Understanding Elementary Students' Emergent Dialogical Argumentation in Science

Seau Yoon FOO[1] and Chee Kit LOOI[2]
[1]*Ministry of Education, Singapore, foo_seau_yoon@moe.gov.sg*
[2]*National Institute of Education, Singapore, cheekit.looi@nie.edu.sg*

Abstract: This paper explores the use of Engle and Conant's (2002) theoretical framework of productive disciplinary engagement to describe a group of fifth-graders' emergent dialogical argumentation about a rocky seashore ecosystem that was triggered by fieldwork activities. Engle and Conant's theoretical framework was mapped onto Weinberger and Fischer's (2006) multi-dimensional conceptual framework for CSCL-based argumentation in order to guide the selection of analytical approaches that would holistically assess students' argumentation along four dimensions (i.e. participation, formal argumentative structure, social modes of co-construction of knowledge and epistemic reasoning). The application of these complementary analyses enabled the exploration of the effects of the different dimensions and the identification of instances of students' more productive argumentation of Science ideas in the Knowledge Forum (KF) platform.

Introduction

Current literature emphasizes the importance of defining meaningful science learning within a discourse of human agency (Fusco & Barton, 2001) that goes beyond telling learners about a discipline (Barab & Hay, 2001). Traditional approaches tend to over-emphasize the passive learning of science facts (i.e. learning about science content). Hence, various research studies (e.g. Scardamalia 2004; Engle & Conant, 2002) have focused on the creation of learning environments to facilitate students to "learn to be scientists" in articulating and improving their own ideas about scientific phenomena. Engagement in the first-hand processes to explore questions, communicate science ideas, collect data to answer questions, form explanations based on data and generate conclusions (i.e. learning to be scientists) is critical for students to truly understand the nature of "doing" science (Driver, Newton & Osborne, 2000).

Fostering a learning environment for students to "learn to be scientists" and engage in science discussions to productively use and generate scientific knowledge is never easy. Studies (e.g. Lipponen, Rahikainen, Hakkarainen, & Palonen, 2002; Bielaczyc, 2006) in the literature have documented the challenges (e.g. the lack of sustained and high quality discussion of science ideas among students) and issues (e.g. teacher readiness and student readiness) in enacting such educational endeavours, especially with the use of Information and Communication Technology (ICT) tools. In order for "school discussions to provide powerful contexts for practising and learning new reasoning behaviour", the conditions of "starting from common experience, having a very problematic object of discussion, and changing the rules of school discourse when the teacher is leading the group" must be present (Pontecorvo, 1993, p.365). Furthermore, Bielaczyc (2006, p. 322) indicated that existing research should move from adopting the "best-practices" and "sanitized" approach in highlighting the end states of achieving optimal uses of the ICT tool towards specifying the implementation paths or trajectories that are "progressive set of phases that teachers need to move through with their students to progress from initial to effective use of a technology-based tool."

Hence, this paper seeks to understand fifth-graders' engagement in the first implementation trajectory of an exploratory study to intertwine online discussions in the Knowledge Forum (KF) platform with fieldwork activities at a rocky seashore ecosystem. Could these activities be successfully implemented to "go against the grain" of regular IRE-based (Initiation, Response, Evaluation) classroom functioning? To what extent would the juxtaposition of fieldwork experiences and KF discussions motivate these students to take increasing responsibility for developing their ideas, theories and explanations in the light of fresh observations (Scardamalia, 2004) and hence, progress towards higher levels of engagement in the KF space? As many progressive implementation paths or trajectories will be needed to move students from IRE-based classroom discourse towards the social construction of science knowledge, what would be an appropriate framework to document the developmental progress that students make in this transition? This paper explores the use of Engle and Conant's (2002) theoretical framework of productive disciplinary engagement to describe how students had been engaged in "learning to be scientists" through their participation in the KF and fieldwork activities.

Theoretical Framework of Productive Disciplinary Engagement

According to Duschl, Schweingruber and Shouse (2007, p. 194), engagement with science "begins with willingness to participate in the science classroom, but it must go beyond simply participating to participating in ways that advance science learning". Engle and Conant's (2002) theoretical framework of productive disciplinary engagement (see Table 1) was utilized for my exploratory study as it emphasized the need to look for evidence of students' engagement that went beyond mere participation. That is, participation had to be sufficiently disciplinary and productive to advance science learning.

