Scripting Collaborative Learning in Smart Classrooms: Towards Building Knowledge Communities

Michelle Lui, Mike Tissenbaum, James D. Slotta, University of Toronto, 252 Bloor Street West Toronto, Canada, ON,
Email: michelle.lui@utoronto.ca, mike.tissenbaum@utoronto.ca, jslotta@oise.utoronto.ca

Abstract: This paper shares preliminary findings on a new program of research on collaborative learning in smart classrooms. Using a co-design method, researchers worked with high school teachers to create engaging curriculum activities that provided the context for two studies in math and physics. The activity designs aim to increase the depth of students' conceptual understanding by breaking down learning goals into manageable sections. Students "tagged" questions in terms of relevant concepts, analyzed visualizations that captured the collective wisdom of the classroom community, critiqued results, and negotiated a shared understanding of domain-specific principles. Twenty-one mathematics students from grades ten and eleven participated in the first study; thirty-two grade twelve physics students participated in the second. Results showed improvements in problem-solving (in the second study), as well as improved tagging proximity to an expert model (in both studies). Issues with collaboration scripts used in the smart classroom are also discussed.

Introduction

Students' lives are increasingly being shaped by technology, and their future in the 21st century workplace will surely demand a deep fluency with information technologies, the most exciting of which are only just emerging (e.g., ubiquitous computing, physical computing, real-time collaboration environments). Yet the primary model of instruction in today's classrooms remains one of traditional didactic pedagogy – particularly in math and science – where lectures, problem sets and exams rule the day, and peer competition is more likely than collaboration. Designing instruction to promote deep understanding means adopting new modes of inquiry where students are encouraged to think deeply about materials and develop their own understandings (Linn & Eylon, 2006; Quintana et al., 2004). Technology environments can help scaffold students and teachers in new forms of learning where they collaboratively engage with materials, coordinated by scripts that help guide the flow of people, materials, and activities (Kollar, Fischer, & Slotta, 2007). However, current means of supporting instruction with technology are typically isolating, with students hidden behind rows of large monitors, as seen in typical computer labs.

The idea of forming knowledge communities, where members are given the responsibility to generate and build upon each other's ideas, ultimately developing their own knowledge base, is becoming more relevant for today's learners who are tasked with establishing collaboration skills, critical thinking and communication skills, in addition to learning content knowledge (Bereiter & Scardamalia, 2003; Partnership for 21st Century Skills, 2009). With the advent of sophisticated collaboration technologies, it is now possible to develop applications that allow for more seamless and dynamic collaboration, supporting real-time face-to-face interactions while maintaining an intelligent knowledge base that represents the collective wisdom of the entire class. This paper presents an ambitious new program of research that investigates how technology-enhanced learning environments can be embedded deeply within the classroom: becoming more visible and yet less intrusive, responding intelligently to student inputs, and capturing the collective wisdom of the classroom community as a resource for all participants. We have developed a new "smart classroom" and applied it in a design partnership with high school mathematics and physics teachers in order to address students' deep conceptual understanding of these traditionally challenging domains. Sections below describe our curriculum designs in two smart classroom activities, our technology and material designs, and the outcome of our studies.

Smart Classrooms

Our research recognizes the potential of technology-enhanced learning environments to enable new forms of learning, where students collaborate within their classroom or across multiple classrooms, dynamically generating knowledge, building on peer ideas, and investigating questions as a knowledge community. Our notion of a smart classroom employs a wide range of technologies to allow investigations of a full spectrum of collaborative inquiry and knowledge construction activities. Our technology framework consists of a portal that allows students to register and log in, an intelligent agent framework that allows tracking of student interactions, a central database that houses curriculum materials and the products of student interactions, and a visualization layer that controls the information presented to students (Slotta, 2010). At present, our implementation of a smart classroom includes four large projected displays in each corner of a classroom, a fifth, larger multi-touch display on the front wall, and twenty laptops, all interconnected via high-speed wireless network.

