A Blended Model for Knowledge Communities: Embedding Scaffolded Inquiry

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Abstract: This study investigates a new approach that connects scaffolded inquiry activities within a knowledge building curriculum in secondary school science. We present a blended model that accounts for the flow of ideas within such a curriculum. Using a co-design methodology, researchers collaborated with veteran secondary science teachers to create engaging curriculum that provided the context for two studies. Study 1 created a four-day biology lesson where 104 grade-ten students developed a knowledge base of ideas about human physiology, then connected those ideas to inquiry activities. Students and teachers succeeded in collaborative knowledge construction, and individual students demonstrated impressive learning gains. Study 2 extended these principles to create an eight-week curriculum unit on biodiversity. This study replicated the co-design process, resulting in a successful curriculum, and further refined our technology environment. The outcomes of this work offer promising evidence for a blended model where knowledge building intersects with scaffolded inquiry.

Introduction

For more than two decades, educational research has considered the notion of knowledge building, where students collaborate with their peers and teachers to develop a shared understanding of their learning goals and the process by which they will reach those goals (e.g., Brown, 1992; Brown & Campione, 1994; Brown & Palincsar, 1989). For example, in the research program called Fostering Community of Learners (FCL) Brown and Campione (1994, 1996) carefully choreographed an elementary classroom, selectively presenting materials to small groups of students with different areas of expertise so that the students and teachers within the classroom grew as a "knowledge community." Scardamalia & Bereiter (1991, 1992) have also investigated a knowledge building approach where students are given exclusive responsibility for the high-level processes of knowledge construction: generating new ideas, building on classmates' ideas, and synthesizing ideas into higher level concepts. Through this process, the student community comes to develop its own knowledge base, supporting individual students in the process of intentional learning, which ultimately supports their development as autonomous learners (Bereiter & Scardamalia, 2004).

However, despite the acclaim given to research approaches of knowledge building and knowledge communities (e.g., Bransford, Brown & Cocking, 2000), the theoretical ideas have made little progress and the instructional method has not been widely adopted by teachers. This is most notable at the secondary level, where teachers are faced with substantial content expectations and traditional assessments, and are thus reluctant to embrace the wholesale changes required to enact a knowledge community model. The knowledge building approach is not only challenging for teachers to enact, but it is also daunting for researchers, in part because of the need for an intensive and sustained collaboration with teachers and the resulting unpredictable, uncontrolled learning activities of students. Thus, the significant theoretical perspective of knowledge communities has suffered a lack of scientific progress, in part because of the challenging methodology that is required to research this theoretical view.

For the theoretical perspective of knowledge building to have a continuing, productive impact within the learning sciences, the ideas and methods must be accessible to researchers (i.e., the ideas must be available for their replication and extension). This paper introduces a new effort to extend the theoretical perspective and research method of knowledge building by integrating a dimension of scaffolded inquiry. The new blended model is applied within a secondary science context with the aim of engaging all students and teachers within a knowledge community while addressing specific science learning goals. The project employed a new technology environment to coordinate all knowledge building and inquiry activities, helping students contribute new knowledge, collaboratively edit their knowledge base, and retrieve knowledge as needed within the context of inquiry activities. The technology environment serves to scaffold the complex movements of people, materials and activities required by the research. Ultimately, the goal of this work is to further the theoretical perspective of knowledge building and enable a wider community of researchers and teachers to explore this important pedagogical approach.

Scaffolded inquiry

The notion of scaffolding was introduced to describe explicit supports provided by teachers or instructional materials that enable learners to achieve intellectual results that would otherwise fall beyond their capacity (Wood, Bruner & Ross, 1976; Palinscar & Brown, 1983). The term "scaffolded inquiry" now refers generally to any method where students are guided through activities and interactions by instructional materials and technology environments (Linn & Eylon, 2006; Linn, Husic, Slotta & Tinker, 2007). Within the scaffolded inquiry literature, complex patterns activities and groupings of students are often referred to as "scripts" (Dillenbourg & Tchounikine, 2007) in loose reference to theatrical scripts in which players and materials move about the stage. Researchers have investigated scripts such as reciprocal teaching (Palinscar & Brown, 1984), peer tutoring (Chi, Siler & Jeong, 2004) and collaborative reasoning (Anderson et al., 2001). The theoretical commitments underlying scaffolded inquiry research are essentially constructivist, concerned with how inquiry activities help students build on their existing ideas to develop a deep understanding of science topics through various kinds of interaction with tools, materials, peers and instructors (Linn & Eylon, 2006).

