to address a concern of this symposium: characterizing what explanations are in order to understand why they help learning.

Subsumption theories propose that explanations show how what is to be explained is an instance of a general pattern or regularity. *Unification* theories propose that explanations are better to the extent they account for diverse observations under a single pattern. These theories predict the privileged relationship between explanation and generalization: trying to construct explanations that satisfy the properties of subsumption and unification constrains learning, by driving learners to reason and form beliefs that allow them to interpret what they are learning in terms of unifying patterns. This drives the discovery of regularities that are present, producing exactly the kind of knowledge that supports generalization to novel contexts.

The basic design examined people's learning about a category when explaining, compared to the control conditions of describing, thinking aloud, and free study. Participants learned about two categories of alien robots, 'glorps' and 'drents', from 8 training items. The items' features (color, body shape, foot shape) supported two different generalizations about category membership: (1) the '75% rule', as 3 glorps and 1 drent had square bodies while 3 drents and 1 glorp had round bodies, or (2), the subtle '100% rule', as all glorps had pointy feet and all drents had flat feet- though each robot's feet were a unique shape. Participants were given a sheet displaying the 8 robots with category labels. The robots were also shown onscreen, and participants either *explained* why robots might belong to a category, *described* robots, *thought out loud*, or were allowed to engage in *free study*. Following study, the sheet was removed and participants categorized new robots that pitted the 75% rule against the 100% rule, received a memory test for the studied robots, and reported perceived differences between glorps and drents.

Relative to the control conditions of describing, thinking aloud, and free study, explaining promoted discovery of the subtle 100% foot rule, which supported generalization of category membership to new robots. Explaining exerted constraints that drove people to discover a regularity that provided a unified explanation for the membership of *all* items, as predicted by subsumption and unification accounts. Despite explanation's beneficial effects on discovery and generalization, describing resulted in better memory for item details and provided insights into what kind of information explaining is useful for learning. A coding of explanations and descriptions suggested that explaining might drive the generation of abstract hypotheses. Experiment 2 further suggested that explaining anomalies plays a role in promoting discovery and rejecting incorrect beliefs, compared to focusing attention on those anomalies.

By testing the predictions of theories of explanation, the experiments give insight into *why* and *how* explaining promotes generalization. They further suggest intriguing possibilities for future research: whether the subsumption and unification constraints of explanation may drive 'illusory' discovery. Speculatively, errors such as forming 'conspiracy theories' or stereotypes could be due to explaining small or unrepresentative samples of observations, which drives the induction of spurious patterns.

Teachers' Pedagogical Content Knowledge of Students' Science Writing and Talk

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The practice of science is not the uncovering of truth; rather, science is fundamentally about a community of scientists developing, debating and refining explanations through the use of evidence (Duschl, Schweingruber & Shouse, 2007). Implicit in this essential process are the scientific practices of explanation and argumentation. Developing an explanation in science focuses on how or why natural phenomena occur (Nagel, 1961). Constructing an argument includes both a social meaning, which focuses on debate between multiple individuals, and an individual meaning, which focuses on the argument product as a claim justified with evidence, warrants, and backing (Jiménez-Aleixandre & Erduran, 2008). Our goal is to combine these two practices to help teachers support their students in developing explanations about phenomena in which they debate and justify their claims with appropriate evidence and reasoning (McNeill, Lizotte, Krajcik & Marx, 2006).

Although recent research suggests the importance of these practices, teachers rarely engage students in explanation and argumentation in their own science classrooms (Newton, Driver, & Osborne, 1999). One reason for why this rarely occurs is teachers' lack of pedagogical strategies to support students in this complex practice (Zohar, 2008). Simon and her colleagues (2006) argue that for teachers to change their classroom practice they need professional development experiences that focus on teachers' existing understanding of evidence, explanation, and argumentation. We cannot expect teachers to incorporate explanation and argumentation into their classrooms if they do not have stronger understandings of these scientific inquiry practices (Zembal-Saul, 2009). Teachers require pedagogical content knowledge (PCK) for scientific inquiry practices or knowledge of how to teach students to engage in scientific inquiry practices (Davis & Krajcik, 2005). Yet there is currently little research in the field focused on teachers' understandings or teacher education in this area of scientific explanation and argumentation (Zohar, 2008). Consequently, our research looks to address the following research questions: 1) How does teachers' pedagogical content knowledge for scientific explanation and argumentation change while participating in professional development focused on this topic?