Table 1: Engle and Conant's theoretical framework of productive disciplinary engagement

Productive	Disciplinary	Engagement
To encompass the additional criteria of demonstrated change over time in student investigations, complexity of argumentation and use of previous investigations to generate new questions, new concepts, and new investigations	To be expanded to include scientific content and experimental activities (including argumentation based on logic and data patterns)	To be defined in terms of students actively speaking, listening, responding, and working with high levels of on-task behaviour

How would Engle and Conant's framework be useful for my exploratory study? Firstly, its differentiation between engagement, disciplinary engagement and productive disciplinary engagement sensitized the researcher to different aspects of engagement that could be achieved within the progressive implementation paths or trajectories to provide a finer-grained description of students' transition from initial to more effective ways of socially constructing science knowledge in the KF platform. For example, the extent of productive disciplinary engagement in an initial implementation path could be described in terms of low student engagement (i.e. low KF participation) or high engagement in non-disciplinary ways (i.e. high KF participation that did not advance science understanding due to the large number of unanswered questions). Secondly, Engle and Conant's framework emphasized classroom discourse as an important data source that would more directly measure student engagement (e.g. Nystrand and Gamoran, 1991; Herrenkohl and Guerra, 1998), as compared to the use of self-report questionnaires and lesson observation in prior research. Analysis of the KF discourse data that enabled the tracing of "the moment-by-moment development of new ideas and disciplinary understandings as they unfold in real-life settings" (Engle and Conant, p. 403) would illuminate ways in which students collaborated productively/unproductively to co-construct science ideas in the KF space. Such an understanding of student processes could not be derived solely from the static comparisons of students' pre- and post-measures. Thirdly, Engle and Conant's framework of productive disciplinary engagement provided the flexibility for the researcher to define what constituted disciplinary and productive engagement based on the conceptions of the disciplines, the specific tasks and topics and the specific groups of students and hence, it could potentially serve as a useful frame for any research that aimed to foster student discussions.

For my exploratory study, the dialogical argumentative aspects in the KF discourse emerged during students' KF discussion of selected questions on the rocky shore ecosystem that required them to take oppositional positions (Foo & Looi, 2006). Argumentation was not taught explicitly during the project duration. Dialogical argumentation refers to arguments that are co-constructed in a collaborative effort among two or more students or arguments that are produced by an individual student, but take into account other students' statements, either to support or to contradict them (Jimenez-Aleixandre & Pereiro-Munoz, 2005). These students' KF postings, being the predominant collaborative group discourse, were analyzed to determine the extent of productive disciplinary engagement. The specific research questions (see Column 2 of Table 2) which served as the identifying features to determine the extent of productive disciplinary engagement (see Column 1 of Table 2) are (1) What were the participation patterns among students? (2) What were the argumentation patterns among students? (3) How had arguments become more sophisticated?

Use of Weinberger and Fischer's Multi-dimensional Conceptual Framework for CSCL-based Argumentation to assess Productive Disciplinary Engagement

Engle and Conant's framework was constrained in that it did not specifically explicate how to assess online argumentation. Hence, Weinberger and Fischer's (2006) conceptual framework (see Column 3 of Table 2) was used to provide the critical dimensions needed for the analysis of online argumentation. The consonance between Weinberger and Fischer's multiple process dimensions and Engle and Conant's productive disciplinary engagement enabled the mapping of the two frameworks, as shown in Table 2, so as to guide the selection of the analytical approaches (see Column 4 of Table 2) for the exploratory study. In contrast with the earlier argumentation studies for teaching and learning of science (e.g. Kelly, Drucker & Chen, 1998) that primarily focused on the use of single process dimensions (e.g. Toulmin's argument structure, 1958), Weinberger and Fischer's conceptual framework ensured the holistic assessment of online argumentation along the different dimensions of participation, formal argumentative structure, social modes of co-construction of knowledge and epistemic reasoning (Clark, Sampson, Weinberger & Erkens, 2007).

Table 2: Proposed framework to assess the extent of productive disciplinary engagement.

