Inquiry-based Learning Environment Using Mobile Devices in Math Classroom

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Abstract

SMILE (Stanford Mobile Inquiry-based Learning Environment) is an inquiry-based mobile learning framework designed to promote student-centered inquiry and reflection leveraging mobile media in the classroom setting. Students can quickly create their own inquiry items based on their own learning and knowledge using SMILE. This paper introduces seven phases of SMILE that are applicable to math classroom environments, and presents the findings from SMILE implementation studies in Argentina and Indonesia. The students had a mobilized inquiry-based learning in math, which was facilitated by teachers and researchers by tapping into the affordances of mobile technologies for supporting their own question generation in class. SMILE was found to engage students in heterogeneous/mixed ability classes and promote both team collaboration and competition in learning math.

Keywords: SMILE, mobile learning, inquiry-based learning, math education

Inquiry-based Learning Activities Using Mobile Devices in Math Classroom

To date, few researchers have conducted mobile learning practices in math education, not to mention proposing effective inquiry-based learning activities or supporting tools to facilitate math learning in classroom settings. To deal with this issue, this research aims at suggesting an inquiry-based mobile learning system, SMILE (Stanford Mobile Inquiry-based Learning Environment), for supporting math learning in the classroom environment. SMILE is an inquiry-based mobile learning framework designed to promote student-centered activities in an engaging way using mobile devices in classroom settings. This study introduces seven phases of SMILE that is applicable to math classroom environments, and presents the findings of SMILE implementation in Argentina and Indonesia. In addition, this study focuses on a mobile inquiry-based activity that guides students to learn during a math activity with mobile devices and wireless communications.

Background

Technology and Math Education

Mobile devices have been prevalent in recent years impacting the global society in numerous and profound ways. Mobile devices are the most widespread information and communication technologies, and the increasing rate is rising rapidly (Valk, Rashid, & Elder, 2010). With the rapid growth of mobile technologies, mobile devices enable educators to focus on the potential to leverage the power of these new technologies to facilitate learning and improve performance, because of their increasing computing power, portability, affordability, ubiquitous accessibility, and storage which can be equipped with diverse educational content, including mobile videos, learning simulations, and education games (Kim, Miranda, & Olaciregui, 2008; Kim, Buckner, Kim, Makany, Taleja, &

Parikh, 2011). Mobile technologies and its innovations are creating new possibilities and mounting pressure to take advantage of such innovations to enhance creative/critical thinking and positive attitude (see Cavus & Uzunboylu, 2009) as well as student learning and engagement.

There have been several approaches of leveraging technology to enhance math teaching and learning, and many studies have tried to find out effective methods to improve learner performance in math. For instance, Nilsson and Pareto (2010) developed a technology enhanced learning game (called *TEL*) to support conceptual understanding of math for learners with math difficulties. In their case study, the result showed the beneficial effects of visual representation, learning-by-exploration, and learning-by-teaching activities to low-performing students. Hwang, Chen, Shadiev, and Li (2010) investigated a multimedia Web-based annotation system (called *Virtual Pen*) to foster math learning process of individual and collaborative learning. In their quasi-experiment over a period of four months, their technological solution has a significant impact on math learning achievement.

In addition, there has been an effort to conceptualize this area. Zhang and Jiao (2011) categorize technology-based math teaching approaches into two areas: (1) online learning environment using already developed math contents; and (2) dynamic math software in which the teaching contents have not been developed. The first category is a traditional courseware based on online learning environment, in which teachers and students can use passively the instructional materials. On the other hand, dynamic math software enables learners to benefit from learning-by-doing (e.g., Nilsson & Pareto, 2010) which is difficult to be achieved by traditional tools or technologies (Zhang & Jiao, 2011). Dynamic math software (e.g., Stahl, Rosé, O'Hara, & Powell, 2010) supports learners' self-explorations. However, dynamic software-based instructions might have negative effect to the high performance students (see Zhang & Jiao, 2011), and it still needs more engaging and collaborative activities.

Mobile technology in math teaching and learning.