Knowledge Communities

Knowledge communities are created through collaboration, where students learn through generating and building upon each other's ideas within their unique knowledge base (Bereiter & Scardamalia, 2003). Brown and Campione (1990; 1996) first offered an interpretation of science classrooms as knowledge communities in their Fostering Communities of Learners research program, where students engaged in research activities, shared findings, and used their collective expertise to develop a shared understanding. A related approach called Knowledge Building instead values advancement or creative work performed as a community (Scardamalia & Bereiter, 2006). In this perspective, students are not recognized for what is in their minds but for contributions they make to the group's knowledge base. Students are more explicitly involved in the process of building upon one another's ideas, with the goal of developing a knowledge community in the classroom (Scardamalia and Bereiter, 1994; 1996). We envision participation in the smart classroom as a portal to a collective knoweledge base. Students engaging in collaborative activities within the smart classroom can use this knowledge base to step back and reflect on their participation, and allow their shared knowledge to emerge over time. Unfortunately, there are numerous challenges in implementing a knowledge community approach, which includes the elevated investment required of teachers to use it, as well as scalability issues for replication in research (Slotta & Peters, 2008). The open-ended nature of topics covered is also unsuitable to secondary school science courses, where teachers often carry heavy curriculum expectations (Peters & Slotta, 2009).

Orchestration of Complex Collaborative Designs

Prior research on supporting complex collaborative learning designs offers some insight into the affordances of new technologies (e.g., awareness or data mining). One common approach is that of the "collaboration script," which has been shown to effectively foster collaboration and improve learning outcomes (e.g., De Wever, et al., 2009; Kollar, Fischer, & Slotta, 2007; Rummel & Spada, 2005; Weinberger, et al. 2005). The script serves to define participants, activities, roles, and groups, specifying how tasks are distributed, how groups are formed and the sequence of activity flow (Kobbe, et al., 2007). Collaboration scripts add structure to activities and distribute responsibility, ensuring that all members actively participate. Scaffolds designed to complement the script can help guide students' cognitive processes (O'Donnell, 1999), as well as their interactions with peers (i.e., from different roles within the script) by providing specific task instructions, modeling, and instruction on skills or methods (King, 1999). Scripts have been found to foster domain-general knowledge, such as argumentation (Stegmann, et al., 2007) and interdisciplinary communication (Rummel & Spada, 2007). Collaboration scripts offer smart classroom curriculum designs structure to maintain focus on specific roles and content expectations, while allowing room for students' free flowing ideas to emerge and be built upon.

Objective

To understand how certain aspects of a smart classroom and carefully designed complex collaboration activities might support learning in a knowledge community, we first investigated how students used collaborative discourse and collective knowledge to make connections among abstract domain concepts in math and physics. Through the use of visualizations as representations of shared knowledge, "tags" to connect concepts, and reflection scripts to enhance understanding, our research team created two iterations of an analogous pedagogical design in sequence, with findings from the first incorporated into the second design. This paper presents findings from both studies.

Method

Our research employs a design-based methodology, which is characterized by iterative cycles of design, evaluation and revision of an intervention for study in authentic settings (Brown, 1992; Design-Based Research Collective, 2003). Using a co-design method (Penuel, Roschelle, Shechtman, 2007), our team of researchers, designers, technology developers, and high school teachers met regulary to develop curriculum activities, content materials and specialized software to coordinate the flow of participants and media amongst various computers, servers, and displays. The studies took place in the aforementioned smart classroom, located at a private, local urban high school, where the excellent students, the creative and reflective teachers, and the supportive administration make this an ideal setting for an ongoing co-design partnership for educational innovations.

Study 1: Connecting Mathematical Concepts

The curriculum, detailed below, was designed to engage several small groups of students working in parallel as they "tagged" a common set of math problems. In so doing, a collaborative visualization emerged as the software synthesized tags from all groups. A set of thirty problems was developed by the teacher. Each problem may be classified into one or more of four category groups: Algebra & Polynomials, Functions & Relations, Trigonometry, and Graphing Functions. The basic goal of this activity was to help students understand the relationships between these four aspects of mathematics by having them visualize the association of math problems with multiple categories.