Scaffolded inquiry research often makes use of technology environments to coordinate the delivery of materials and provide cognitive and procedural guidance (Slotta & Linn, 2000). Such a method has been employed to investigate inquiry activities such as modeling (White & Frederickson, 1991), anchored instruction (Vanderbilt, 1993), personally relevant scenarios (Linn & Songer, 1982), scientific visualizations (Pea & Gomez, 1993; Edelson et al., 1999), argumentation (Bell, Davis & Linn, 1996; Linn & Hsi, 2000), and many other aspects of learning and reasoning. One example of such a technology environment is WISE, the Web-based Inquiry Science Environment (see http://wise.berkeley.edu). WISE was developed to scaffold students as they conduct technology-enhanced inquiry projects that include a variety of activities (e.g., viewing web sites, collecting data, debating arguments, holding online discussions, drawing concept maps). WISE also helps to scaffold teachers as they adopt such activities for their classrooms (Slotta, 2002, 2004).

Thus, unlike the theoretical domain of knowledge communities, that of scaffolded inquiry has received considerable attention from a large number of researchers. In part, the relative success of scaffolded inquiry methods is due to the fact that they are so accessible to researchers. Because of the range of possible approaches and inquiry models, learning scientists can easily embed theoretical ideas within a scaffolded inquiry framework. Research materials can be developed in advance of any classroom study by graduate students or other research assistants who work in partnership with teachers. The resulting curriculum and assessment materials are typically straightforward to enact in classrooms, with student responses providing ample data to serve as measures in the study. Thus, the broad domain of scaffolded inquiry has been scientifically productive because it is so accessible to the research community. Researchers can share their materials and technology environments, such as when several research labs adapted the WISE technology environment and curriculum materials for their own purposes (e.g., Kollar et al., 2004; Kollar, Fischer & Slotta, 2007; Gobert et al., 2002; Jorde & Mork, 2007).

Embedding scaffolded inquiry within a knowledge community: A blended model

The present work builds on more than a decade of research on inquiry science learning with particular emphasis on scaffolding technologies (Author, 2004, 2007). This work has been conducted with a number of different collaborators, and has addressed a variety of theoretical conjectures about inquiry. During this time, the notions of knowledge building and knowledge community have been compelling but elusive. Inspired largely by the work of Brown and Campione (1996) and Scardamalia and Bereiter (1989) we sought to expand on the scope of the learning context that is typically addressed by scaffolded inquiry. One of the most compelling notions was that a classroom of students might be thought of as a community of learners. However, achieving this vision is quite a challenge, and is one of the primary obstacles facing researchers who may want to adopt the methods of knowledge building. This is largely because the goal of helping a classroom of students come to identify as a learning community inherently includes the challenge of helping the teacher of that classroom embrace that same vision. However, the potential rewards in terms of rich, collaborative, authentic learning are profound. We were thus drawn to the idea of transforming a classroom into a learning community where students build upon one another's ideas and come to reinterpret the purpose of learning from one of individual consumption to one of collaborative growth.

While our program of research is still in its early stages, we recognize the importance of developing explicit models and representations of the complex inquiry processes that we will investigate. Figure 1 presents our first effort to capture the flow of knowledge and activities within a classroom in a blended model where knowledge building and scaffolded inquiry are combined in a complementary fashion. This model emerged from our efforts to develop an accessible knowledge building curriculum unit in an advanced secondary science program, working with an outstanding teacher. This teacher had attempted a knowledge building approach some years before and given up because it was not well suited to the high level of content coverage for which she was responsible. To paraphrase her initial comments, "I started to use the knowledge building method, but it takes so long to get the kids to generate any of the important ideas in my course, and they were frustrated because they didn't feel they had much guidance." Of course, one of the main objectives of knowledge building is for students to take responsibility for their own learning. However, in high school science, teachers must ensure that students come to understand major segments of theory (e.g., genetics, biodiversity, chemical equations) and it is very difficult to motivate all students in the classroom to efficiently pursue the understanding of such topics as a knowledge community. In secondary science instruction, teachers must generally feel that every class period is used efficiently and that students are engaged in learning relevant science topics. Any curriculum lesson or unit must be able to fit within a tight schedule of content coverage, with outcomes that are assessable by conventional measures.

