Co-Designing Collaborative Smart Classroom Curriculum for Secondary School Science

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Abstract:

The everyday lives of children are increasingly being shaped and mediated by technology; and yet, the schools tasked with educating these children have been largely untouched by the evolving digital landscape. In response to this challenge we have begun development of a “smart classroom” framework that embeds technology directly into the design of the curriculum proving exciting new avenues for coordinating students, curriculum, and contexts alike. In addition, the ability to digitally collect, aggregate, and report on the products of student interaction in real-time can enable teachers to adjust their instruction “on the fly” to more effectively aid students in overcoming misconceptions or developing deeper understandings of the curriculum under investigation. To address this we have developed, through a series of iteratively co-designed curriculums, a collaborative Physics curriculum for high school and college students. The current curriculum engages students at home individually and in-class in small groups to solve, reflect, discuss, and revisit concept physics problems. Throughout this intervention teachers are provided with real-time information on the students’ work through the use of large format displays and a Teacher Visualization portal, allowing them to dynamically adjust the class script to address student needs. The final stage of data collection will be conducted during a semester long run of the curriculum beginning in Spring 2011, and the researcher hopes that participation in the Red Conference will help in addressing some of the methodological and theoretical challenges of the current project.
Project Goals and Background

The everyday lives of children are increasingly being shaped and mediated by technology; and yet, the schools tasked with educating these children have been largely untouched by the evolving digital landscape (Buckingham, 2007; Tyack and Cuban, 1999; diSessa, 2000). A recent report on cyberlearning (NSF, 2008) concluded that a lack of deliberate efforts to coordinate technology into science and math curriculum could seriously hinder students, in terms of their success in related careers, and more generally in becoming productive members in a modern technological society.

Creating an environment where the production, assessment, and aggregation of content results from the contributions of all members of the community rather than from a single authoritative source, mirrors the types of interactions with technology that students are often faced with outside of the classroom (e.g. Flickr, YouTube, Facebook). Implementing such a “socially oriented” model of classroom instruction (Ullrich et al., 2008) can enable students to take more active roles in the classroom environment and to become creative producers of their own curriculum content (Buckingham 2007; Ito et al., 2009). Introducing digital media into the learning environment can free students from traditional “canned lab” approaches, and embed problem solving activities in more deeply collaborative curriculum (Slotta & Linn, 2009; Soloway et. al, 1999). Complicating the successful integration of these kinds of technologies into classroom curriculum is that most educators are not sufficiently familiar with new pedagogical models of technology-enhanced learning (Ertmer, 1999; Slotta and Linn, 2009). Additionally, those developing technology environments for learning often do not have the pedagogical understanding to develop effective applications for their products (i.e., the use of “smartboards” and clickers, which are typically left to the teachers to determine how best to use them). This issue can be particularly problematic if not properly implemented due to the significant costs in both resources and class time in introducing these kinds of environments into a classroom setting.

In response to this challenge a central goal of this research is to bridge the gap between technology and pedagogy, working closely with teachers, in the development of learning spaces that harness technology to provide powerful new opportunities for students and teachers alike.

My dissertation is investigating these new forms of learning in classroom communities, supported by a “smart classroom” framework for coordinating students, curriculum, and contexts. The description below begins with a discussion of the theoretical perspective underlying this research, followed by a description of the technology environment that has been constructed to enact the research, and finally a description of the various iterations of the curriculum under investigation, including a description of the data collected and challenges to my analysis.

Scripting Learning Across Contexts

Developing curriculum in a technology enhanced learning environment can allow for the real-time tracking of the products of student interaction across a variety of contexts (formal/informal environments) and configurations (individual/small group/whole class interactions), giving teachers and researchers new opportunities to design the ways in which students interact with the curriculum. The intentional orchestration of the nature and timing of activities, as well as the particular roles that each student plays within the larger curriculum is often compared to that of a theatrical script (O’Donnell & Dansereau, 1992). To be effective, the design of these scripts must take into account the unique contexts in which each of these activities takes place. Individual actions – such as asking a question, answering a question, and the evaluation of answers – may all take place at different times and locations, effecting how students understand and process an activity (Lemke, 2000). Careful scripting of a curriculum can help insure that the natural granularity of the individual tasks matches the granularity that is most beneficial to student learning (Dillenbourg & Jerman, 2007). Scripting can also build time and opportunities for reflection (O’Donnell & Dansereau, 1992) which not only help students build their own personally relevant understandings from their educational experiences (Bransford et al., 1999; Krajcik et al., 2008; Linn and Eylon, 2006), but can also provide rich data for teachers to gain insight into students’ understandings of the curriculum. Access to student ideas during instruction can allow teachers to adjust their instruction “on the fly” to more effectively aid students in overcoming misconceptions or developing deeper understandings of the curriculum under investigation (Dillenbourg & Jerman, 2007).