Participants

A total of twenty-one student volunteers in grades ten and eleven from our research partner high school participated in the study. Nineteen students participated in the pre-test and curriculum activities. Ten students completed the post-test, two of which did not participate in the curriculum activity. The curriculum activity was co-designed with a high school mathematics teacher.

Design

Part A - Tagging

Students were provided with individual laptops and logged in to a specially-designed system that coordinated the flow of activities for the session. The software agents distributed students into four groups, each specializing in one of the four mathematics categories. Each group gathered in a specified area of the room, where the individual students within that group were presented with a set of math problems. For each problem, the student decided whether it should belong in their group's category, without solving the problem. A projection screen in front of each group displayed a semantic map of that group's category, with each of the math problems as nodes. If a problem was tagged with their group's category, a connection between the problem and the category was made (Figure 1). This was represented on the screen as a line, linking the problem node to the category node. At the front of the room was a larger screen that showed the collaborative visualization, which displayed an aggregate of the connections made between the questions and all four categories.

Part B - Solving

Once the four groups reviewed all the questions, they were provided with pencil, paper, and calculators. The software agents presented students with only those problems that were tagged as belonging to their group's category as well as at least one other category. Students were then instructed to solve each problem, working as a group. Once completed, they took a photo of their solution using the laptop camera and uploaded it to the system.

Part C – Reflecting

Next, the students in each group were shown the tags that other groups had assigned to the questions they just solved and asked to vote on the credibility of those tags. For example, students in the "Algebra & Polynomials" group might be presented with a problem that had been tagged by their group as well as the "Trigonometry" group. Students would be informed that the problem had been tagged as being "Trigonometry" as well, and asked whether they agreed with the "Trigonometry" connection. After stating their agreement or disagreement, the students would then be prompted to explain their choice in reflection notes. The visualizations were updated in real-time – the lines representing connections that had stronger consensus became thicker, and uploaded solutions appeared as new nodes.

Procedure

Students were given a paper-based pre-test of twelve questions. Rather than solve the questions, they were asked to identify problems as "Algebra & Polynomials", "Functions & Relations", "Trigonometry", and/or "Graphing Functions". They could check off more than one category, and were also asked to point out any other themes the questions were related to. These were collected and compared with the same task as performed by the teacher, who had helped to assemble the problems. The post-test was similar to the pre-test, except it was in the form of an online survey and a new set of problems were used. Boxes for comments were made available for students' input on their experience on the pre-test, curriculum activity and post-test. Qualitative analysis was performed on video captured during the activity and audio data collected at group workstations.

Results

For the pre- and post-test, as well as evaluation of the tagging from part A of the curriculum design, we examined two constructs, accuracy and structuredness. Accuracy scores were compiled by looking at the group average of correct connections against the total number of connections made by the teacher. Following previous work using mathematics concept maps (Hasemann & Mansfield, 1995), the "structuredness" for each set of data was evaluated with the number of connections made compared against the total number of potential connections. On the pre-test, students achieved an accuracy rate of 72% (SD = 6.16); the structuredness level was 52% (SD = 15.70). During the curriculum activity, students made more connections between problems and categories, with an accuracy rate of 80% (SD = 17.41) and a structuredness rate of 80% (SD = 23.44). On the post-test, the accuracy rate for the smart classroom group was 77% (SD = 6.04), and the structuredness rate was also 63% (*SD* = 19.16). For those who did not participate in the activity, the accuracy was 76% (*SD* = 4.82), while the structuredness rate was 50% (*SD* = 5.89), as shown in Figure 2.

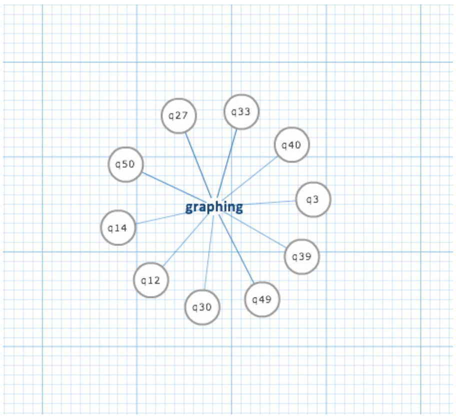

Figure 1. Tags Made by the Graphing Group.

