Integrating Technology and Pedagogy for Inquiry Based Learning: The Stanford Mobile Inquiry-based Learning Environment (SMILE)

Elizabeth Buckner and Paul Kim[1]

Abstract

Despite the long-standing interest in educational technology reforms, many studies have found that incorporating advanced information and communications technologies (ICT) into classrooms has proven difficult. A key limitation to many ICT projects, particularly in the developing world, is a lack of integration between pedagogy and technology. This article presents a framework for how ICT technology and inquiry-based pedagogies can be integrated in classroom settings, known as the Stanford Mobile Inquiry-based Learning Environment (SMILE) The article then outline findings from a series of studies that test the effectiveness of the SMILE model in various country contexts. Findings indicate that SMILE successfully spurs student questioning and changes student-teacher dynamics in class; however, we also find that students' initial abilities to form deep inquiries depend on school and country contexts, and is more difficult to implement in areas where rote memorization pedagogies are typical. We advocate further research to study the effect of longer-term interventions.

Keywords:
mobile devices, mobile phones, technology, ICT, student-inquiry, student-centered pedagogy

[1] Stanford University, Graduate School of Education

Author Biographies

Elizabeth Buckner is a PhD Candidate in International and Comparative Education at Stanford University. She has researched the potential of mobile learning in Palestine, Tanzania and Jordan. Contact: ebuckner@stanford.edu

Paul Kim is the Chief Technology Officer and Assistant Dean for Stanford University School of Education. He has been leading various academic technology initiatives and teaching graduate courses related to digital innovations in education since 2001. He is currently one of senior researchers for Programmable Open Mobile Internet, an NSF project to develop and evaluate ubiquitous wireless mobile computing and interactive systems for K-20 formal and informal learning and assessment scenarios. His research interests are on contextualized innovations in education, mobile empowerment design, and enterprising and sustaining education ecosystems for under-served communities in developing countries. Contact: phkim@stanford.edu

Introduction

Despite the long-standing interest in educational technology reforms, many studies have found that incorporating advanced information and communications technologies (ICT) into classrooms has proven difficult (Schweisfurth 2011; Warschauer 2012). A key limitation to many ICT projects, particularly in the developing world, is the lack of integration between pedagogy and technology. Simply placing technology hardware into classrooms is not a comprehensive solution to bridging the digital divide, despite a plethora of well-meaning projects that bring computers, connectivity, or other technology to rural schools (Muller et al. 2007).

Indeed, there has been a proliferation of worldwide technology initiatives that have put computers into schools, linked computers to the Internet, or gave all children laptops. Yet, the dominant model in these initiatives is to present teachers, students or schools with hardware, without giving them the necessary support and training to make that technology an educational tool. All too often, educational technology has not proven as revolutionary as educational development experts have hoped. A prime example is the One Laptop Per Child (OLPC), which has received substantial media coverage, but had lack-luster results in practice. In Uruguay and Rwanda, national policymakers purchased laptops for hundreds of thousands of children, but most are not being used in classrooms – they are often simply sitting in school closets because teachers do not know how to use the devices or are afraid they will break them. Also, in many cases, teachers do not find appropriate reasons to use them in classrooms because the hardware does not come with appropriate computer applications for learning (Warschauer and Ames 2010; Kraemer, Dedrick, and Sharma 2009).

One of the major problems with OLPC initiatives is that they failed to take into consideration the needs and realities of developing countries. Shah (2011) explains that: “Several studies have concluded that the primary reason for the failure of the OLPC project was its lack of consideration for and adaption to the local cultures and societies” (94). Hardware was developed and disseminated without a deep understanding of local communities, meaning it was not particularly useful to the communities using it. By way of solution, Willoughby (2011) contends that future initiatives aiming to distribute technological innovation to developing countries should employ the “appropriate technology rule” before implementing educational technology projects. By his standards, the selection of appropriate technology would require: “knowledge of a diversity of technical options for given purposes, careful analysis of the local human and natural environment, normative evaluation of alternative options, and the exercise of political and technological choice” (Willoughby 2011:8). Additionally, in practice, a one-device-per-child model completely ignores and eliminates the opportunity for collaborating and sharing among students within classrooms or across multiple classrooms, making such models not only out of touch with much research that finds benefits in collaborative learning, but also much more expensive and less sustainable economically.

Meeting the development challenges of under-resourced regions requires tying technology to meaningful educational content strongly and contextualized pedagogy– essentially, using technology to engage students in active researcher, creator, and evaluator roles (Muller et al. 2007). In response to the limitations of current practice, this article presents a framework for how

ICT technology and inquiry-based pedagogies can be integrated in classroom settings by exploring how mobile devices can promote students' collaborative questioning. We first present a model for how mobile technologies promote inquiry-based pedagogies in schools, and then outline findings from a series of studies that test the effectiveness of the proposed mobile inquiry model conducted in various country contexts. Our primary interest lies in understanding how mobile learning devices can promote inquiry-based pedagogies, and what the specific advantages and limitations of mobiles are in different countries. The ultimate goal is to better inform the educational development community's efforts to use technology to advance educational outcomes and student learning, particularly in rural and under-resourced areas of the world.