<table>
<tr><th>Productive Disciplinary Engagement</th><th>Identifying Features</th><th>Weinberger & Fischer’s conceptual framework for assessing online argumentation</th><th>Proposed analytical methods for the exploratory study</th></tr>
<tr><td rowspan="8">To be defined in terms of :
students actively speaking, listening, responding, and working with high levels of on-task behaviour
incorporation of scientific content and experimental activities (including argumentation based on logic and data patterns)
demonstrated change over time in student investigations, complexity of argumentation and use of previous investigations to generate new questions, new concepts, and new investigations</td><td rowspan="2"><u>RQ1: What were the participation patterns?</u>
e.g. proportion of participating students, students’ contributions that are responsive to those of other students</td><td colspan="2">Participation dimension</td></tr>
<tr><td>Quantity of participation</td><td>Analytic Toolkit (ATK) analysis</td></tr>
<tr><td rowspan="2"><u>RQ2: What were the argumentation patterns?</u>
e.g. students monitoring one’s own comprehension of another’s ideas, students challenging the claims put forth by others, students coordinating theories and evidence</td><td colspan="2">Argument dimension</td></tr>
<tr><td>Construction of single arguments and sequences of arguments</td><td>Erduran et al’s (2004) Levels of Argumentation</td></tr>
<tr><td rowspan="4"><u>RQ3: How had the arguments become more sophisticated?</u>
e.g.   more complex arguments, more elaborated and plausible explanations, more developed ideas, new questions and concepts generated based on previous discussions</td><td colspan="2">Dimension of social modes of co-construction of argumentative knowledge</td></tr>
<tr><td>Extent to which students operate on the reasoning of their peers</td><td>Gunawardena et al’s (1997)’s Interaction Model Analysis</td></tr>
<tr><td colspan="2">Epistemic dimension</td></tr>
<tr><td>Use of epistemic operations</td><td>Chan’s (2001) Surface and Problem-centred Discourse Moves</td></tr>
</table>

Data Analysis

Table 3 provides an overview of the proposed analytical methods to assess the dialogical argumentation in the KF space. In order to analyze the participation patterns (RQ1), the Analytic Toolkit (ATK) afforded by the KF platform was utilized to provide the relevant statistics (e.g. number of notes written/read) on students’ participation patterns.

Table 3: Proposed analytical methods for assessing dialogical argumentation

(RQ2) Argument dimension - Erduran et al’s (2004) Levels of Argumentation	**(RQ3) Dimension of social modes of co-construction of argumentative knowledge -** Gunawardena et al’s (1997)’s Interaction Model Analysis	**(RQ3) Epistemic dimension -** Chan’s (2001) Surface and Problem-centred Discourse Moves

Level 1: Arguments that are a simple claim versus a counter-claim or a claim versus a claim. **Level 2:** Arguments consisting of claims with grounds but no rebuttal **Level 3:** Arguments consisting of claims with grounds and the occasional weak rebuttal **Level 4:** Arguments consisting of claims and a clearly identifiable rebuttal **Level 5:** Extended arguments with more than one rebuttal	**Phase 1:** Sharing/Comparing of information **Phase 2:** Discovery and exploration of dissonance or inconsistency among participants **Phase 3:** Negotiation of meaning/co-construction of knowledge **Phase 4:** Testing and modification of proposed synthesis or co-construction **Phase 5:** Agreement statement(s)/Applications of newly constructed meaning	**Surface moves:** Ignoring differences, rejecting alternative views, making ad-hoc rationalization, patching to eliminate differences, focusing on task **Problem-centred moves:** Problem recognition, problem formulation, formulation of questions, construction of explanations

In terms of the argumentation patterns (RQ2), students' KF postings were individually coded using Toulmin's Argument Pattern (TAP) which anchored most of the existing argumentation studies (e.g. Erduran, Simon & Osbourne, 2004). From the TAP perspective, the stronger arguments should contain more of the structural components (e.g. claim, data, warrants, backings, rebuttal and qualifier) than weaker arguments. However, the use of TAP had its methodological problems. To more reliably code single arguments using TAP, Toulmin's data, warrants and backings were collapsed into the single category of "grounds" (Erduran et al, 2004). As Toulmin's TAP was more suited to examining single arguments (Kelly et al, 1998), Erduran et al's analytic method had to be utilized to examine longer argument sequences (e.g. claim versus counter-claim, extended arguments with rebuttals) in order to categorize them into different levels of argumentation (see Column 1 of Table 3). The assumption behind Erduran et al's analytical method was that the rebuttal in the higher levels (i.e. Levels 4-5) played a significant role in raising the quality of the argument by "forcing both participants to evaluate the validity and strength of that argument" (p. 921) which otherwise would not have occurred.