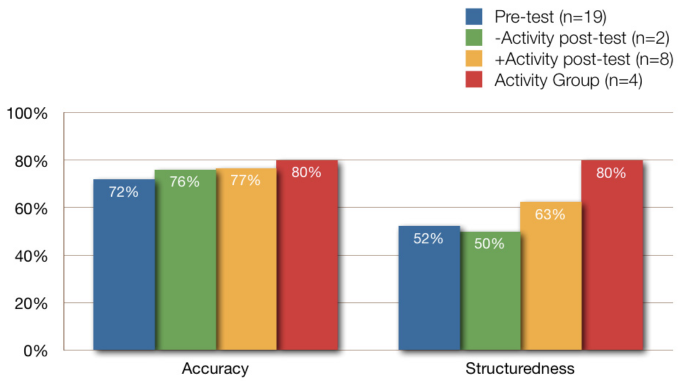

Figure 2. Accuracy and Structuredness Results.

Qualitative analysis of student comments showed that overall students found the visualization useful in showing different mathematical themes from which a problem could be approached. One student indicated that the visualization was helpful when he could not solve a problem. Students also stated that, over time and with more contributors, the system would become increasingly valuable for studying purposes. Students also commented that they became more cognizant of the connections amongst mathematics ideas and themes. It is noteworthy that students gained awareness that one could discuss properties of math problems and their relevant themes rather than simply solve them.

For part A of the activity, video recordings revealed that students worked on the tagging individually but commented to each other about the connections they created in the group visualization (between the problem and their group category). In part B, the videos indicated that students made concerted efforts to solve problems collaboratively, although some groups were more successful than others. One group showed two students taking turns actively solving, while a third member interjected occasionally with valuable comments. Another group initially solved questions individually then compared answers as an approach; soon after it became clear that one member was faster at solving than the others and he took on more responsibility for this portion of the activity. Discussion in the groups ranged from reading out questions, talking aloud while thinking through strategies, asking other members what certain formulas are, to verifying or questioning approaches and answers. Since students only solved problems that were tagged as their group's category, students also discussed the appropriateness of the tag for certain questions. In the post-test, one student commented that solving math problems in groups was valuable because it is not something they usually get to do. In the last part of the activity, the amount of discussion varied amongst groups. Some discussion revolved around whether they solved the problem from the category's perspective to determine whether they agree with the connection or not. In some groups, the agreement was straightforward, and voting was completed without debate.

Study 2: Collaborative Problem-solving

The second study addressed our objective by engaging students in a slightly more complex collaborative problem-tagging activity where they worked individually and in groups to identify the important conceptual elements within a set of qualitative physics problems. Key differences between this and the math curriculum lies in students providing answers as well as tags in the first step, which gave groups more collective information to work with in subsequent steps. Also, with the problems being more conceptual in nature, students could focus on discussing higher-level issues rather than manipulating numbers, which seemed to elicit more individual work. Learning outcomes are measured in terms of i) students' precision in answering the qualitative problems, and ii) their classification and assignment of conceptual characteristics to the physics problems. The problem-tagging activity is followed by a problem set-up activity, where students worked collaboratively to set up the equations and approaches for solving a long-answer physics problem. The curriculum activity was designed for enactment over a class period of ninety minutes, as an end-of-term review activity. Students were randomly assigned to groups of four. Each student was given a laptop computer and the group was also provided with a projection screen to be used for the display of the collaborative visualizations.

Participants

A total of thirty-two student volunteers enrolled in grade twelve physics at our research partner high school participated in the activity. Two smart classroom sessions were conducted over two days with sixteen students in each cohort. The curriculum activity was co-designed with a high-school physics teacher.

