Using Chat, Whiteboard and Wiki to support knowledge building

Gerry STAHL[1], Juan Dee WEE[2] , Chee-Kit LOOI[3]
[1]Drexel University, Philadelphia, USA
[2]National Institute of Education, Singapore
Gerry.Stahl@drexel.edu, JohnWee@pmail.ntu.edu.sg, Cheekit.Looi@nie.edu.sg

ABSTRACT

The Virtual Math Teams (VMT) knowledge building environment has been used in Singapore and in the United States. It includes support for synchronous, quasi-synchronous and asynchronous online interaction using text chat, whiteboard drawing and wiki summarization. It has been used for groups of students to collaborate on challenge problems in mathematics, on sequences of math curriculum and on whole courses. In this paper, we discuss the design of topics and activities to encourage innovative knowledge building by individuals, small groups and whole classes.

Keywords

Knowledge building, mathematics, text chat, social interaction

INTRODUCTION

The idea of providing computer support for students in school classrooms to build knowledge collaboratively by developing textual knowledge artifacts—much as research communities do with their conference and journal papers—was first proposed by Scardamalia & Bereiter (1994) in connection with their CSILE software. Subsequent analyses of knowledge building in classrooms often focus on the use of CSILE or its successor, Knowledge Forum (Scardamalia & Bereiter, 2006). However, these are asynchronous discussion forums. We have found that discourse among students can be more engaging in synchronous text chat, given the proper context. In particular, the Virtual Math Teams (VMT) environment has been designed to foster collaborative knowledge building by supporting chat in small groups of students. In this paper, we look at how the VMT system has evolved through a design-based research effort to promote knowledge building discourse among math students.

Many countries have recently made commitments to re-orienting their educational systems more strongly toward the development on creative thinking and deep understanding. Educators and researchers in places like Singapore and Hong Kong—as well as Scandinavia and Canada—have turned to computer-supported approaches using Knowledge Forum and similar software to achieve this transformation. In this paper, we primarily report on trials using VMT in Singapore. Near the end of the paper, we briefly describe some trials with VMT in the USA that suggest ways to move even further toward a pedagogy of creativity, deep learning, collaborative knowledge building and group cognition.

1. EVOLUTION OF THE VMT ENVIRONMENT

Starting in 2003 from a simple text chat system, the VMT environment has grown to incorporate a shared whiteboard and even a wiki, with many features to support math problem-solving, social networking and communication. The system has been used by students during a number of events organized by researchers at the Math Forum in Philadelphia. Over a thousand student-hours of chat logs have been recorded. During the past year, VMT has started to be used by researchers elsewhere, including in Singapore. The VMT service has been developed to meet the needs of students engaged in collaborative online math problem solving, as well as those of researchers interested in studying such activities.

Figure 1 shows the VMT chat room. The math problem is posted on the shared whiteboard by the teacher or otherwise via the "Workspace" tab. The "Summary" tab functions as an alternative location for students to post their work or summarize the discussion. Content information pertaining to the problem is made available under the "Topic" tab. The "Wiki" tab allows the group to post information that is found to be useful after the discourse. The "Help" tab accesses the VMT user guide.

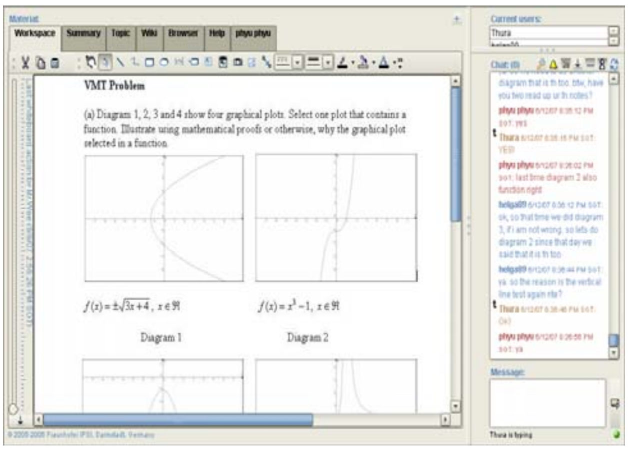

Figure 1: VMT chat room.