In terms of whether arguments became more sophisticated over time (RQ3), the focus was to evaluate the arguments on the basis of their collaborative value in contributing to the conversation rather than solely on the development of normative science concepts (Grice, 1975). Gunawardena et al's coding scheme (see Column 2 of Table 3) was used to determine the "extent learners refer to contributions of their learning partners" by operating on the reasoning of their peers to move from lower to higher mental functions (i.e. Phases 1 to 5) rather than "make contributions to the argumentative discourse without reference to other contributions" (Weinberger & Fischer, 2006, p. 78). Gunawardena et al's coding scheme was chosen as it was able to track the progression of ideas in accordance to phases. Finally, Chan's coding scheme (2001) was used to understand why certain argumentative sequences became more sophisticated. Unlike other researchers (e.g. Jimenz-Aleixandre, M., Rodriguez, A., & Duschl, R., 2000), Chan went beyond the content domain to define students' epistemic operations (see Column 3 of Table 3) in terms of how they would process new information (i.e. problem-centred or surface moves) from peers to collaboratively construct arguments, especially in encountering unfamiliar discussion topics. According to Bereiter (1992), students who took the problem-centred approach were more likely to view the new or contradictory information in their peers' arguments as problematic and hence, formulated more questions of inquiry or explanations to resolve these problematic areas. Though these students' explanations might be inaccurate, they would be able to detect "anomalies in upcoming information and to revise their models continually" (Chan, 2001, p. 29).

Discussion

Tables 4 and 5 showed a subset of the students' argumentative KF postings that discussed the differentiation of plants, animals and living things at the rocky seashore. Table 4 started with P5 (L80) externalizing his claim about the characteristics that differentiated a plant (i.e. green and should not move) from an animal (i.e. moving around) at the rocky seashore. It was evident that P5 had drawn upon his prior knowledge of land animals and plants to put forth his claim for the seashore context. This was a typical starting point for most of the arguments on the characteristics of seashore plants and animals. The multiple rebuttals served to get students to clarify the source and extent of their disagreements, resulting in the restating of positions by a few students. For example, in lines 84 – 92, the students explored the different ideas they had about the movement of seashore animals. In line 84, P2 knew that the sea anemone was an animal and yet found it incongruent that it did not seem to move. However, this claim was rebutted by P5 who elaborated on the sliding movement of the sea anemone. This led P11 and P2 to highlight how the movements of land animals and seashore animals were different. P9's rebuttal also served to explicate that movement had to be controlled by the organisms.

Table 4: Predominantly Phase 2: Discovery and exploration of dissonance and inconsistency for the concepts of "plant" and "animal"

Student	Note Content	Argument operations	Phase	Epistemic Operations
P5: (L80)	If it is a plant, it should be green and should not move. If it is an animal it should be moving around.	Claim	Ph1	Makes a statement
P9: (L81)	SARGASSUM. Sargassum seaweed is not green but brown, but still photosynthesizes.	Rebuttal with grounds	Ph2	Problem-centred move: problem recognition
P3: (L82)	yup.....they have brown chlorophyll, not green	Support with grounds	Ph2	Agrees with P9
P10: (L83)	Sargassum is not green, does it make food? If it does, how?	Query	Ph2	Problem-centred move: question generation
P2: (L84)	But isn't sea anemone an animal but it does not move about......	Rebuttal (to P5) with grounds	Ph2	Problem-centred move: problem recognition
P10: (L85)	Its tentacles move.	Rebuttal (to P2)	Ph2	Problem-centred move: construction of explanations
P2: (L86)	I was saying that it does not move about the beach.	Support (for P2)	Ph2	Makes clarifying statement
P3: (L87)	Their movement of the tentacles is caused by waves.	Support (for P10) with grounds	Ph2	Problem-centred move: construction of explanations
P5: (L88)	But according to a book the sea anemone moves but only slowly. They slide their muscular bases along the rock surface.	Rebuttal (to P3) with grounds	Ph2	Problem-centred move: construction of explanations
P11: (L89)	The movement between land animals and beach animals are different. Land animals usually travels through a longer distance, hence they usually hop, run, walk or fly. Unlike land animals, beach animals usually travel through a shorter distance, hence they usually use a smaller movement.	Support (for P5) with grounds	Ph3	Problem-centred move: construction of explanations
P2: (L90)	The different movements are burrowing (snails, worms and starfish), creeping (limpets), walking (crabs) and swimming (fish)	Support (for P11) with grounds	Ph3	Problem-centred move: construction of explanations
P9: (L91)	Some plants can be stuck to a fixed place yet because of the water they can sway back and forth and this is considered movement to me.	Rebuttal (to P5's earlier claim about plants cannot move)	Ph2	Problem-centred move: problem recognition - present a different view
P3: (L92)	But the movements are not controlled by the organism. Like the sea anemone, the movement of the tentacles is caused by waves. (I read up from the book called Coral Reef)	Rebuttal (to P9)	Ph2	Problem-centred move: construction of explanations