The Advantages of Mobile Technology

There is a growing interest in the role of mobile devices in meeting educational challenges. Indeed, many researchers have pointed out the distinct benefits that mobile devices offer as educational tools (Thornton and Houser 2005; Kim et al. 2011; Pietrzyk et al. 2011; Ally 2009). Today's mobile devices can store and deliver a vast amount of information, including a wide variety of curricula materials targeted to appropriate ages. The rapid innovations and advances in information and communication technology (ICT), specifically, increases in processing power, memory, and connectivity for mobile, handheld devices have made mobile devices more interactive and media-rich than ever before (Pea and Maldonado 2006).

Moreover, mobile devices require substantially less infrastructure and electricity, which gives them many advantages over traditional computers. Mobile devices have already reached the most isolated populations and had a tremendous impact on individuals' lives (Attewell 2005). Research has shown mobile learning devices have the potential to widen access and supplement education in the most remote and underserved areas of the world (Zurita and Nussbaum 2004; Kim 2009). Many have noted that this makes them more apt tools for large-scale impact (Kim, Miranda, and Olaciregui 2008).

Mobile devices also have an advantage over computers with respect to educational content. A key limitation of computer-centric initiatives is the lack of varied and robust learning software applications. The rapid growth of mobile applications (i.e. apps) on mobile phones has greatly expanded opportunities for learning with mobile devices. There are "over 500,000 apps available on iTunes and over 300,000 on Android" (Schuler 2012, p. 7). In a comprehensive study of the educational app Schuler (2012) reports that: "Apps are an important and growing medium for providing educational content to children, both in terms of their availability and popularity" (2). Moreover, many apps are able to promote learning in a game-like environment, making them far more engaging than traditional learning pedagogies.

Because of their ubiquity, mobile devices have had an impact on the traditional school environment. Many students in both developed and developing regions carry mobile phones to school – and research has shown that students actively try to communicate with each other during class using mobile phones (Dodds and Mason 2005). Unfortunately, the influence of mobile phones is often decried as a distraction, leading many schools to ask students to leave their phones off while in class. However, today's mobile phones can be powerful multimedia learning devices; by requiring students to turn them off, schools are missing out on the opportunity to capitalize on mobiles' computational capacity and interactive nature. This is because there are practically no pedagogical techniques designed to utilize numerous mobile phones to support learning. This article addresses the question of how mobile technology can take advantage of students' natural creativity as a basis for classroom learning. Rather than executing memorized rules (such as arithmetic problems), we believe that the real power of mobile devices in classrooms is to prepare children to be creative thinkers and active problem-solvers. The next section discusses the importance of questions in learning and then presents a model for how technology can be used to increase student-inquiries in class.

Challenges to Inquiry-Based Pedagogy

Inquiry-based learning emerged from a deep literature on constructivist approaches to teaching. Constructivist theories of learning argue that students learn best when discovering and unpacking content for themselves (Yu 2005; Cole 2009). It is premised on the idea that students should participate actively in the learning process, and that in so doing, students actually learn better, as student inquiry furthers comprehension and synthesis of knowledge.

Questions are the core of inquiry-based learning, and have been recognized as central to the learning process more broadly (Becker 2000). Prior research has found that asking questions while reading is crucial to literacy development; Davey and McBride (1986) find that in posing questions, students gain powerful meta-cognitive skills, including the ability to evaluate sources and monitor their own comprehension (Davey and McBride 1986). Similarly, Chin and Brown (2002) explain that question generation "focuses the attention of students on content, main ideas, and checking if content is understood" (King 1994; Rosenshine, Meister, and Chapman 1996; Chin and Brown 2002). Student questions require students to revisit and often expand upon prior curricular material (Chin and Brown 2002). Questions can also reveal students' thought processes as they work through new or difficult material, as well as their gaps in knowledge or understanding (Watts et al. 1997). Additionally, research suggests that the practice of question generation actually deepens student comprehension, as it requires students to actively monitor their reading or pay deeper attention to what they are learning in class (Mosteller 1989; Wilson 1986). In short, in posing deep questions themselves, students revisit previous materials and reshape their thoughts, thereby deepening their understanding (Yu 2009).

Despite the many educational benefits associated with questioning, research consistently demonstrates that students ask very few questions in schools, even when teachers probe for student-questions (Gall 1970; Nystrand 1997; Cazden 1988). In fact, studies show that only a small percent of questions asked in class are student-generated. For example, in observational studies of classroom interactions, