Innovations for Online Collaborative Learning in Mathematics

Rodney Nason
Queensland University of Technology, Australia

Earl Woodruff
OISE - University of Toronto, Canada

INTRODUCTION

The field of computer-supported collaborative learning (CSCL) has been growing in a number of areas and across a number of subjects (Koschmann, 1996; Koschmann, Hall, & Miyake, 2002; Wasson, Baggetun, Hoppe, & Ludvigsen, 2003). One of the most promising pedagogical advances, however, for online collaborative learning that has emerged in recent years is Scardamalia and Bereiter's (1996) notion of knowledge-building communities. Unfortunately, establishing and maintaining knowledge-building communities in CSCL environments such as Knowledge Forum® in the domain of mathematics has been found to be a rather intractable problem (Bereiter, 2002b; Nason, Brett, & Woodruff, 1996). In this chapter, we begin by identifying two major reasons why computer-supported knowledge-building communities in mathematics have been difficult to establish and maintain.

1. The inability of most "textbook" math problems to elicit ongoing discourse and other knowledge-building activity
2. Limitations inherent in most CSCL environments' math representational tools

Therefore, in this chapter, we argue that if mathematics education is to exploit the potentially powerful new ways of learning mathematics being provided by online knowledge-building communities, then the following innovations need to be designed and integrated into CSCL environments:

1. authentic mathematical problems that involve students in the production of mathematical models that can be discussed, critiqued, and improved, and
2. comprehension-modeling tools that (a) enable students to adequately represent mathematical problems and to translate within and across representation modes during problem solving, and (b) facilitate online student-student and teacher-student hypermedia-mediated discourse.

Both of the above innovations are directed at promoting and sustaining mathematical discourse. The requirement that the mathematical problems need to be authentic ensures that the students will have the contextual understanding necessary to promote a discussion about the mathematical models. Comprehension-modeling (Woodruff & Nason, 2003) further promotes the discourse by making student understanding yet an additional object for discussion.

Most textbook math problems do not require multiple cycles of designing, testing, and refining (Lesh & Doerr, in press), and therefore do not elicit the collaboration between people with special abilities that most authentic math problems elicit (Nason & Woodruff, 2004). Another factor that limits the potential of most textbook math problems for eliciting knowledge-building discourse is that the answers generated from textbook math problems do not provide students with much worth discussing (Bereiter, 2002b).

Another factor that has prevented most students from engaging in ongoing discourse and other mathematical knowledge-building activity within CSCL environments is the limitations inherent in their mathematical representational tools (Nason et al., 1996). Most of these tools are unable to carry out the crucial knowledge-building functions of (a) generating multiple representations of mathematical concepts, (b) linking the different representations, and (c) transmitting meaning, sense, and understanding.

Two clear implications can be derived from this review of the previous research. First is that different types of mathematical problems that have more in common with the authentic types of mathematical problems investigated by mathematics practitioners than most existing types of textbook math problems need to be designed and integrated into CSCL environments. Second, a new generation of iconic mathematical representation tools also needs to be designed and integrated into CSCL environments. In order to differentiate these tools from previous iconic math representation tools, we have labeled our new generation of tools as comprehension-modeling tools.

Each of these two issues will be discussed in the next two sections of this chapter.

AUTHENTIC MATH PROBLEMS

Credence for the viewpoint that the integration of more authentic types of mathematical problems into CSCL environments may lead to conditions necessary for the establishment and maintenance of knowledge-building activity is provided by the findings from two recent research studies conducted by the coauthors. Although both of these studies were situated within elementary schools, it should be noted that the same math problems used in these research studies could also be used within online CSCL environments to facilitate the development of mathematical subject-matter knowledge in high school students and preservice teacher-education students. Therefore, we believe that the findings from these two studies have much relevance for the establishment and maintenance of math knowledge-building communities not only in elementary schools, but also in secondary school and higher education institutions, too.

In a series of research studies, Nason, Woodruff, and Lesh have been investigating whether having students engage in model-eliciting mathematical problems with collective discourse mediated by Knowledge Forum would achieve authentic, sustained, and progressive online knowledge-building activity. In this section, we focus on two of these research studies.

In the first of the research studies (Nason & Woodruff, 2004), 21 students in a Grade-6 class at a private urban Canadian school for girls were asked to devise an alternative model that could be used for ranking nations' performance at the Olympic games that de-emphasized the mind-set of "gold or nothing." In the second research study (Nason, Woodruff, & Lesh, 2002), 22 students in another Grade-6 class at the same school were asked to build a model that could help rank Canadian cities in terms of quality of life.

In both studies, the students were initially presented with an article setting the scene for the model-eliciting activity and a set of focus questions based on the article. After this 45-minute warm-up activity, the students went through the phases of (a) initial model building (Phase 1, one session of 45 minutes), (b) sharing of initial models (Phase 2, one session of 45 minutes), and (c) iterative online critiquing and revision of models within Knowledge Forum (Phase 3, four sessions of 45 minutes). The sharing of the initial models in Phase 2 was done face to face within the classroom. After the face-to-face sharing of the initial models had been completed, each group attached their math model to a Knowledge Forum note where it could be viewed and evaluated by other participants within the online CSCL community. During the online critiquing and revision of models in Phase 3, Knowledge Forum provided the contexts and scaffolds for intergroup online discourse.

Five important elements of activity consistent with Scardamalia's (2002) principles of knowledge building were observed during the course of these two studies.

1. Redefinition of the problems, which highlights Scardamalia's principles of improvable ideas and rising above
2. Inventive use of mathematical tools, which highlights Scardamalia's principle of improvable ideas
3. Posing and exploration of conjectures, which highlights Scardamalia's principles of idea diversity and knowledge-building discourse
4. Collective pursuit of the understanding of key mathematical concepts, highlighting Scardamalia's principles of community knowledge and collective responsibility
5. Incremental improvement of mathematical models, which highlights Scardamalia's principle of improvable ideas

Much of the success in establishing and maintaining the online mathematics knowledge-building communities in these two studies can be attributed to the rich context for mathematical knowledge-building discourse provided by the model-eliciting problems. In both problems, students were required to produce a mathematical model for issues that the students found meaningful and relevant. Therefore, they were willing to proceed through multiple cycles of developing, evaluating, and revising their models. This process of proceeding through multiple cycles encouraged much online discourse between the groups in each classroom. The model-eliciting problems also had many different possible solutions. Because of this, there was much heterogeneity in the initial models produced by the groups of students. In order to understand other groups' models and also to explain their own model to other groups, each group had to engage in much iterative online discourse with other groups. During this discourse, they had to ask good questions, propose how other groups' models could be improved, and elaborate on and/or modify their explanations. Finally, the models themselves provided students with artifacts that could be discussed, evaluated, compared, and improved (just like the artifacts built by mathematics practitioners). Unlike the answers produced in most textbook problems that tend to only enable discourse about correctness (or incorrectness), the models produced from the model-eliciting problems were artifacts that could be evaluated

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