Design

Part A - Individual Solving & Tagging

The curriculum was designed to engage several small groups of students working in parallel as they answered a common set of sixteen multiple-choice concept-based physics questions. Each student answered and tagged four multiple-choice concept problems with expert-defined "element" tags (e.g., Newton's first law, net force, kinetic energy, conservation of momentum, etc.), selected in advance by the co-design team. The goal of this activity was to familiarize students with the elements with which experts would typically categorize problems.

Part B - Group Review

Once students had completed tagging their four concept problems, they worked as a group to review the responses and tags made by other students for four of the problems. Collaborative visualizations displaying those results were generated to facilitate this process. Students were instructed to critique the various solutions contributed by their classmates, as well as the collective tags, then re-negotiate the "definitive" answers and element sets, and write a brief rationale to explain their choice of elements (Figure 3).

Part C - Long Problem Setup

Upon completion of the concept question reviews, four complex quantitative physics problems were presented to each group. For each long problem, students were asked to select from a list of four concept questions that they felt was most related to the long problem. Once the selection was made, students were asked to choose a set of elements and equations that would help set up the problem for solving. Finally, groups provided explanations for their choice of formulas.

Figure 3. Students Reviewing Class Responses in Step 2.

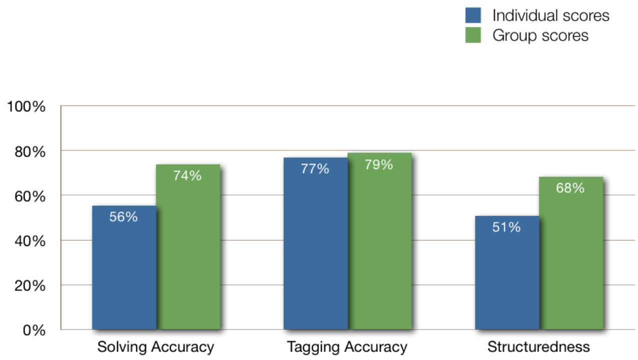

Figure 4. Accuracy and Structuredness Results.

Data Analysis

Data were gathered during the activity sessions. Preliminary data screening was conducted to determine whether there were differences between students who participated in the activity in day 1 compared to those who participated in day 2. Their individual scores (part A) as well as group scores (part B) were assessed and no significant differences were found. Participant data in from both days was pooled and analyzed together. Individual performance on concept questions was compared with group performance using a paired samples *t* test. Element tags were analyzed using accuracy and structuredness scores, using the protocol described in study 1. Qualitative analysis was performed on video captured and audio data collected at group workstations.

Results

A paired samples *t* test was conducted to evaluate whether students performed better at the group review step than at solving individually. The results indicate that the mean group scores (M = 74.00, SD = 23.78) were significantly higher than the mean individual scores (M = 55.65, SD = 30.40), $t(30) = -2.74$, $p < .05$ (see Figure 4). Further analyses showed no significant differences among group scores between the eight groups. For tagging accuracy and structuredness, groups tended to tag their problems closer to the expert model than individuals, with average accuracy scores of 79% (SD = 4.84) compared to 77% (SD = 7.40), although the difference was only marginally significant. In terms of structuredness, students' group scores (M = 68.43, SD = 13.21) were significantly higher than their individual scores (M = 50.92, SD = 18.51) by approximately 18%, $t(30) = -5.654$, $p < 0.05$ (see Figure 4).

Video recordings of classroom activity and group level audio data indicated that students generally worked independently in part A, with some seeking help with equations (e.g., for elastic potential energy) and a few asking group members how to approach certain problems. In part B, students noted what others in the class chose as the right answer and compared that to their own choices. They discussed formulas and verified which should be used, and used analogies to explain concepts to other group members. Students also discussed how the problem should be approached, often using their own answers as a starting point for discussions. They also seemed to connect element tags to formulas that should be used in solving the problems, which was in line with analyses of the written rationales.