Knowledge Building and Scaffolded Inquiry: A KCI Approach

The concept of Knowledge Building, where students work in collaboration with their peers and teachers in the formulation of their learning goals and the ways in which they will reach them, have been in development for more than two decades (Brown & Campione, 1996; Brown, 1988; Palincsar & Brown, 1984). An example of this form of learning can be seen in Fostering Communities of Learners (FCL) (Brown & Campione, 1996), where students were presented with carefully chosen aspects on a topic of inquiry and then required share their understanding with the rest of the class. This sharing of knowledge was achieved through a series of activities that placed the responsibility of mastery of the content on the whole class allowing them to grow together as a “knowledge community.” Similarly, Scardamalia and Bereiter (1996, 2002) developed a knowledge building approach that places the student community at the center of the development of a shared knowledge base. The
process whereby this knowledge base is constructed, through the constant revision, refinement, and expansion of ideas by the community, supports students in the development of intentional learning, which in turn supports their development as autonomous learners (Bereiter & Scardamalia, 1989).

Building on these two ideas, with the aim of adding an additional layer of scaffolded inquiry is the model of Knowledge Community and Inquiry (KCI) (Slotta, 2007; Peters & Slotta, 2010). In scaffolded inquiry, students are often engaged in activities where the delivery of materials and the coordination of activities and interactions are often mediated by technology environments (Linn, Husic, Slotta & Tinker, 2007; Slotta & Linn, 2000). By combining the concepts of knowledge community with scaffolded inquiry, KCI aims to focus the goals of knowledge construction towards specific curriculum learning adjectives.

The goal of this project is to apply and extend the notions of the KCI model through the development of a technology space that leverages the ability to aggregate the growth of the collaboratively constructed knowledge base towards helping the students develop a deep understanding of the broader curriculum. In this way the cumulative product of the students’ knowledge can be leveraged across a semester or even across scholastic years. In essence, the more knowledge that is placed in the knowledge base the more powerful a tool for student learning it becomes.

Co-design

Successfully integrating technology into a curriculum is no easy task, and is further complicated by the specific constraints and requirements of the teachers who are tasked with enacting the curriculum. The success of any research of technology-enhanced learning is therefore critically dependent on the teacher’s own investment in, and understanding of, the proposed intervention. The best way to achieve this “buy-in” by the teachers is to employ a co-design approach (Penuel et al., 2007), where researchers and teachers work in tandem to develop all of the curricular materials and the flow of activities. The use of such an approach also gives both the researchers and the teachers a deeper understanding of the values and perspectives of the other. This can also ensure that the materials being developed are not simply tools for research but are also suitable for teachers’ curricular goals (Peters & Slotta, 2007). This is especially critical in a long running iterative project because of the tensions that commonly arise between the various participants. Through the co-design approach these tensions can be harnessed to increase agency, reflections, and ownership by the teacher – a critical aspect to prolonged success and adoption of a research design (Roschelle, Penuel, & Schechtman, 2006).

Developing a technology rich learning environment

New forms of knowledge media and data repositories offer a wealth of opportunity for researchers and curriculum designers who can take advantage of the varying contexts (i.e., within the classroom, at home, or in field activities) and devices (e.g., laptops, smartphones, interactive table tops, and large format displays). This new functionality allows for exciting new kinds of instruction where students collaborate across contexts, dynamically generate knowledge, build on peers’ ideas, and investigate questions as a knowledge community.

My research recognizes the potential of technology enhanced learning environments to enable such pedagogical models. I have helped to advance the notion of a “smart classroom,” which employs a wide range of technologies for investigating a full spectrum of collaborative inquiry and knowledge construction activities. The work centers around the development of a powerful, flexible open source platform called SAIL Smart Space (S3), which in turn builds on the rich framework of SAIL (Scalable Architecture for Interactive Learning – Slotta & Aleahmad, 2009). S3 specifies a framework in which devices and displays are configured, building on a set of core underlying technologies: (1) a portal for student registration and software application management; (2) an intelligent agent framework for data mining and tracking of student interactions in real time; (3) a central database that houses the designed curriculums and the products of student interactions; and (4) a visualization layer that controls how materials are presented to students on various devices and displays (Slotta, 2010). The current S3 smart classroom implementation involves 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 (Figure 1).