It is important to note that any hybrid or blended approach that satisfies such requirements will probably not adhere to the strictest definition of knowledge building, although such definitions are not well specified in the literature. Our goal in this work is simply to move forward in our own theoretical description of knowledge communities, in hopes of eventually building connections to the broader theory in this domain. We began by articulating a basic model of how knowledge can be created collaboratively by students, with the resulting knowledge base made available within subsequent inquiry activities that in turn create new connected knowledge.

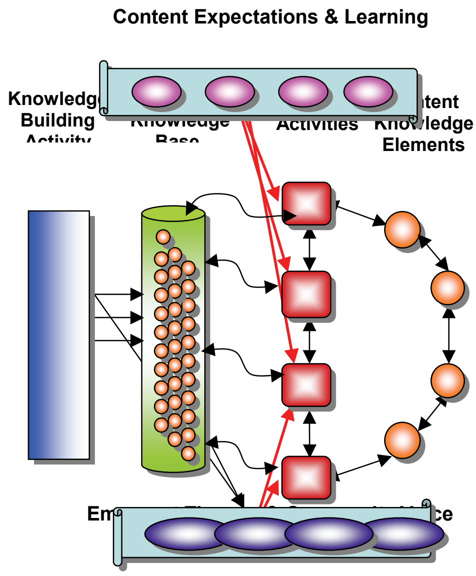


Figure 1. The flow of knowledge and activities within a classroom community.

The model begins with a knowledge-building activity (left side of Figure 1) where students explore and investigate their own ideas in the context of a broader knowledge building activity. The resulting knowledge elements (e.g., notes, wiki pages, files or discussion comments) are then aggregated into a "Community Knowledge Base." One of the essential features of knowledge building (Scardamalia & Bereiter, 1996) is that learning activities (e.g., inquiry-type investigations) must be guided by the community itself through the knowledge construction process. Common themes, challenges or interests should emerge, reflecting the "voice" of the community. The instructor must listen to this voice and respond by way of the kinds of activities presented to students. The model above acknowledges this critical juncture in the process, with the influence of "Emergent Themes and Community Voice," that feed into the design of the scaffolded inquiry (represented as "Scripted Activities"). However, in designing any inquiry activities, the instructor must also address the "Content Expectations and Learning Goals" of the curriculum. This is clearly not an easy task - designing inquiry activities that respond to the community interests while addressing the learning goals, all within the time-sensitive context of a specific curriculum unit. Students work independently or collaboratively in the scripted activities, drawing upon the knowledge elements from the community knowledge base, producing new contributions to that knowledge base as well as specific outcomes that serve as assessments of individual understanding.

Method

This model used in this research represents our ideas about how inquiry activities can be deeply interconnected with the processes and resources of a knowledge community approach. Of course, describing the process and actually creating such a learning community are two very different matters. In the following two sections, we describe two additional characteristics required for this research to succeed: i) a scaffolding technology environment to support students, teachers and researchers in all project activities; and ii) a co-design process to ensure that all materials designed for use in our partner school were ecologically valid and able to be implemented by teachers with no assistance from researchers. Following those sections, we describe two studies where the model was enacted in a curriculum where knowledge building was interconnected with scaffolded inquiry activities.

A scaffolding technology environment

This project employed a unique new technology infrastructure to support the design and delivery of all research materials, including the various scripted activities and knowledge building processes. This technology environment is based upon the Scalable Architecture for Interactive Learning (SAIL) – an open source framework developed over the past five years by a community of researchers and technologists in order to support the rapid development of tools and environments across the learning sciences. We participated in this vision, employing SAIL to develop a technology environment that supports various methods of knowledge building and many different tools and user interfaces for scaffolded inquiry activities.

To begin, researchers carefully designed the knowledge building environment, including customized knowledge entry forms that are accessed by students via the Web. A wiki provided the ideal functionality for knowledge building, as students could easily access and edit one another's ideas, reorganize pages in order to capture emerging themes, and build connections between related ideas. We created a new hybrid wiki environment that improved our control over student accounts, groups, editing permissions and other features. While we wanted to preserve the open-ended feeling of collaborative editing that typifies wikis, we needed a simple, structured way for students to create wiki pages so that we could scaffold their treatment of science concepts. We thus developed a capability of "New Page Scripts" that allowed students to simply click a link on a wiki page in order to add a new page – but instead of the usual "new wiki page" functionality, they are taken to a special Web form (implemented in the Ruby on Rails language). The Web form queries students about the name of their new page and collects metadata (using check boxes and radio buttons), then generates a new wiki page that is linked to the proper location, with pre-specified headers and all the relevant authoring and access permissions. This new method has greatly expanded the capability of wikis for use in our research. The wiki is one important layer within the broader technology environment, which includes a server and portal that coordinate all student accounts and a variety of java-based interactive inquiry tools. This rich infrastructure ensures that students always have a clear understanding of what to do, receiving scaffolding in the form of web pages or other technology scripts, and thus ensuring faithful adherence to the curriculum design.