This study took place with twenty-four grade 5-8 teachers in a large urban district in New England. The teachers participated in a series of workshops over the span of four months. Multiple data sources were collected to evaluate teachers' initial pedagogical content knowledge as well as to determine whether or not that knowledge changed. Data sources included: pre and post surveys, videotapes of the professional development workshops, artifacts produced by the teachers, and samples of strong and weak student writing that the teachers brought to the workshops. The coding schemes for the data sources were developed from the theoretical framework and iterative analyses of the data (Miles & Huberman, 1994). Data sources were coded by two independent raters and all disagreements were resolved through discussion.

Preliminary analysis of the data suggests that the majority of teachers began the professional development with different understandings of what counts as high quality student writing compared to high quality student talk. On the pre-survey when teachers were asked to analyze samples of student writing, 67% of teachers included in their discussion whether or not the student was using evidence in their scientific explanations and 29% commented on students' reasoning for why their evidence supported their claim. This is in contrast to their discussion of the transcripts of student talk where only 48% of the teachers discussed the role of evidence and 15% discussed the students' reasoning. Rather, the teachers tended to focus more on the teachers' questions and comments in the transcript (59%) and student interactions (26%). This suggests the importance of supporting scientific explanations and argumentation as discourse practices that are not limited to one form of communication, but rather are essential to developing an effective science classroom culture. The final poster will explore how these and other aspects of the teachers' pedagogical content knowledge changed over the course of the workshops.

Toward an emphasis on evidence and explanation in K-5 science teaching

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In this work, scientific explanations can be likened to Roth's description of science content ideas (Roth et al., 2009). They are the "big ideas" accepted within the scientific community, which also serve as the intended outcomes of student learning. Engaging students in the discourse and practices of science is a means by which explanations are socially negotiated in school science.

The Framework for Teaching School Science as Argument (Zembal-Saul, 2009) leverages essential elements of inquiry (NRC, 2000), emphasizing evidence and argument in the development of scientific explanations (NRC, 2007). Three main components are fore-grounded in the framework: (1) using an argument structure to organize learning opportunities, navigate classroom discourse, and shape the science explanation; (2) reasoning publicly about the construction and evaluation of evidence-based claims; and (3) engaging authentically with the language of science. Guided by this framework, participation in investigations is not an end in itself, but rather provides the evidence for negotiating scientific explanations and making sense of science concepts. The aim is to be explicit and intentional about moving beyond activities in K-5 science teaching and toward co-constructing evidence-based explanations.

In recent years, argumentation in school science has gained support within the science education community (Driver, Newton & Osborne, 2000; Erduran & Jimenez-Aleixandre, 2008; Erduran, Simon & Osborne, 2004). This is due in part to the potential of argumentation practices to engage learners with the language of science and science learning (Mortimer & Scott, 2003), make thinking visible (Linn, 2000), and support an understanding of science concepts (Jimenez-Aleixandre, Rodriguez & Duschl, 2000). Some have suggested that arguing to learn may not be productive given how limitations in content knowledge constrain engagement with the task and quality argumentation (von Aufschnaiter et al., 2008). There is increasing evidence, however, that scaffolded argumentation can contribute to meaningful science learning (Andriessen, 2006; Clark & Sampson, 2007). Moreover, contemporary definitions of proficiency in K-8 science (NRC, 2007) identify the centrality of constructing, evaluating, and using scientific explanations, as well as participating in scientific discourse, including argumentation.