Table 5 showed how the students' later arguments became more sophisticated through moving from Phase 2 to Phases 3 - 5. P8 started by summarizing the key agreements on the characteristics of "plant", "animal" and "living things" that were mentioned by her peers in their previous arguments through the use of qualifiers. P8's synthesis of ideas was considered to be a very high mental function as it was indicative of her uptake of prior ideas contributed by her peers. Other students started to test the "soundness" of P8's proposed synthesis. P9 used the the velcro crab as an example of a seashore organism which could not be considered as a plant even though it had plants growing on it more for the purpose of camouflage. It was also becoming evident to some of the students that physical and behavioural characteristics alone might not be sufficient to determine whether an organism was a plant or an animal. In addition to these attributes, P6 indicated the importance of the biological process of making food in order for the organism to qualify as a plant. Students' productive arguments resulted from their problem-centred moves that operated on each other's reasoning to develop their ideas.

Table 5: Moving into Phases 3 to 5 - Negotiation of meaning of the "plant" and "animal" concepts with testing/modification of proposed synthesis

Student	**Note Content**	**Argument operations**	**Phase**	**Epistemic operations**
P8: (L120)	FOR KNOWING IF IT IS A PLANT: it is USUALLY green, it USUALLY has signs of leaves, it USUALLY does not move FROM ONE PLACE TO ANOTHER, it is USUALLY stuck to something (soil/stone) and it USUALLY has no sign of animal parts (arms/legs/hands…) FOR KNOWING IF IT IS AN ANIMAL: it NORMALLY moves about (needs to hunt for food/escape from predators), it NORMALLY has legs/arms/head....and something needs to move if the animal wants to move. MOVEMENT IS LEAPING, RUNNING, HOPPING, MOVING..... FOR KNOWING IF IT IS A LIVING THING: If you touch it, and it reacts, it is likely to be a living thing.	Claim with grounds	Ph5	Problem-centred move: construction of explanations
P9: (L121)	Like the VELCRO CRAB, it decorates itself with plants that live near it so that it can escape detection. But it doesn't mean that it is a plant!	Rebuttal with grounds	Ph4	Problem-centred move: problem recognition – presents a different view
P3: (L122)	Your theory fits for most plants and animals as you put USUALLY but what are the theories that you can differentiate them without usually or rather ways of confirming that they are plants or animals.	Rebuttal	Ph3	Problem-centred move: problem recognition - present a different view
P6: (L123)	The main reason is plants can make their own food.	Support for rebuttal with grounds	Ph3	Problem-centred move: construction of explanations
P6: (L124)	We can test it out by using a leaf from a plant and a non plant…we can cover the leaves with iodine solution. The iodine will turn the starch blue black. Those parts of the plant's leaf which are blue black contain starch. The non plant will be yellow brown which shows that there is no presence of starch**….**	Support with grounds	Ph4	
P10: (L125)	After testing out Grace's idea, we can find out that fungi cannot make food as it is not a plant.	Support with grounds	Ph4	

Table 6 showed the application of the proposed framework to assess the extent of productive disciplinary engagement. In terms of argumentation patterns, both excerpts in Tables 4 and 5 comprised Level 5 argumentation. However, the use of Gunawardena et al's coding scheme, as explained in the previous two paragraphs, was able to further explicate that the earlier arguments in Table 4 were predominantly in Phase 2 (Discovery of dissonance and inconsistency) while the later arguments in Table 5 had moved into the higher levels of Phases 3-5 (Agreement/Application of newly constructed meaning). Hence, the arguments had become more sophisticated moving from Table 4 to Table 5.

Table 6: Evidence for Productive Disciplinary Engagement

Productive	Disciplinary	Engagement
RQ3: How had the arguments become more sophisticated? • More sophisticated arguments evolved. Argumentation moved from Phase 2 in Table 4 to Phases 3-5 in Table 5. Tables 4 and 5 showed students' use of problem-centred moves. • But students did not resolve the problem of understanding.	**RQ2: What were the argumentation patterns among the students?** • Tables 4 and 5 constituted Level 5 argumentation. Students were able to construct extended arguments with more than one rebuttal. In these arguments, students attempted to use fieldwork data to support their claims.	**RQ1: What were the participation patterns among the students?** • Students participated to build on each other's ideas.