There have been attempts to use mobile technology in math teaching and learning. As a result of the reciprocal research and development process, Jimenez, Nakaue, Pea, and Russell (2009) suggest a mobile application (called *Go Math!*) for supporting collaborative activity and encourage math practices of daily life. Through the interview session with 74 participants they drew design implications for mobile math environments, such as situation-driven, promoting enjoyment of math, or a complement to school. van't Hooft, Swan, and Bennett (2009) investigated the use of a mobile application that provides learners with basic math facts. The results show that mobile technology group has a positive impact on the math knowledge improvement. Hawkes and Hategekimana (2009) conducted the quasi-experiment comparing mobile and classroom environments of an algebra course. The result shows there are statistically significant positive effects of mobile learning on their math assessment scores. Wijers, Jonker, and Kerstens (2008) developed a mobile math application (called *MobileMath*) which is for a group to gain points by creating virtually constructed mathematical shapes. They demonstrated the math learning application can be employed in an ordinary school setting. In sum, most of these researchers concluded that the mobile technologies have the potential to be an effective pedagogical tool for math teaching and learning.

There are a variety of formats for technology-based resources that serve specific goals by using interactive technologies, which provide immediate feedback and create visual representation. However, Bos (2009) points out that not all uses of technology lead to the desired result in math teaching and learning. She suggests that in order to use technologies effectively the software should not be limited in the math content, and should lead a conceptual understanding of math principles.

The current use of mobile technology may help learners grasp the conceptual understanding of math principles. In particular, mobile math games may engage students to think critically before planning and executing solutions to solve mathematical problems. For instance, Fire Rescue Math (Kim, Buckner, Kim, Makany, Taleja, & Parikh, 2011) engages children to recognize the need to rescue people on different floors by picking the right size ladder. The game is not asking students math questions directly, but it asks students how many floors you need to be go up or down to save people. The game includes multiple reinforcement mechanisms to facilitate numeric skill development. It teaches the concept of positive or negative number addition and subtraction. However, these approaches have limitations in the use of technology to facilitate student collaboration and reflection in math education. As part of the effort to overcome the limitations, we introduce new approach to math teaching and learning using inquiry-based activities using mobile technology. SMILE (Stanford Mobile Inquiry-based Learning Environment) is better situated to increase student engagement, interaction, reflection, peer evaluation, competition, collaboration, learning outcome tracking, and multimedia use in broad learning scenarios.

SMILE

SMILE is a Stanford University project led by Dr. Paul Kim. SMILE enables students to create their own questions (e.g., multiple choice questions) and share them with their peers using mobile devices. Students can review personal and question-related data including which student answered the most questions accurately and which student created the highest-rated question. They respond to and rate each other's questions. In addition, SMILE provides an activity management application for teachers. It allows the teachers to control the progress of the activity in real time and to view all student activity data.

SMILE has been tested in various conditions and settings and found positive outcomes. Seol, Sharp, and Kim (2011) report that participants were satisfied with SMILE in their implementations. Students specified that they most enjoyed the opportunity to create their own questions and share them with peers. In their study, the participants also reported that they viewed SMILE as a valuable way to review class materials. The students created highly relevant questions for each other with a range of complexity spanning multiple levels of Bloom's Taxonomy (Seol, Sharp, & Kim, 2011).

SMILE could be an appropriate tool for math learning because of the identified advantages. SMILE provides unique sets of advantages in increasing learner participation, engagement, motivation, competition, and collaboration which all lead to better learning and enjoyment. As suggested in the study of Seol, Sharp, and Kim (2011), there are five significant features of SMILE: (1) students can include photos in their questions and gain learning benefits associated with presenting materials in multimedia; (2) students create multiple choice questions requires them to think critically in order to create three distractors for each question; (3) students rate each other's questions provides feedback and incorporates an element of peer-assessment; (4) students experience the review process in a less-pressured competitive learning environment, which has been demonstrated to increase intrinsic motivation; and (5) SMILE supplies teachers with all of the students' questions and responses through the activity management application provides invaluable formative assessment information, which has been demonstrated to improve student learning. For all of these reasons, SMILE may provide particularly effective means of promoting student-created activities in the math education field.

Since mobile devices have advantages of reaching even the most marginalized areas, it has the potential to widen access and supplement education in developing areas of the world (Kim et al., 2011; Song, Karimi, & Kim, 2011). However, inequalities of opportunities to access to educational resources continue in the developing world, and the delivery of cost-effective and quality education remains a problem (Valk, Rashid, & Elder, 2010). We believe SMILE has great potential to cause substantial pedagogical paradigm shift especially in the developing world because there is generally more lack of resources, less hierarchical bureaucracies in regions where formal schooling is not an available option or found to be ineffective. Whereas in the developed regions, there are usually rigid curriculum standards and strict periodic tests that students need to prepare for, leaving little room for innovative pedagogies. In this respect we have tested SMILE for math learning in Argentina and Indonesia. In this paper, we report the SMILE math model, its process, and initial findings. We also offer suggestions for educators and researchers.