2. USE OF VMT IN A SINGAPORE JUNIOR COLLEGE LUSTRATIONS

2.1 H2 mathematics - VMT curriculum framework

The Singapore Ministry of Education revamped the ‘A’ level curriculum for 2006 to one (H2 mathematics) that places more emphasis on thinking and communicating (MOE, 2005). The mathematics syllabus had a 10-15% reduction in curriculum content, giving students increased opportunity to reflect and explore problems critically. Stein & Henningsen (1997) argued that it is important for a classroom environment to engage students actively in deep conceptual mathematical activity, to develop their ability in mathematical reasoning. The VMT online environment complements the Ministry's new initiative. It serves as a useful platform for exploration of mathematical ideas, creating opportunities for students to construct and manipulate representations in order to promote their mathematical conceptual understanding (Alagic, 2003). Research studies have shown that collaborative learning is effective in improving academic skills compared to individual study of mathematics (Reglin, 1990; Yetter et al., 2006). The teaching of H2 mathematics supported by the VMT environment allows students to construct mathematical knowledge collaboratively in situations where they are not co-located.

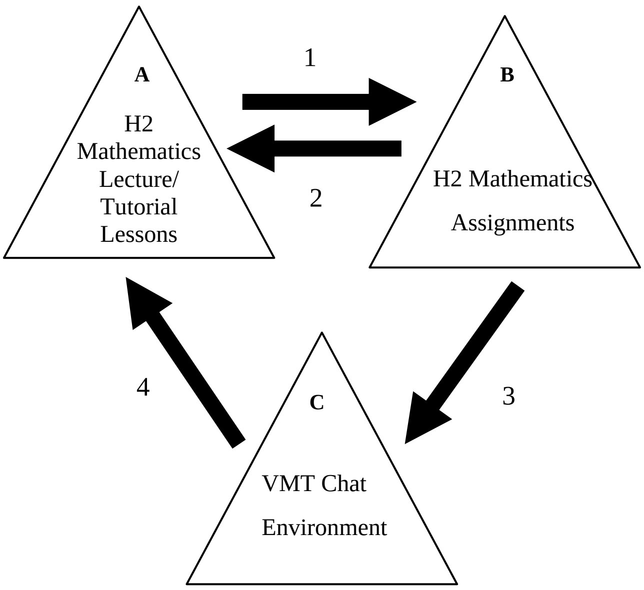

Figure 2: H2 mathematics - VMT curriculum framework.

Figure 2 presents an overview of the H2 Mathematics - VMT Curriculum Framework. Triangle A represents the tutorial/lecture where students learn new mathematics concepts. During tutorials, teachers review mathematical concepts covered in the lectures. Arrow 1 shows students applying the knowledge learned from the lectures/tutorials to solve problems in the assignment. Triangle B represents students applying the learned concepts to solve math problems in assignments. Arrow 2 shows students clarifying doubts with the teacher pertaining to the assignments. Triangle C represents students collaboratively solving math problems using VMT chat. Students form groups to solve mathematical problems similar to those found in the assignment (arrow 3). A focus group session is conducted by the teacher to review the problem-solving process, reinforcing concepts taught earlier (arrow 4) in upcoming tutorial sessions. The teacher, through the focus group session is also able to clarify misconceptions or emphasize learning points from the VMT in subsequent lectures.

2.2 Implementation of VMT trials

A total of 15 teams (45 JC 1 students) from Jurong Junior College participated in the first VMT trials in 2006. Prior to the VMT trials, the students attended training sessions at the college’s computer laboratory. The training sessions provided the students with knowledge to navigate around the VMT environment, type mathematical symbols on the shared whiteboard and explore the functionality of VMT. It was the first time that the students had the opportunity to collaborate to solve math problems online. They were told that working in small groups was an experience of team effort to solve the problem and that it would be especially challenging at the beginning. The teacher implemented chat room rules to ensure cooperation and order among team members. The rules included: ensuring that all members were present before commencing the math problem solving; reading up adequately on the topic before logging onto VMT; understanding that quality of participation depends on cooperation among group members; giving fellow team members time to read the question; showing consideration to fellow team members.