A fundamental strand of my research investigates the ways in which teacher preparation experiences informed by the argument framework mediate learning to teach science (Zembal-Saul, 2009, 2007, 2005). This poster will report on a small-scale study of five preservice elementary teachers' enrolled in their science methods course and concurrent field experience. The research questions underlying this work are: What is the nature of participants' initial science teaching? What do participants' self-analyses of teaching reveal about the ways in which they make sense of the framework? The primary sources of data were (1) video recorded science instruction of each participant, which consisted of three consecutive 45-50 minute lessons, and (2) video-based self-analyses of teaching, which consisted of 10-15 minutes of edited video with text captions justifying why particular clips were selected. The teaching events were coded using Studiocode® video analysis software, and event maps were constructed. Event maps provided a starting point for examining participants' self-analyses. Analytic categories were generated through examination of the teaching events and of the focus of preservice teachers' self-analyses. These categories helped identify the ways in which participants employed aspects of the argument framework to inform their initial science teaching, as well as how they used the framework to make sense of their practice. Results suggest that the ways in which preservice teachers think about the role of evidence in science teaching is critical for an appropriate emphasis on scientific explanations. Additionally, approaches to scientific discourse appear to be closely linked to preservice teachers' thinking about children's engagement in constructing explanations from evidence.

Disentangling conceptual and epistemic influences on scientific explanation

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Constructing a good scientific explanation would seem to require both a sound conceptual understanding of whatever is being explained and an understanding of the epistemic requirements of what makes an explanation good. The epistemic standards for a good scientific explanation have been refined historically in response to the issues that arise from not making conceptual claims and their warrants clear (Bazerman, 1988). This process of making one's claims and the evidence for them clear involves rhetorical moves aimed not just at making explanations persuasive, but comprehensible (Kitcher, 1991). For students then, learning to construct scientific explanations entails more than just learning the scientific theories and concepts that are relevant to explaining particular phenomena. It includes learning what counts as a good explanation and how to articulate one. It is not simply a cognitive skill (Kuhn & Udell, 2003; von Aufschnaiter, Erduran, Osborne, & Simon, 2008), but a complex discursive practice driven by epistemological motives that students often fail to appropriate in the science classroom (Berland & Reiser, 2009). The analysis of students' explanations of scientific phenomena, therefore, can illuminate both what students know about a particular topic – their conceptual understanding – and what they know about how to make a scientific explanation – their epistemic understanding. In practice, disentangling these influences simply by looking at students' explanations can be problematic (Kelly & Takao, 2002; Sandoval, 2003).

The study described here attempts to at least partially disentangle the influences of students' conceptual and epistemic understanding on their ability to construct good explanations for a complex question in biology. The study was conducted as part of a field test of curricular materials designed to support guided inquiry into topics of plant biology and evolution. The specific focal topics included photosynthesis, transpiration, structure-function relationships (in leaves), and evolutionary adaptation. More than 400 grade 6 and 7 students from a large, urban school district completed a three-week unit, *Why do plants look different?* The field test employed a pre-post design to measure learning of the focal topics. The capstone activity of the unit was students' investigation of remote sensing data to construct an explanation to the driving question. Analyses of the written explanations are based on a scheme that assesses three aspects of causal explanations: 1) conceptual quality; 2) degree of warrant for claims; and 3) rhetorical reference (Sandoval, 2005). That is, how well do students apply the conceptual ideas targeted in the unit to explain a complex problem; how well do they understand the epistemic criterion to have evidence for causal claims; and how well do they justify the relations between evidence and claims? These last two elements reflect students' appreciation of the epistemic demands of scientific explanation.

We pursue two questions in our analysis, which is currently underway. The first is whether or not students' prior knowledge, as measured by the pre-test, predicts their performance on the explanation task. We expect that prior knowledge should only affect scores of conceptual quality, if anything. If this expectation holds true, it would suggest students learning something important during the unit about the epistemic demands of explanation. If, on the other hand, all three aspects of explanation performance are predicted by pre-test score, it would support the claim that conceptual knowledge is what separates good explanations from bad. A second question we pursue is whether or not performance on the explanation task, particularly on the epistemic aspects of the task, predicts learning gains from the unit. If so, it would suggest that learning the epistemic demands of scientific explanation help to consolidate, at the very least, conceptual understanding when learning science. Whatever the specific outcomes of our analyses, they will clarify the influences of conceptual and epistemic understanding on students' efforts to construct, and learn from, scientific explanation.