A co-design community for curriculum, assessment and technology tools

It is challenging to design complex instructional materials that accurately embed a theoretical model while complementing a teacher's curriculum. The effectiveness of any classroom-based research will depend critically on the teacher's understanding and enactment of the materials and approaches. Technology environments can provide scaffolding, but a complex method such as knowledge building requires complete investment of the participating teachers. This can best be achieved through a process known as co-design (Roschelle, Penuel, & Schechtman, 2006) where all research materials and instructional designs are developed in close collaboration between researchers and teachers, with each group learning about the values and perspectives of the other. Working together, the co-design team creates materials that address the research questions as well as the teacher's learning goals (Peters & Slotta, 2007). The resulting curriculum is likely to be enacted faithfully by teachers, since they were essentially in charge of the design process. While this entails a more intensive process of ongoing design discussions and trade-offs, it does ensure that teachers accurately understand the research and that they firmly believe in all curriculum materials. One benefit of this approach is that the researcher can remain completely hands-off when it comes time to enact the designs, ensuring a high level of ecological validity (Roschelle et al., 2006). Finally, because the teacher's enactment is not likely to deviate from the design, we can be more confident that any measures (e.g., of student understanding) would truly reflect the underlying theoretical model (Slotta, 2007).

Two years prior to the work reported in this paper, we initiated a co-design community with a local partner school. This process required a considerable effort in the beginning, and expanded on an existing partnership with one of the science teachers in the school. We began meeting with the school principal and vice principal for curriculum, as well as the other science teachers in the department to discuss the prospect of establishing a long term curriculum planning community. We wrote a small grant proposal to help sustain the community, and introduced the process of co-design, as well as our blended model of knowledge building and how we might put it into practice within the school. This is one of the premier secondary science schools in Canada, with a reputation for excellent preparatory instruction. The excellent students, the creative and reflective teachers, and the supportive administration make this an ideal setting for an ongoing co-design partnership.

Study 1: Co-design of a knowledge building lesson

For three months, two teachers and two researchers co-designed a 4-day physiology lesson where students collectively built a knowledge base by creating wiki pages about human system diseases. The research began by conducting field visits to the school to learn about the practices that teachers were using in the classroom. For the next several months, the researchers and teachers participated in a series of design meetings where teachers learned about the theory and methodology of knowledge building and researchers learned about the values held by the teachers and the specific content requirements related to human physiology.

The study used both qualitative and quantitative methods to analyze the co-design process and the flow of ideas in the knowledge building activity. Data were drawn from: i) teacher and student interviews; ii) student contributions to the wiki and to the scaffolded activity; and iii) student scores on the physiology section of the final exam. Teacher interviews added to our understanding of the co-design process, and helped provide a measure of the success of the designs. Student interviews provided insight into learners' experiences and satisfaction with the lesson. Quantitative data from students' final exam scores were analyzed and compared against those from previous years to gauge differences in course achievement levels.

Participants

Participants included two veteran high school biology teachers and 104 grade ten students from an urban school in the Toronto metropolitan area. The students were distributed into four sections of an intermediate-level biology class (two sections per teacher). All 104 students worked as a community, collaboratively editing the wiki across all four periods. This unusual design led to a fascinating interplay between class periods, and helped to underscore the value of knowledge communities for everyone involved in this project.

Design

Students began by creating a wiki that covers human diseases of three different body systems (respiratory, digestive and circulatory), including the specific biological processes relating to the disease. Students created disease pages in the wiki using a special "New Page Script" where they were able to specify the metadata for the disease (see Figure 2). Students were free to create new disease pages or edit any existing disease page within their assigned body system. Thus, students became specialists in one body system and relied on their peers to adequately prepare the wiki materials for the other two systems. Students then performed a scripted activity where they applied their knowledge to create "challenge cases" for their peers where a fictitious person was described in terms of physical symptoms that required diagnosis (Figure 3).