Discussion

Collective Knowledge and Connections

Both studies employed large projected displays of the aggregated input from the individual members working within a small group. In study 1 (math curriculum), the collaborative visualizations served as representations of collective knowledge on small group levels as well as on a whole class level. They helped students make connections between math problems and themes, but also provided researchers a means of assessing the connections that students made by comparing their answers to those of the teacher (or another normative source). The collaborative visualizations also provided a record of the aggregated connections, artifacts (e.g. problems, solutions) and communications amongst students over time, which can be used to inform the design of subsequent learning activities. As a result, students in study 1 seemed to gain an appreciation that problems may exhibit characteristics from more than one distinct category. However, they did not discuss meaningful differences among concepts, perhaps due in part to the overall activity design and to the limited amount of information shared in the visualizations.

Study 2 (physics curriculum) also showed improved tagging accuracy over time when connecting problems to underlying concepts. In particular, the structuredness score revealed a significant difference between individual and group efforts, which indicates an improved willingness of students to characterize problems from different perspectives. This was accompanied by a significant improvement in accuracy for answering conceptual questions over the course of the activity session. From analysis of video and audio data, the improvement is likely due to a combination of the collaborative discourse and the "wisdom of the crowd" (i.e., by way of reviewing of class answers). For each question that groups reviewed, students took into consideration how fellow classmates answered the question and what element tags they assigned to it. However, the bulk of the group discourse was centered on the elements and how they contributed to the correct answer. Collaborative tagging of elements also seems to help students set up quantitative physics problems. Rationales for tag selections as well as their collaborative discourse around the elements appear to have provided a rich conceptual space for students in which they can organize key concepts.

Dynamic representations of the knowledge base were important design features in the smart classroom. In study 1, the four corners of the room represented different location of expertise, with the aggregated knowledge of all four groups shown at the front of the room. Students took notice of the representation and looked around the room at various points of the activity, paying special attention to the front of the room. In study 2, a more distributed approach was taken to represent the knowledge base. Class responses were associated with particular questions (e.g., in the review step, the group would see fellow classmates' responses for question one while reviewing the first question, once they submitted their final answers for the question, they would then review the next question and see the class responses pertaining only to the second question). In study 2, there were no persistent representations of the knowledge base, and the behaviors of the class as a whole was less cohesive. Students tended to look around at other groups for indications of their progress completion during the activity, rather than how other groups made connections and solved problems. Casual comparisons between student behaviors in study 1 and 2 indicate that specialization of groups and persistent representations of the class-wide knowledge base may improve learning experiences in the smart classroom (e.g., embodiment, engagement), although this was not explicitly measured in either study.

Orchestration of Smart Classroom Activities

Both studies also employed the notion of orchestration, which was in the form of an individual tagging phase, group review and a reflection phase. Asking students to perform slightly different tasks using collaboration scripts at each of these phases revealed how they can be utilized optimally for learning in the smart classroom. The individual phase in both studies served as a "model-building" phase of the participants' initial collective knowledge base. Although some students occasionally consulted with fellow group members during this stage, they generally completed the phase individually. The affordances of the smart classroom were not put to use in this phase in both instances, which means this phase can potentially be placed outside the room, perhaps as homework assignment.

Asking students to only tag concepts to problems in the first phase (as in study 1) provided limited information for groups to discuss in the second phase. Giving additional collective information to students in study 2 (i.e., more tags, adding answers to question) seemed to elicit more deliberation, but the goal of the discussions tended to be restricted to finding the correct answer. Perhaps if a richer context was used as part of the activity and a variety of information, including different types of connections and media, was given to students, the collaborative discourse could increase in complexity and raise the level of knowledge construction.

In the reflecting scripts, we expected to see more discourse around group decisions and creating rationales. In study 1, group members seemed to attain a similar mental model of each of the problems they were asked to reflect upon, either through directly solving the problem, or in discussing the strategy to solve the problem. Not much discussion was necessary to reach consensus. In study 2, discussions around problem-solving strategy were complementary to selecting element tags. One person tended to take over responsibility in creating the rationales based on what the group talked about. In order to draw out student thinking behind the reflection process, scripts may need to include more "think aloud" instructions for students to share their thoughts. Alternatively, we could recognize reflection as an individualistic process and script accordingly, rather than force this to be a collaborative process.