Towards a Taxonomy of Explanations in Science Education

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One major goal of science education is for students to develop sophisticated explanations of the natural world (NRC, 2000). Scientists create and revise conceptual scientific models that they employ to develop and refine explanations. Scientists also have distinct forms and criteria for accepted explanations. Likewise, inquiry-based teaching enables students to ask questions, develop conceptual models and explanations, and critique and refine their explanations. However, students build upon existing, everyday ideas to make explanations that are different than those of scientists and judge explanations differently than the way that scientists judge them (Brewer, Chinn & Samarapungavan, 1998). Most existing approaches evaluate students' explanations along scientific criteria and overlook learners' existing ideas and skills in generating explanations. Instruction that encourages students to use, distinguish and refine these existing ideas can promote sophisticated and robust explanations (Linn & Eylon, 2006).

We aim to characterize learners' existing and developing explanatory capabilities by creating a taxonomy of explanations that builds from literature in psychology, cognitive science, philosophy of science, and science education. Existing definitions and operationalizations of scientific explanations tend to be specific to particular domains with widely varying grain sizes. We see students' explanations containing a variety of ideas and forms that cut across these existing taxonomies. For example, students may have naïve ideas about a scientific phenomenon yet use sophisticated deductive reasoning within their explanation. Students can provide insight into their understanding of causal mechanisms using narrative forms in explanations. A broad taxonomy of explanations that builds upon the diversity of expert and novice explanations can capture these varied types of ideas and reasoning. By doing so, a general taxonomy can identify the fruitful aspects of explaining that novices gain from everyday experience, as well as identify aspects of expert explanations that novices should develop. Ultimately, this taxonomy can guide curriculum and assessment development, and help students and teachers develop a meta-level understanding of what constitutes a good explanation.

This poster presents our taxonomy as developed from our review of the literature and refined through coding of student and expert explanations in various domains. Our taxonomy outlines general categories of purpose, form, content, characteristics, reasoning, and meta-talk. *Purpose* identifies causality and mechanism within the explanation. The *form* category captures the overall structure of the causal explanation, such as a causal chain or cyclical causality. *Content* distinguishes specific domain ideas used, such as laws or facts. *Characteristics* include attributes of explanations that have been identified as important in the literature, such as generalizability or varying perspectives. *Reasoning* captures the various forms of reasoning embedded within explanations, such as deductive or inductive reasoning. *Meta-talk* captures the explainer's higher-level knowledge about what makes a good explanation and what are good strategies for explaining, as well as regulatory awareness, such as monitoring of the effectiveness of an explanation. Our poster will present these categories in detail with data from expert and student explanations.

References

Amsterlaw, J., & Wellman, H. (2006). Theories of mind in transition: A microgenetic study of the development of false belief understanding. *Journal of Cognition and Development,* 7, 139–172.

Andriessen, J. (2006). Arguing to learn. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences.* Cambridge, NY: Cambridge University Press.

Bazerman, C. (1988). *Shaping written knowledge: The genre and activity of the experimental article in science*. Madison, WI: University of Wisconsin Press.

Berland, L. K, & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education, 93*, 26-55

Brewer, W. F., Chinn, C. A., & Samarapungavan, A. (1998). Explanation in scientists and children. *Minds and Machines, 8*, 119 – 136

Chi, M.T.H. (2000). Self-explaining: The dual processes of generating inferences and repairing mental models. In R. Glaser (Ed.), Advances in Instructional Psychology (pp. 161–237). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Chi, M. T. H., de Leeuw, N., Chiu, M.H., & LaVancher, C. (1994). Eliciting self-explanation improves understanding. *Cognitive Science*, 18, 439–477.

Clark, D. & Sampson, V. (2007). Personally-seeded discussions to scaffold online argumentation. *International Journal of Science Education, 29(3),* 253-278.

Crowley K. & Siegler, R. S. (1999) Explanation and generalization in young children's strategy learning. *Child Development,* 70, 2 pp. 304-316

Davis, E. A. & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational researcher, 34*(3), 3-14.