Arithmetic and geometric series problems based on traditional problem designs were posted on the shared whiteboard by the teacher. Here is one such problem:

> *Find an expression for the nth term of the series:*
> 2 + 22 + 222 + 2222 + ….
> *and deduce that the sum of the first n terms of the series is:*
> $\frac{20}{81}(10^n - 1) - \frac{2n}{9}$.

Students are expected to carefully analyze the series 2 + 22 + 222 + 2222 + …. and to use their prior experience in problem solving or formulas to derive the nth term of the series. After that, they are to deduce the expression $\frac{20}{81}(10^n - 1) - \frac{2n}{9}$ using the expressions developed in the earlier part. Students accessed VMT from home to solve the problems. Following the VMT sessions, the teacher conducted interviews with participants to review the problem-solving process in VMT.

In 2007, seven new teams (21 JC 1 students) from the same college participated in the second VMT trials using different problem designs. The next section will describe in detail the different types of problem designs implemented in VMT. Prior to the VMT trials, the students attended training sessions at the college's computer laboratory and explored the VMT chat environment through a *Learner-Centered Project Work* assignment. Students in groups consisting of four to five students took turns to act as facilitators to conduct chat meetings, building knowledge from previous chat sessions. The students then worked in groups of three to solve an open-ended math function problem (see figure 3). The students had the opportunity to use the whiteboard tools to construct graphical plots and state their agreed-upon solutions in the summary page (figure 4).

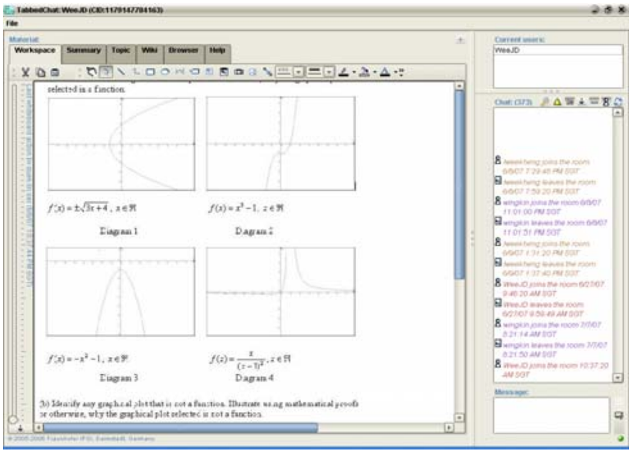

Figure 3: VMT math problem: functions

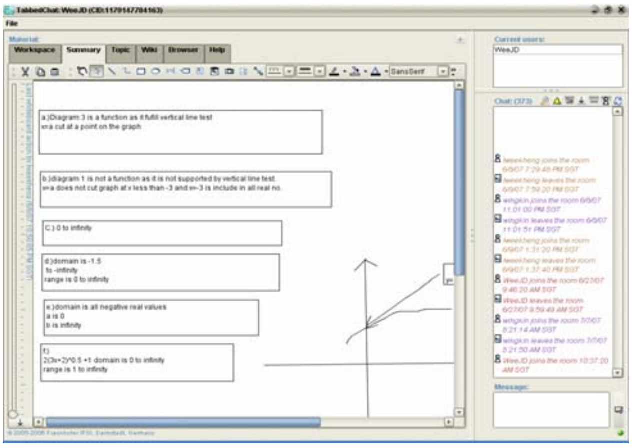

Figure 4: Student solution.

Subsequent VMT activities for these groups required them to focus on discussion of mathematical situations rather than solving a specific problem. Here is one such problem:

> *The functions* f *and* g *are defined* $f : x \to 4x^2 + 3$, $x > 0$ and $g : x \to 3 + e^{-2x}$, $x \in 0$. *With the aid of the graph* $y = f(x)$, *explain why* f *is a 1-1 function. Find* (i) $f^{-1}(x)$ (ii) $f^{-1}g(x)$, *giving the domain of each function.*

Mathematical concepts were explored and developed as the groups interacted, helping students to obtain a deeper conceptual understanding of the structure of the mathematical situations (problem), rather than focusing on the manipulation of symbols and equations in a routine manner.