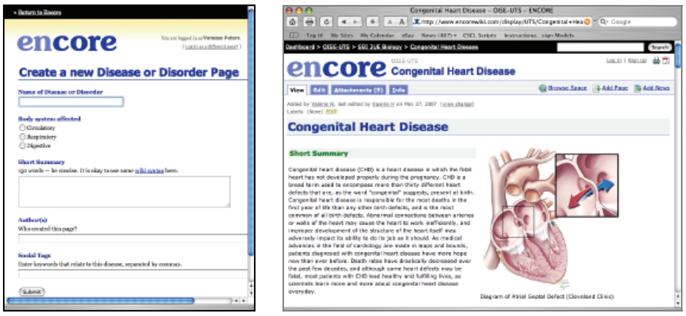


Figure 2. "Disease Page" Script and Completed Page.

Figure 3. "Challenge Case" Page.

Study 1 Findings and Discussion

Both teachers were able to successfully enact the curriculum in their classrooms with no interventions from the researchers. Teachers and researchers were excited by the level of engagement demonstrated by students in the creation of their disease pages. Across the four classes, students created wiki pages for seven respiratory diseases, ten circulatory diseases, and six digestive diseases. One worry expressed by teachers and researchers during the design meetings was that students would be reluctant to work with their peers' materials, preferring instead to create a new disease page of their own. However, approximately half of all students' authoring efforts were focused on editing a pre-existing page. When solving their challenge cases, the researchers worried that students would use Google instead of their own knowledge base. However, classroom observations by the teachers and researchers revealed that students made nearly exclusive use of the disease wiki pages, presumably because of the ease with which students could access directly relevant information. Another hopeful interpretation of this phenomenon is that there was a strong identity amongst students within their own knowledge community.

We also measured the impact of the lesson on student achievement. We compared the scores of our participants on the physiology portion of their final exam with the scores from the same two teachers' grade ten students from the previous year who received a more traditional physiology unit consisting of lectures and a lab (n = 67). The final exam in each year employed similar open-ended questions where students were asked to describe the role of human physiology within biological processes. Results from the analysis revealed a significant difference in students' scores. Those who participated in the knowledge building activity ($M = 8.84$, $SD = 1.59$) had significantly higher scores than students from previous years who were taught with the regular curriculum ($M = 7.90$, $SD = 1.15$), $p = .011$. Both teachers commented that students' exam performance had surpassed their expectations.

Study 2: Expanding the model to an 8-week curriculum unit

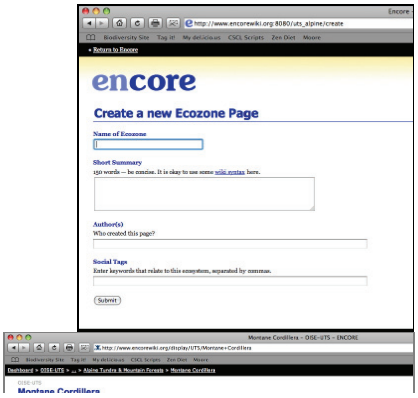
The second study was conducted in the following term with a new cohort of students. The co-design team was expanded from two science teachers to three, as over the summer a new biology teacher was recruited who wished to join the project. Over the course of 4 months, we held 14 co-design meetings, using laptop computers and a computer projector to take running minutes within our own wiki design space. A separate wiki space was used for creating the student wiki pages and New Page Scripts. This dynamic archive became a valuable resource to our group – indeed, our own community knowledge base – that was referred to frequently in all phases of the research partnership.

Participants

Student-participants were 113 grade ten students who were enrolled in an intermediate-level biology class. One teacher taught two classes of 28 and 29 students, respectively; the second and third teachers each taught one class of 28. In the classroom, students used wireless laptop computers for all wiki-related activities. This arrangement allowed students to freely maneuver when interacting with their classmates and teacher during an activity.

Design

The knowledge building activities that were designed for the biodiversity unit were patterned after our successful experiences in the first study. In pairs, the students created wiki pages for all Canadian ecozones and biomes. They were free to create a new page or edit an existing one. The New Page Script (see Figures 4 and 5, below) was designed to collect metadata for each ecozone, and to generate a page that included headers that would help focus students' edits on the specific biological organisms and ecosystems that were unique to their chosen territory. This provided a level of consistency among the ecozone pages, and ensured that students included specific biological content.