Concluding Remarks

The application of the complementary analytic approaches (i.e. Erduran et al's levels of arguments, Gunawardena et al's Interaction Model Analysis, Chan's surface and problem-centred discourse moves) on a subset of students' KF discussions provided evidence to determine the extent of productive disciplinary engagement that occurred in the first implementation trajectory of an exploratory study to intertwine KF discussions with fieldwork activities. Taking the structural perspective of argumentation alone (which anchored most of the existing argumentation studies) or doing frequency counts of categories might not have sufficed to provide new insights in terms of how students had been developing their arguments in the KF space. The complementary use of Gunawardena et al's Interaction Model Analysis and Chan's surface and problem-centred discourse facilitated greater understanding of students' sense-making efforts in action that led to more productive co-construction of arguments in the KF space.

References

Barab, S.A., & Hay, K.E. (2001). Doing science at the elbows of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching*, 38(1), 70-102.

Bereiter, C. (1992). Referent-centred and problem-centred knowledge: Elements of an educational epistemology, Interchange, 23(4), 337-455.

Bielaczyc, K. (2006). Designing social infrastructure: Critical issues in creating learning environments with technology. *Journal of the Learning Sciences*, 15(3), 301 – 329.

Chan, C. K. K. (2001). Peer collaboration and discourse patterns in leanring from incompatible information. *Instructional Science,* 2, 443-479.

Clark, D. B., Sampson, V., Weinberger, A., & Erkens, G. (2007). Analytic frameworks for assessing dialogic argumentation in online learning environments. *Educational Psychology Review*, 19(3), 343-374.

Driver, R., Newton, P. & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84(3), 287 -312.

Duschl, R. A., Schweingruber, H. A. & Shouse, A. W. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8*. National Science Academic Press: US.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education*, 88, 915-933.

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.

Foo, S.Y. & C-K. Looi (2006) A Case Study of Elementary Students' Argumentation in Science, Proceedings of the International Conference on the Learning Sciences, Bloomington, 175-181.

Fusco, D. & Barton, A.C. (2001). Representing student achievements in science. Journal of Research in Science Teaching, 38(3), 337-354.

Grice, H.P. (1975) Logic and conversation. In P. Cole & J. L. Morgans (Eds.), *Syntax & semantics 3: Speech acts*. London: Academic Press

Gunawardena, C. N. & 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(4), 395-429.

Herrenkohl, L. R. & Guerra, M. R. (1998). Participant structures, scientific discourse and student engagement in fourth grade, *Cognition and Instruction*, 16(4), 431-473.

Jimenz-Aleixandre, M., Rodriguez, A., & Duschl, R. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education*, 84(6), 752-792.

Jimenz-Aleixandre, & Pereiro-Munoz, C. (2005). Argument construction and change while working on a real environment problem. In Boersma, K., Goedhart, M., De Jong, O., & Eijkelhof, H. (Eds.), *Research and the Quality of Science Education.* Dordrecht: Springer.

Kelly, G. J., Druker, S., & Chen, C. (1998). Students' reasoning about electricity: Combining performance assessments with argumentation analysis. *International Journal of Science Education*, 20(7), 849-871.

Lipponen, L., Rahikainen, M., Hakkarainen, K., & Palonen, T. (2002). Effective participation and discourse through a computer network: Investigating elementary students' computer-supported interaction. *Journal of Educational Computing Research*, 27, 355 - 384.

Nystrand, M. & Gamoran, A. (1991). Instructional discourse, student engagement and literature achievement. *Research in the Teaching of English*, 25, 261-290.

Pontecorvo, C. (1987). Discussing for reasoning: The role of argument in knowledge construction. In E.De Corte, H. Lodewijks, R. Parmentier, & P.Span (Eds), Learning and Instruction: A publication of the European Association for Research on Learning and Instruction (Vol 1, p. 71-82). Oxford:EARLI

Scardamalia, M. (2004). Collective cognitive responsibility for the advancement of knowledge. Retrieved 30/10/2004 from www.ikit.org.

Toulmin, S. (1958). The uses of argument. Cambridge: Cambridge University Press.

Weinberger, A. & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning, *Computers & Education*, 46 (1), 71-95.