3. VMT PROBLEM DESIGN IN SINGAPORE

Three different designs were used to construct these VMT problems. The first type is the traditional closed-ended design that leads to a standard solution. The second type is the open-ended problem design. The third design explores the use of strategies to solve the problem, rather than focusing on the solution itself.

3.1 Traditional closed-ended problem (TCEP) design

Initial versions of VMT problems used traditional closed-ended problem design. Such designs were adopted from textbooks in which students had to read a given problem, and the solution led to a standard answer. The reasoning process for solving H2 mathematics TCEP designs is minimal compared to the manipulation procedures used to solve the problems.

3.2 Traditional opened-ended problem (TOEP) design

Subsequent VMT problems were designed to explore the use of traditional open-ended problems to encourage students to reason mathematically about their problem-solving steps. TOEP designs lead to many possible answers. However, such designs are often perceived as not very useful in preparing students for tests and examinations. There is a need to construct problems that not only prepare students academically for examinations but also strengthen their mathematical reasoning in the process.

3.3 Polya's problem-solving strategy design

The latest VMT problem was constructed using a hybrid design which combined the merits of both TCEP and TOEP designs. The problem is first constructed using a TCEP design. Solving the problem requires the first two stages of Polya's four stage problem-solving model (Polya, 1952): (1) understanding the problem and (2) devising a plan to solve the problem. Part of the problem-solving process requires students to justify their approaches taken to solve the problem, thus developing their mathematical reasoning. Students collaboratively explore mathematical concepts taught in class and reason about the feasibility of using them to solve hybrid design type problems.

4. OUTCOMES OF VMT TRIALS IN SINGAPORE

Each VMT problem-solving session lasted an average of 2-3 hours. When solving TCEP designs, most groups were able to solve the initial parts of the problem. However, there were often "breaks" in the problem-solving process where one student obtained the answer and shared it with the rest of the group, but did not appropriately show the problem-solving process on the shared whiteboard. Group members acknowledged with a "yes" to indicate understanding, but there was no explicit evidence to demonstrate this understanding.

Students explored different approaches in TOEP designs. There were situations (in the case of the VMT function problems) when curves were wrongly selected from the start, leading to both unproductive and productive discourse. Although the curve selected was wrong and the students did not obtain any of the possible correct solutions, the group applied appropriate mathematical concepts to justify their work, leading to productive knowledge construction.

In the hybrid design, students were able to explore mathematical concepts learned in the class, discussing possible approaches to the solution. There were instances where students queried their group members on the purpose of the suggested approaches, sprouting a series of mathematical conceptual debates on the whiteboard as well as in the chat.

5. PIVOTAL MOMENTS IN THE COLLABORATION INTERACTION MODEL

Analysis of the logs of the chats at the junior college resulted in the formulation of a "Collaboration Interaction Model" (CIM), which represented the flow of responses of the students to each other (Wee & Looi, 2007). The graphical representation featured certain "pivotal moments" termed *Pivotal Contribution* in the CIM, which exerted major effects upon the progress of the student groups. The emergence of meaning-making patterns leading to the construction of the *Pivotal Contribution* and patterns of knowledge construction diverging from the *Pivotal Contribution* form the basis for analyzing how shared meaning making is achieved at a group level, rather than at an individual level. Pivotal Contributions are currently viewed from the researcher's perspective. On-going work explores how *Pivotal Contributions* can be understood from the participant's perspective, primarily through focus group sessions conducted by the instructor.

A paper presented at ICCE 2005 in Singapore (and given the "best paper" award there) analyzed how pairs of student chat postings often work to sustain the problem-solving work of a small group of online students (Stahl, 2005). One student makes a bid at a math proposal and then the rest of the group responds, either accepting the proposal and starting to work on it, objecting to it or seeking clarification. Of course, the bid can also be unsuccessful and be ignored by the group. If it is successfully taken up, it can serve like the pivotal moments identified in the CIM and contribute to the online team's group cognition (Stahl, 2006). Data from VMT sessions can also be analyzed in detail to reveal the meaning-making process at work in the group interaction (Stahl, 2007). Through an analysis of the chat interactions in a VMT session—using the CIM approach extended with a close analysis of the verbal content of the proposal bid and uptake—one can observe the meaning-making processes by which teams of students create shared mathematical knowledge.