Recent research on scripting approaches has focused on "fading" such scaffolds over time (Wecker & Fischer, 2007), or providing scripts with adaptive scaffolds (Dillenbourg & Tchounikine, 2007; Rummel and Weinberger, 2008). While these investigations are still in their infancy, we aim to make use of our dynamically generated knowledge base to modify collaborative processes in real-time, which can provide opportunities for teachers and students to monitor, evaluate, and adapt learning activities during class time. For example, progress reports could be given to students and groups between activity phases, and the amount of scaffolding provided to groups may be adjusted based on formative assessments. Data may be provided to teachers in real-time, allowing them to guide students more effectively, and even potentially "flagging" those who need assistance most. Using more complex "intelligent agents" (e.g., teacher agents, student agents, and group agents) for data mining and reporting group activity, we wish to enhance the awareness and detection capabilities of the smart classroom framework to support group collaborations, student interactions, as well as classroom management. The present research represents an early effort in understanding how collaboration scripts organize smart classroom activities.

Collaborative Activities for Building Knowledge Communities

We recognize from prior research that a strong knowledge community can only be formed over a lengthy period of time (i.e., over weeks and months) around a shared set of knowledge and experiences, rather than in the short time frame in the enactment of the two studies described above. However, these short studies granted us the opportunity to look for evidence of how students might use real-time collective knowledge in various representations and how its use would form a cohesive community of learners. Examining student interactions from both studies, we gained valuable insight regarding the importance of i) representing clear, defined expertise or roles for students or groups of students to undertake; ii) providing clear and persistent representations of the community's knowledge base; and iii) focusing on a rich learning context to guide collaborations. Individuals and/or groups that assume distinct roles strengthen the collective knowledge base, possibly by imparting students with a sense of identity and ownership within the community. The presence of clear and persistent representations of the knowledge base provides students with concrete evidence of their shared knowledge, however dynamic the knowledge may be, and allow ideas to be built upon. Moving forward within the larger research program, our team will apply the findings from these initial studies and investigate more complex pedagogical configurations, involving longer duration curriculum and dynamic changes to the shared knowledge base over time. We will further develop the smart classroom environment and curriculum materials based on our ongoing series of design-oriented studies with a view to extend our basic approach to build knowledge communities for transformative learning.

References

Bereiter, C., & Scardamalia, M. (2003). Learning to work creatively with knowledge. In E. De Corte, L. Verschaffel, N. Entwistle, & J. van Merriënboer (Eds.), *Powerful learning environments: Unraveling basic components and dimensions* (Advances in learning and instruction series, pp. 55-68). Oxford, UK: Elsevier Science.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences*, *2*(2), 141-178.

Brown, A. L., & Campione, J. C. (1990). Communities of learning and thinking, or a context by any other name. In Kuhn, D., (Ed.), *Developmental Perspectives on Teaching and Learning Thinking Skills*, (vol 21, pp. 108-126). Basel, NY: Karger.

Brown, A.L., & Campione, J.C. (1996). Psychological theory and design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education* (pp. 289-325). Mahwah, NJ: Lawrence Erlbaum Associates.

De Wever, B., Van Keer, H., Schellens, T., & Valcke, M. (2009). Structuring asynchronous discussion groups: the impact of role assignment and self-assessment on students' levels of knowledge construction through social negotiation. *Journal of Computer Assisted Learning*, 25, 177-188.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, *32*(1), 5-8.

Dillenbourg, P., & Tchounikine, P. (2007). Flexibility in macro-scripts for computer-supported collaborative learning. *Journal of Computer Assisted Learning*, *23*(1), 1-13.

Hasemann, K. & Mansfield, H. (1995). Concept mapping in research on mathematical knowledge development: Background, methods, findings, and conclusions. *Educational Studies in Mathematics*, *29*, 45-72.