![Figure 1: S3 Smart Classroom Setup](image-url)
**First Pilot**

In order to understand the necessary functions of the environment, as well as to establish a good co-design method would result in curriculum that engaged students in the smart classroom a pilot study was conducted in the summer of 2009. The co-design team included a mathematics teacher, three researchers, and two technologists. Student participants were 19 grade twelve students. This team worked in collaboration with several technology developers, to create a functional smart classroom environment that would support the organization, movements and activities of a high school mathematics class as they engaged with topics in rich visual displays, with an emphasis on the role of semantic metadata, in the form of social “tags” or keywords, that were applied to a set of qualitative mathematics problems.

**Design/Procedure**

The curriculum project responded to the math teacher’s concern that students did not grasp the interconnections between branches of mathematics, instead perceiving math as consisting of discrete elements (e.g., Algebra, Graphing Functions, Polynomials, and Exponentials) as represented in textbook chapters. On a pre-test (see Figure 2), students made far fewer connections between problems than the teacher, and varied widely in the connections they did make.

Students individually logged into laptops, were automatically grouped (i.e., by the room), assigned to one of the room’s visualization displays, and asked to “tag” (label) a total of 30 questions. Each group’s display showed a graphical visualization of their responses. Students were then asked to collaboratively solve their tagged questions and vote and comment on the validity of other groups’ tags. A central display showed a larger real-time aggregate of all groups’ tags as a collective association of links (see Figure 3). As students voted on these tags, positive votes resulted in thicker link lines than those that fostered disagreement.

**Findings**

An important outcome of this study was the curriculum itself. Our design successfully engaged students in a collaborative, distributed, mathematics learning activity that leveraged technology and visualizations: no small feat. In post-interviews, one student noted that the availability of the macro-visualization allowed him to understand and solve a problem that had previously eluded him. Students also articulated the functional connections to questions - something they do not often normally do when solving problems. Furthermore, The math connections students made more closely corresponded with those of the teacher; and, the high variability of students’ connections within individual problems observed during the pre-test was seen to diminish dramatically during the curriculum and on a subsequent post-test (Tissenbaum & Slotta, 2009).

**Second Pilot**

Our second implementation of S3 involved two grade 12 Physics classes (n =32), engaged in a similar activity, but with adaptations that responded to the finding from the previous cycle, while extending the design to the domain of physics problem solving. For this iteration the co-design team consisted of three physics experts, a high school physics teacher, four researchers, and three technology developers. The activity was conducted over two days with to different instructional conditions and sixteen students in each condition.
Design

The curriculum placed students in four groups as they worked synchronously to individually answer and tag, from a list of expert-defined element tags (i.e., Newton’s first law, net force, kinetic energy, etc.), a set of sixteen multiple-choice concept based physics questions. All questions belonged to four distinct themes: 1) Kinetic energy and work; 2) Potential energy & conservation of energy; 3) Force & motion; 4) Circular motion. Once the first step was completed, students remained in their groups and were shown four of the sixteen questions along with the aggregate of the all answers that had been posted (from the wider class) to those problems. They were then asked as a group to form a consensus concerning a “final answer,” a final set of tags, and a rationale for their choices (See Figure 4). Upon completion of the group reviewing of the concept questions, four complex, quantitative physics problems we presented to each group. For each long problem each group was asked to select from a list of four of concept problems, from the previous step, 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. Between the two interventions a special condition was imposed: during the first day’s activity the student groups collaborated around a single shared laptop; on the second day each groups’ work was shown on the large format displays in front of them.

Data Sources

Data were drawn from four sources: (1) All answers, tags, and rationales were captured by the system; (2) Video recordings of the overall curriculum activity; (3) researcher field notes were collected; (4) Follow-up debriefing with the co-design teacher. The combination of the field notes and video capture provided us with insight into how the design of the smart classroom facilitated the curriculum enactment, student collaboration, and teacher intervention. The follow-up debriefing added to our understanding of the co-design process and the teacher’s perceived match of the intervention to their curricular goals. The captured student data was analyzed to determine changes in their correct answers as individuals versus groups, and to determine the accuracy and structuredness scores of their element tagging.