Procedure

Students from all four periods of the biology class created new wiki pages or revised existing ones, resulting in an anthology of 25 terrestrial and seven marine eco-areas. In response to teachers' concern for quality control within the wiki, we added a peer-review activity where pairs of students provided feedback regarding the content and aesthetics of several other wiki pages. Students were provided with the opportunity to revise their pages before the teacher's assessed them for accuracy and completeness. The resulting knowledge base became the main resource for subsequent scripted activities.

Students' next assignment was to create new "Biodiversity Issue" pages in the class wiki that often affected several ecozones within Canada. For example, the invasion of the Zebra Mussel (a species of shellfish that was transported from Russia to North America several decades ago) has now influenced all the Great Lakes, with serious implications for more than a third of the ecozones in Canada. Students are scaffolded to find relevant ecozones by the metadata attached to those wiki pages, including social tags that they populated in an earlier knowledge building activity. Further scaffolds within the "biodiversity issue" pages help students focus on the scientific elements of these authentic environmental problems, with particular emphasis on matters of biodiversity. These issues included sufficient detail to enable students to formulate solutions that addressed a real biological concern.

After students had created biodiversity issues, we addressed the element of the model where the "emergent themes and community voice" would influence the design of subsequent inquiry activities. The teachers and researchers met for an afternoon meeting to review the current knowledge themes within the wiki, particularly those biodiversity issues that seemed most compelling to students and most connected to the community knowledge base. Teachers and researchers built a consensus on the most important themes relating to biodiversity. These were used in creating a final inquiry activity: for students to create a scientifically plausible response to the issues, with optimistic outcomes over a 50 year time frame. Students were assigned to create this response using creative writing or other media formats.

Study 2 Findings and Discussion

This study further confirmed for all participants – teachers, students and researchers alike – that a knowledge community focus can have a powerful influence on students at a secondary science level. The final student activities have just recently been completed, and the school principal has already announced that the innovative student solutions are to be published nationwide. Students are literally telling their teachers that they don't ever want to hold another class where there is not an aspect of student-generated knowledge. Students are continuing to edit their wiki pages, even though the due-date for their completion has long passed. For those of us in the co-design community, this genuine level of enthusiasm and participation is a powerful demonstration of community, more than any theoretical description or model.

Based on the formative analysis of the ideas within the biodiversity wiki, we identified three powerful themes: climate change, habitat destruction, and invasive species. The majority of the biodiversity issues raised by students were determined to be related to one or more of those categories (e.g., climate change will often influence the loss of habitat). Thus, the students were instructed to include at least two of the themes in their responses, and to connect their solution scenario to as many ecozones as possible. Student solutions were highly creative and deeply connected to the science. This latter aspect of the inquiry assignment was of high priority to the teachers, who felt strongly that the final assignment of this unit must be heavily connected to science content goals. Students were thus told that their solutions would be assessed for both creativity as well as scientific merit, and both dimensions were taken to heart.

Measures from Study 2 include all student wiki pages, peer review comments, biodiversity issues and creative solutions, as well as student and teacher interviews. The co-design community is currently working on a new curriculum unit on nutrition and sustainable food, using sophisticated scaffolding technologies for interconnecting the inquiry activities and the community knowledge base. As part of a larger dissertation study by the second author, we are analyzing the wiki contributions of students in order to understand the growth of knowledge within the community, as well as to the impact of the community knowledge on student reasoning. This will include a detailed analyses of student interactions and achievement, including a comparison of final exam results with previous cohorts.

The co-design team has overcome a number of challenges, particularly in relation to working with teachers during the school term. Both researchers and teachers agreed that small pockets of time became extremely valuable, with meetings often taking place in the school staffroom during a lunch break. We are developing new wiki-based models for supporting these often fragmented planning cycles, so that all co-design participants can maintain contact and manage the creation of their own knowledge community.

Conclusion

Our research provides support for the blended knowledge community model, in which scaffolded inquiry activities provide students with incentive and opportunity to make use of the community knowledge base. The co-design method was effective, and indeed essential for helping teachers feel deeply committed to the curriculum. This commitment from teachers was itself essential in order to ensure that students felt engaged by the curriculum and actively participated. The findings of this study demonstrate that knowledge building methods can be successfully designed for high school biology classrooms, and offers a powerful mechanism for how such methods can succeed. Our wiki-based method for knowledge building, coupled with scaffolded inquiry activities that target specific content learning goals allows us to leverage the wider knowledge base of the community as a productive curriculum resource. This work thus responds to an ongoing challenge of how to make knowledge building activities more relevant for secondary teachers, and opens up possible avenues for future research and theoretical models.

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