Chapter 2.14
Innovations for Online Collaborative Learning in Mathematics

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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 math-

ematical models that can be discussed, critiqued, and improved

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

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