Findings

When examining the accuracy and structuredness of the element tagging the students working in groups across both classes tagged their problems closer to the expert model than as individuals (Figure 5). Average accuracy scores were 80.94% (groups) compared to 76.57% (individuals), although the difference was only marginally significant. In terms of structuredness, groups (69.73%) significantly outperformed individuals (50.11%) by 19.62%, \( F(1, 30) = 10.756, p = 0.003 \) (Lui, Tissenbaum & Slotta, submitted). The second examination concerned the results of the varied group display conditions. Although in both conditions better group performance was attained versus individual performance, the shared display groups showed higher gains in their correct answers (from 50% to 81.25%) as compared with the group who used only laptops (from 60.38% to 69.23%) (Figure 6). One possible explanation is that the large format displays provided the teacher with the ability to see what students were writing in their summary responses, and engage them in meaningful interactions. For example, in one episode, the teacher was watching one group discussing the aggregated answers of the class and saw that no students from the individual phase had approached the problem correctly. In other words, the aggregate data was completely incorrect! The teacher was able to adapt the script, advising students (in this case) not to listen to “the wisdom of the crowd.”
Dissertation Study

Results from the two pilots are encouraging, as they demonstrated that the co-designed curriculum could engage the students as a knowledge community while helping them understand and overcome conceptual misconceptions, and develop strategies for solving more complex problems. The pilot physics activity has now been extended to run as a part of the regular classroom activities in two college classes, which is being used a final pilot towards a full semester-long run of the same design for data collection during the Spring 2011 semester. The co-design team for the Spring Physics run will expand from one Physics teacher to two, adding the perspective of another experienced science teacher. Participants will include approximately 60 grade eleven students from an urban high school in a large North American city. The students will be divided evenly between two Physics classes, each taught by one of the two teachers. All 60 students will be provided with their own unique login and password to aid in the tracking of individual interactions within the space. All descriptions below are based on the current, final pilot curriculum being used with the collegiate level classes.

Design and Procedure

All curriculum materials have been designed and regularly revised by the co-design team throughout the pilot studies. Regular weekly meetings are held with the co-design team over Skype (and in person when possible), and recorded in a combination of a wiki design space and a shared Google Doc (a web-based collaborative document tool). In the smart classroom, each student is supplied with a laptop connected to the wireless network. This arrangement allows students to move freely about the classroom for purposes of grouping and collaboration. Additionally, the teacher is equipped with their own laptop from which they can access the real-time class reports and lesson customization tools.

There are two main goals for the co-designed curriculum to be used in the dissertation study. The first is to aid students in collaboratively negotiating a shared understanding of the content as a way of overcoming novice misconceptions of the curriculum, and then applying this understanding to the solution of more complex problems. In order to achieve this goal, the co-design team (currently engaged in the meeting and design process) will create a curriculum that works in conjunction with the teachers’ regular course designs over 13 weeks. This curriculum will weave individual student problem solving at home with scripted in-class group work and discussion, in addition to an array of other instructional activities that have been used in previous years by the teachers. The in-class activities reported here will comprise about 20 percent of the total class time within the unit. The homework activities will comprise about 70 percent of the out of class homework activities within the unit.

The second goal is to enable the teacher to adjust the class script based on the information received by the system. To this end, the smart classroom has been further enhanced by adding a “teacher portal” to support the customization of curricular activities, access visual representations of all individual and group activities in real-time, and adjust lesson plans “on the fly” without any technical help from the research team. Of particular interest in this stage of the research will be how the teacher benefits from access to students’ collected homework responses, presented in a report prior to the class and accessed through an online teacher portal (i.e., in the development of that day’s lesson plan). Below I detail the flow of activities within the curriculum, followed by a discussion of the planned data sources and analysis.

Individual Problem Solving Stage:

Before each class session, the teacher will be able to log into the design space and upload the questions to be given to the students (see Figure 7) – these questions can be deleted or added at any time until the students begin solving them (this condition was set to ensure that all the students are answering the same question set). At the end of each class, all 60 students will be asked to solve the questions uploaded by the teacher as homework. In addition to solving the questions students will be required to provide a brief reflection on why they chose the answer they did, and then to select from a list of predefined (by the teacher) element tags those
that best apply to that particular question (see Figure 8). All of the individual students answers, reflections, and tags will be collected and uploaded to the server and the aggregate of the students’ responses will be available to the teacher at any time (see Figure 9). In this way when planning the next class’ lesson the teacher can adapt it to address any conceptual misconceptions the class may have.