Driver, R. Newton, P. & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education.* 84, 287-312.

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (Eds.). (2007). *Taking science to school: Learning and teaching science in grades k-8.* Washington D.C.: National Academy Press.

Erduran, S., & Jiménez-Aleixandre, M. P. (Eds.). (2008). *Argumentation in science education: perspectives from classroom-based research*. Dordrecht: Springer.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulimin's argument pattern for studying science discourse. Science Education, 88(6), 915 – 933.

Jiménez-Aleixandre, M., Rodriguez, A., & Duschl, R. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. Science Education, 84(6), 757–792.

Jiménez-Aleixandre, M. P. & Erduran, S. (2008). Argumentation in science education: An Overview. In S. Erduran & M. P. Jimenez-Aleixandre (Eds.). *Argumentation in science education: Perspectives from classroom-based research*. (pp. 3-28), Dordrecht: Springer.
Kelly, G. J., & Takao, A. (2002). Epistemic levels in argument: an analysis of university oceanography students' use of evidence in writing. *Science Education, 86*, 314-342.
Kitcher, P. (1991). Persuasion. In M. Pera & W. R. Shea (Eds.), *Persuading science: the art of scientific rhetoric* (pp. 3-27). Canton, MA: Science History Publications.
Kuhn, D., & Udell, W. (2003). The development of argument sklls. *Child Development 74*(5), 1245-1260.
Linn, M. (2000). Designing the knowledge integration environment. International Journal of Science Education, 22(8), 781 – 796.
Linn, M. C., & Eylon, B. –S. (2006). Science education. In P. A. Alexander & P. H. Winne (Eds.) *Handbook of Educational Psychology*, *2nd edition.* Mahwah, NJ: Erlbaum.
Lombrozo, T. (2006). The structure and function of explanations. *Trends of Cognitive Sciences*, *10* (10), 464-470.
McNeill, K. L., Lizotte, D. J, Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences, 15*(2), 153-191.
Miles, M., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook (2nd edition).* Thousand Oaks, CA: Sage.
Mortimer, E., & Scott, P. (2003). Meaning making in secondary science classrooms. McGraw-Hill International.
Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological Review, 92,* 289-316.
Nagel, E. (1961). *The structure of science: Problems in the logic of science education.* New York, NY: Harcourt, Brace, & World, Inc.
National Research Council (2000). *Inquiry and the national science education standards.* Washington, D.C.: National Academy Press.
National Research Council (2007). *Taking science to school: Learning and teaching science in grades K-8.* Washington, D.C.: National Academy Press.
Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education*, 21(5), 553-576.
Roth, K., Chen, C., Lemmens, M., Garnier, H., Wickler, N., Atkins, L., Calabrese Barton, A., Roseman, J. Shouse, A. & Zembal-Saul, C. (2009). Coherence and science content storylines in science teaching: Evidence of neglect? Evidence of effect?
Sandoval, W. A. (2003). Conceptual and epistemic aspects of students' scientific explanations. *Journal of the Learning Sciences, 12*(1), 5-51.
Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education 89*(4), 634-656.
Siegler, R. S. (2002). Microgenetic studies of self-explanations. In N. Granott & J. Parziale (Eds.), *Microdevelopment: Transition processes in development and learning* (pp. 31-58). New York: Cambridge University.
Simon, S., Erduran, S. & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28*(2-3), 235-260.
von Aufschnaiter, C., Erduran, S., Osborne, J. & Simon, S. (2008). Arguing to learn and learning to argue: Case studies of how students' argumentation relates to their scientific knowledge. *Journal of Research in Science Teaching*, 45(1), 101-131.
Zembal-Saul, C. (2009). Learning to teach elementary school science as argument. *Science Education,* 93(4), 687-719.
Zohar, A. (2008). Science teacher education and professional development in argumentation. In S. Erduran & M. P. Jimenez-Aleixandre (Eds.). *Argumentation in science education: Perspectives from classroom-based research.* (pp. 245-268), Dordrecht: Springer.

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