Analysis of the sessions in Singapore and of recent sessions in the USA using different kinds of tasks suggest ways of further evolving the problem designs to more explicitly promote student explorations to construct and manipulate representations in order to promote their mathematical conceptual understanding.

6. THE VMT SPRING FEST

Each year, the VMT project holds a math Festival and invites teams organized by teachers. In 2006, this was organized as an international contest, with prizes to the groups that worked together for four sessions and that were then judged the most collaborative. The first prize was tied by a team in the USA and one in a high school in Singapore. These teams explored the mathematics of sequences. During this contest, a wiki was introduced to allow teams to share their findings with other teams. Interestingly, one of the winning teams was inspired to work on a problem created by another team and shared in the wiki. In the end, they found a mistake in the other team's posting and posted a wiki note with their analysis. This was a first step toward knowledge building in the larger community of the Festival participants, connecting all the teams working in their separate chat rooms.

This past Spring, the VMT project tried to integrate the wiki much more closely with the problem solving in the chat rooms. Small groups were encouraged to collaboratively construct summaries of their work each session and to post these summaries to a wiki. All the groups worked on a set of probability problems, whose solutions were organized on the wiki. The idea was that the student groups would contribute to a math knowledge wiki site for students interested in probability. The community of VMT user groups would thereby construct knowledge about school math on the model of Wikipedia—combining knowledge building by the individual students, their teams and an international community.

By having teams create their own questions that interest them about a shared math domain and having them share their analyses with other teams (e.g., through a wiki), we try to combine the advantages of synchronous small group interaction with those of asynchronous community knowledge building.

7. SUPPORTING EXTENDED KNOWLEDGE BUILDING IN VMT

Also this past Spring, the VMT environment—now expanded to include the chat rooms, a wiki, multiple shared whiteboards, browsers, a portal to the chat rooms and some social networking supports—was used for a graduate online course on human-computer interaction. The course took place over ten weeks, with small workgroups of students meeting online each week to review academic papers and to accomplish weekly design projects. All the group work in chat rooms was summarized by the groups and posted on the wiki for sharing with the instructor and the other groups. The goal of the course was to build knowledge about the design of social networking software. The entire course was run in the VMT environment, with assignments and readings available on the wiki, students forming groups in the portal lobby, student teams reviewing the readings and discussing design tasks in the chat, summarizing on the whiteboard, and posting results on the wiki. The instructor organized the course assignments and the students carried them out over a ten week period, with weekly deliverables, each requiring a couple of online chat collaborations. The class as a whole built up knowledge about the course topic and documented its findings in the wiki, where students in future courses can build upon it further.

The successes of the online course using the VMT environment provides a model of knowledge building over a longer span of time—in this case, ten weeks as opposed to the two weeks of the VMT Festival. Here, the students became quite comfortable in the software environment and in the online collaborative context. The combination of synchronous and asynchronous media—integrated through a number of tools and features—gave the students both flexibility and structure in negotiating the timing and style of their participation. The nature of the assignments and the sharing of their work encouraged creativity, peer feedback and self-reflection.

The context of the use of the VMT chat environment in the USA setting is different from the trials reported from Singapore. The USA participants generally do not know each other from face-to-face activities. In Singapore, the VMT chat environment is used to complement routine lecture/tutorial sessions, allowing interleaving and integration of chat discourse with classroom discourse. In these online sessions, each student already knows the other participants. The teacher has opportunities to bring issues and problems arising from observations of the online group discourse into lecture or tutorial discussions. The teacher can actually reference examples of successful chat discourse and run through the discourse with the students in class, highlighting pivotal moments, constructive suggestions, non-sequitors, and moments when everyone seems to miss out an opportunity to construct further knowledge. This raises interesting research questions, for example, whether modeling and inspecting knowledge building episodes or processes can create better metacognitive awareness in students, leading to better knowledge building.