Collaborative group work

When in class, the teacher has the flexibility within the script to either offer a short, targeted lecture that clarifies concepts that students may have shown difficulties with, or to have students go right into the group work activity. During this activity, students are grouped and placed throughout the room in front of one of the large format displays and are presented with a interface showing all the student answers from the homework. Students are prompted to click on the graph bars representing the number of students who chose each multiple choice option, and upon doing so are given a histogram showing the element tags that students who chose that answer assigned to the problem. Students are also given a list of all of the rationales that students provided for choosing that multiple choice answer (see Figure 10). Students are then tasked to discuss within their groups which answer seems the most correct, submit their “final” group answer, element tags, and rationale for choosing those elements. Each question that was assigned is completed in turn, but are designed so that the teacher can stop the students between questions in order to engage the students in discussion or to correct any lingering misconceptions. The teachers are enabled in understanding these misconceptions and other reasons for intervention in real-time through their ability to see the student work pages (on the large screen displays as in the second pilot) and on the Teacher Visualization discussed above.

Upon completion of the group work task, the teacher once again has an opportunity to engage the students in discussion by bringing the Teacher Visualization for the group activity up for the whole class to see on the central display. A web page is then generated which shows the correct answer for each multiple-choice problem, the elements that were selected by groups that chose that answer and finally a long-format challenge problem that leverages the concepts addressed in the homework problems. The teacher then has the option of assigning the challenge problem as homework or having the students solve it in class – in the case of assigning the problem as homework the teacher can email the generated webpage to all of the student in the class.

Data Sources and Analysis

Data will be obtained from the following sources: Teachers’ journals taken each day recording any resulting design revisions to that day’s lesson; all student recorded data from the interventions (both individual and group); student focus groups; and scores from the mid-term knowledge quiz and final exam. Teacher interviews will also be conducted by the researcher.
Students’ learning outcomes will be measured by examining changes in accuracy of problem solving and tagging activities, as compared with the teacher’s expert model, throughout the intervention. These measures, together with a content analysis (Chi, 1997) of student reflections will help to reveal in the development of students’ understandings of relevant science topics. The impact of these innovations on the teacher’s classroom practices will be evaluated in terms of instructional changes that were made before, during and after the classroom sessions, including an analysis of when and how often teachers made changes to the curriculum “on the fly,” as well as the content of their interactions (captured on videotape) with students.

Focus for the Red Conference

Given that the data collection will be conducted during the period in which this consortium will occur, it would be timely to discuss the analytic approach and other possible advice on analyzing the rich qualitative data that is being generated by the teachers’ reflections. In particular, the research would benefit greatly from discussion regarding the specific form-function modeling technique advanced by Saxe (1991), as well as general strategies for the coding of the student reflections and interpretation of the findings within the theoretical framework of the study. I would also like to present the analyses conducted in the earlier pilot studies (i.e., of connectedness and structuredness) in order to get a sense of their generalizability to the more complex tasks used in the current physics curricula. Specific methodological and theoretical challenges are outlined below:

Methodological Challenges: I will benefit greatly from the opportunity to discuss with mentors and peers how I can show that students are gaining a better understanding of the content (i.e., beyond that which they would get from normal class activity) by analyzing their reflections and scores. What can the large set of individual student reflections stored over the curriculum reveal about students’ progress, and the role of the wider knowledge community? When the response of the group to the short answer problems is different from that of individual students, what happens to the individuals’ conceptualization? How can I address such questions with the data from student reflections? How does the teacher contribute to a knowledge community through his engagement with the students’ aggregated responses and reflections? How can I interpret the teacher’s actions based on data logs, and their impact on student ideas?

Theoretical Challenges: This research combines elements of two theoretical constructs: knowledge communities and scripted inquiry, to investigate a new pedagogical model known as knowledge community and inquiry (KCI). This work will specifically address the challenge of incorporating all student responses from the class into a dynamic community knowledge base that serves as a relevant, accessible resource to students and teacher alike. This design will allow me to investigate the complex ways in which a teacher can access and adapt to the combined ideas of the students. Additional questions will address the implications of making the existing and stored student data from previous iterations available to the teacher – how could this be used to inform or aid in the next year’s course offering (either as a resource for students or for the teacher)? In general, this work is poised to make contributions to this theoretical perspective, but I will benefit greatly from discussions about how to connect my specific interventions to the KCI model.

Figure 10: Student group review page
References