King, A. (1999). Discourse patterns for mediating peer learning. In A. M. O'Donnell & A. King (Eds.), *Cognitive perspectives on peer learning* (pp. 87-117). Mahwah, NJ: Lawrence Erlbaum Associates.

Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., & Fischer, F. (2007). Specifying computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning*, *2*(2–3), 211–224.

Kollar, I., Fischer, F., & Slotta, J. D. (2007). Internal and external scripts in computer-supported collaborative inquiry learning. *Learning & Instruction*, *17*(6), 708-721.

Linn, M. C., & Eylon, & B. - S. (2006). Science education: Integrating views of learning and instruction. In P. A. Alexander, & P. H. Winne (Eds.), *Handbook of Educational Psychology* (pp. 511–544). Mahwah, NJ: Lawrence Erlbaum Associates.

Partnership for 21st Century Skills. (2009, December). *Framework for 21st Century Learning*. Retrieved October 15, 2010, from http://www.21stcenturyskills.org/documents/P21_Framework.pdf

Penuel, W. R., Roschelle, J. & Shechtman, N. (2007). Designing formative assessment software with teachers: An analysis of the co-design process. *Research and Practice in Technology Enhanced Learning*, *2*(1), 51-74.

Peters, V. L., & Slotta, J. D. (2009). Co-designing curricula to promote collaborative knowledge construction in secondary school science. In C. O'Malley, D. Suthers, P. Reimann, & A. Dimitracopoulou (Eds.), *Proceedings of the Computer Supported Collaborative Learning (CSCL) Conference* (pp. 204-213). International Society of the Learning Sciences (ISLS).

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., Kyza, E., Edelson, D., & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *Journal of the Learning Sciences*, *13*(3), 337-386.

Rummel, N., & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting collaborative problem-solving in computer-mediated settings. *Journal of the Learning Sciences*, *14*(2), 201-241.

Rummel, N., & Spada, H. (2007). Can people learn computer-mediated collaboration by following a script? In F. Fischer, H. Mandl, J. Haake, & I. Kollar (Eds.), *Scripting computer-supported communication of knowledge: Cognitive, computational and educational perspectives* (pp. 39–55). New York: Springer.

Rummel, N., & Weinberger, A. (2008). New challenges in CSCL: Towards adaptive script support. In G. Kanselaar, V. Jonker, P.A. Kirschner, & F. Prins, (Eds.), *International perspectives of the learning sciences: Cre8ing a learning world. Proceedings of the 8th international conference of the learning sciences* (pp. 338–345). Utrecht, NL.

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

Scardamalia, M., & Bereiter, C. (1996). Computer support for knowledge-building communities. In T. Kotchmann (Ed.), *CSCL: Theory and practice of an emerging paradigm.* Mahwah, NJ: Lawrence Erlbaum Associates.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 97-118). New York: Cambridge University Press.

Slotta, J. D. (2010). Evolving the classrooms of the future: The interplay of pedagogy, technology and community. In Mäkitalo-Siegl, K., Kaplan, F., Zottmann, J. & Fischer, F. (Eds.). *Classroom of the Future: Orchestrating collaborative spaces* (pp. 215-242). Rotterdam: Sense.

Slotta, J. D., & Peters, V. L. (2008). A blended model for knowledge communities: Embedding scaffolded inquiry. *Proceedings of the 8th international conference on international conference for the learning sciences*, 2, 343-350.

Stegmann, K., Weinberger, A., and Fischer, F. (2007). Facilitating argumentative knowledge construction with computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning, 2*, 421-447.

Wecker, C., & Fischer, F. (2007). Fading scripts in computer-supported collaborative learning: The role of distributed monitoring. In C. A. Chinn, G. Erkens, & S. Puntambekar (Eds.), *Proceedings of CSCL 2007: Of mice, minds and society* (pp. 763–771). New Brunswick, NJ, USA.

Weinberger, A., Ertl, B., Fischer, F., & Mandl, H. (2005). Epistemic and social scripts in computer-supported collaborative learning. *Instructional Science, 33*, 1-30.