SMILE Math Learning Model

We have modeled the inquiry-based math learning process to foster learners' self-directed learning and collaborative activities of their inquiry-based learning. As students are creating their own math questions, they can use SMILE tools available on the mobile devices to support their activities. Teachers, students, and researchers can have access to students' questions, answers, and results of peer evaluation during and after classes. Mediated by mobile technology, students share their questions with images that they took by themselves or got from their Internet searches and cooperate together on their learning activities. Students can collaboratively compare and contrast their own questions and answers on their individual mobile devices.

Phase 1. Introduction and device exploration.

The introduction and device exploration phase is necessary for those who are not familiar with mobile devices. Students' technology skills need to be refined in order to develop a meaningful and successful experience (Kim, 2008). Although teachers may be present in the classroom to observe student learning, it is not necessary to engage in the student exploration. In this phase, we let students freely explore and also teach themselves as they quickly augment and exchange knowledge of the devices within less than 40 minutes. This process has dual goals: (1) to get students to quickly understand how to effectively manipulate the devices to capture photos, videos, or type text to generate questions; and (2) to provide an opportunity for teachers – especially skeptical, inexperienced, and technically challenged – to watch and observe how fast children can quickly get the handle on the devices and ready themselves for productive work.

Phase 2. Prompt for problems.

Students are asked to generate their own math questions that they believe to be well-designed and difficult (e.g., tell students that “try to generate questions your teachers would not be able to solve!”). We expect that this process will maximize the sense of challenge and motivation for students to engage in the inquiry-based activity. In this phase, students are told that they can create multiple choice questions and use photos or other images as appropriate to express their questions.

Phase 3. Student grouping and generating questions.

If students have never created questions or have not been familiar with generating questions by using mobile devices, they are asked to make questions on papers. While students are generating questions, facilitators go around and guide them or help them understand what good versus bad questions may be. In this process, students attempt to solve their own questions and verify the proposed answer to the exclusion of all other possible answers (i.e., distractors). This process typically takes the most of the time in the SMILE process. Students are grouped into three or four members so they can collaborate in generating questions. This creates a sense of competition between groups.

Phase 4. Question generation.

Students draw mathematical figures or graphics on paper and take pictures with the mobile devices while typing question texts or answer options on the mobile device. As students submit questions, the teacher's screen shows the students questions in real-time as they are generated. The facilitator can see which group has finished or is still working on generating questions. Once all groups submit a question or as many as planned by the facilitator, the facilitator can click on a button to distribute the entire questions set back to the students. Though each group may have created one question, they can be solving all questions generated by the entire class.

Phase 5. Question solving.

Students solve their peers' questions and review them. After identifying a correct answer for each question, they are asked to rate each question. This provides the students with an opportunity to reflect on peer generated questions. The facilitator can monitor which group has completed answering and rating all questions in real-time through the activity management application. Once all of the ratings and answers are submitted, the facilitator can click a button to send the automatically tallied rating and score card to all student groups.

Phase 6. Result review.

Students review the correct answer and compare it with their own answer for each question. Students get to see the question ranking (e.g., which question received the highest rating) and also student group ranking (e.g., which student or group answered the most questions correctly).

Phase 7. Reflection.

After the review, students are asked to explain why they created their specific math questions and why they chose certain sets of answers for their questions. Usually, the group or individual that received the highest ranking will get the first opportunity to explain their questions.

Repetition and enrichment.

After the first round of SMILE, students will tend to want to do it again because they now understand the whole process of SMILE and are more motivated to generate higher ranking questions. Facilitators can decide the follow-up activities at this point (i.e., repeating with the same guidance, providing extra supports, giving instructions to cover certain question topics or types, etc.). In most cases, students learn to generate better questions over time. At the same time, students get to solve and reflect on a variety of questions generated by peers.

SMILE Implementation

For this project we implemented SMILE through classroom observations, analysis of classroom photos and videos, analysis of the artifacts produced by participants, assessment of learner performance, and interviews with the teachers and students. The students in Argentina and Indonesia experienced a total of 1 week of the math class using SMILE. The mobile device chosen was the smartphone Motorola which runs Android (version 2.2) operating system.

Implementation 1 – Argentina.

The students in Argentina experienced a total of 1 week of the mobile inquiry-based math class using the SMILE application. Students identified how questions created by their peers may have been incorrectly designed, how certain questions may generate multiple answers, and why the assumed correct answer was not indeed correct. During the class, the students did not reveal the questions they generated to their peers (see Figure 1. c). Most groups spent over 50 minutes verifying their answers and making sure the answer proposed was correct.