In each case where VMT has been used, it has become very clear that the most important thing to do is to coordinate the various aspects of the environment and student experience. This includes the design of the problems, the formation and preparation of the groups, the uses of the technology, the seeding of the wiki and of its interconnections in the environment, the instructions to the students, and any feedback given to the students between sessions. It is necessary to structure the entire experience carefully to be a rich but focused knowledge-building experience.

Just as has been found in studies of the use of Knowledge Forum, the “care and feeding” of a knowledge building community is a subtle and elusive business. The larger knowledge building at the classroom level is hard to attain, particularly in school cultures dominated by individualized reward systems.

However, we have found that chat can support a different kind of discourse than discussion forums: it is typically more intense, focused on the resolution of mathematics problems or other designed activities for the small groups. The shared whiteboard provides a flexible area to post drawings and textboxes that serve as knowledge artifacts for the group memory. A wiki can supply a persistent memory store for the community, allowing the outcomes of the chats to be summarized onto web pages that support yet a different kind of discourse. Together, the intermixed digital media support a complex process of knowledge building within different collaborative groupings—individual, team, class and community—and across different temporalities—synchronous, quasi-synchronous and asynchronous.

With the increased complexity of the affordances come increased coordination requirements: the curricular materials and technologies must be carefully designed to work together; the students must learn to navigate the intricacies and to develop appropriate interaction methods.

Usage of the VMT environment in Singapore and the USA has allowed us to identify some of these needs and to begin to explore solutions. Computer support can make new educational settings possible, such as the international VMT Festivals or online courses. It can also put powerful computational and representational tools in the hands of students and allow for increased collaboration. However, in the end, the achievement of progressive educational goals still requires innovative, careful pedagogic planning and sequencing of tasks and problems.

ACKNOWLEDGMENTS

We thank the Jurong Junior College, the NIE Learning Sciences Lab, the American NSF, the Math Forum at Drexel University and the VMT team for making this research possible.

REFERENCES

[1] Alagic, M. (2003). Technology in the mathematics classroom: Conceptual orientation. *Journal of Computers in Mathematics and Science Teaching, 22(4),* 381-399.

[2] Ministry of Education. (2005). Breadth and flexibility: The new 'A' level curriculum 2006. Singapore: Curriculum Planning and Developmental Division.

[3] Polya, M. (1957). *How to solve it (2nd ed,)*. New York: Doubleday.

[4] Reglin, G. L. (1990). The effects of individualized and cooperative computer assisted instruction on mathematics achievement and mathematics anxiety for prospective teachers. *Journal of Research on Computing in Education, 23,* 404-412.

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

[6] Scardamalia, M., & Bereiter, C. (2007). *Knowledge building: Theory, pedagogy, and technology*. In K. Sawyer (Ed.), Cambridge Handbook of the Learning Science. Cambridge, UK: Cambridge University Press.

[7] Stahl, G. (2005). *Sustaining online collaborative problem solving with math proposals.* Paper presented at the International Conference on Computers and Education (ICCE 2005), Singapore.

[8] Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge.* Cambridge, MA: MIT Press.

[9] Stahl, G. (2007). *Meaning making in CSCL: Conditions and preconditions for cognitive processes by groups.* Paper presented at the international conference on Computer-Supported Collaborative Learning (CSCL '07), New Brunswick, NJ.

[10] Stein, M. K., & Henningsen, M. (1997). Mathematical tasks and student cognition: Classroom-based factors that support and inhibit high level mathematical thinking and reasoning. *Journal for Research in Mathematics Education, (28),* 524-549.

[11] Yetter, G., Gutkin, T.B., Saunders, A., Galloway, A. M., Sobansky, R. R. & Song, S. Y. (2006). Unstructured collaboration versus individual practice for complex problem solving: A cautionary tale. *The Journal of Experimental Education, 74(2)*, 137-159.

[12] Wee, J.D, & Looi, C.-K. (2007). *Model for analysing collaborative knowledge construction in a quasi-synchronous chat environment*. Paper presented at the International Conference on Computers-Supported Collaborative Learning (CSCL '07). Chat Analysis Workshop, New Brunswick, NJ.