Technical challenges.

Initially, participants' photo quality was poor. They had to rewrite text questions in boldface with a larger typesetting so the camera could capture their questions or figures more vividly. Some photos were incorporated at wrong angles. Thus, the students received some basic guidelines to assist in taking better quality pictures of their questions.

Figure 1. SMILE in Argentina. a) Taking a Picture of Math Questions (Left); b) Solving the Questions Created by Peers (Middle); c) Covered when Creating Math Questions (Right).

Implementation 2 – Indonesia.

The students in Indonesia experienced a total of 1 week of the mobile inquiry-based math class using the SMILE application. In most groups, there was a dominating member of each group that led the process of generating math questions (see Figure 2. a). Students were excited to see their questions posted and projected on screen (see Figure 2. b). Other students appeared to look and make distracting noises (see Figure 2. c).

Figure 2. SMILE in Indonesia. a) A Student Leads the Solving Process (Left); b) Projected Screen (Middle); c) Other Class Students are Peeking (Right).

Discussion

Mobile learning has increased access for students who cannot attend schools (e.g., who would not be able to follow courses in a traditional educational setting) (Valk, Rashid, & Elder, 2010). However, mobile learning does not particularly need to be in the outside of school situation nor individualized context. Mobile learning could be effective in classroom settings. In both two implementations, students shared their math questions and answers using SMILE, which activities led collaborations in the classroom environment.

Despite the effectiveness of technology and its potential for math learning, teachers still need to leverage technology resources in ways that extend and increase their effectiveness as meaningful pedagogical tools (Ertmer & Ottenbreit-Leftwich, 2010). Even though teachers have increased their professional uses of technology (see Zhao, Wan, Yu, & Luo, 2006), with the rapid development and enhancement of mobile technology, teacher training programs have a limitation for meeting the needs of recent students. In SMILE implementations, students were enthusiastically adopting and learning with mobile technology without additional teachers input. Students could get started mobile learning in several minutes since they adopt new technologies immediately and mobile learning devices minimize the initial learning curve (Kim, 2008). Overall, the mobile learning technology adoption was rapid, seamless, and actively driven by the students rather than the teacher (Kim, Hagashi, Carillo, Gonzales, Makany, Lee, & Garate, 2011).

As to the technology and its integration into the classroom, a teachers' role could be less focusing on teaching, but more on facilitating. The SMILE framework provides the flexibility for a teacher to be a facilitator by enabling students to create questions that are appropriate to individuals' and/or subgroups' levels for personalized learning. The activity management application allows teachers to control and monitor all of the students' activity in real time. The approach of SMILE is one solution that reduces teachers' burden to learn new technologies and provides engaging learning activities for students. In addition, given that social interaction plays a significant role in effective learning, mobile devices need to impact educational outcomes by facilitating communication (Valk, Rashid, & Elder, 2010). In this sense, SMILE provides students with collaborative learning opportunities creating, reviewing, and discussing their own questions and answer.

This paper describes the implementations of a mobile inquiry-based learning environment designed to promote student-created questions in math teaching and learning. We focused on applying inquiry-based learning strategies to facilitate student-centered learning in math education. In this study, students shared their math questions and answers using SMILE, which aided in providing activities led to collaboration in the classroom environment. The students enthusiastically adopted learning with mobile technology without additional teachers' input. It may be clear that there was a minimal initial learning curve, as it only took participants several minutes to start using the mobile learning devices. The students pursued inquiry in a personalized way without teachers' unidirectional instructions or its sequential order.

Conclusion

The pedagogical paradigm shift from teacher-centered to student-centered learning utilizing an inquiry-based learning technique is becoming possible. In the traditional concept of the classroom, particularly in the developing world, pedagogies and curriculums remain highly unidirectional and teacher-centered. Students need to be empowered to explore and learn by themselves. SMILE is an inquiry creating and assessment tool which allows students to quickly create their own inquiry items based on their own learning and prior knowledge. Inquiries drive knowledge generation and more knowledge leads to more useful and creative inquiries. SMILE can create a new global learning community of inquiry generators by sharing global knowledge through mobile technology. Our redesigned math teaching approach using mobile technology can be adoptable in real classrooms. Our inquiry-based learning approach is intended to provide instruction and learning designed around peer-created math questions and the pursuit of significant collaborations.

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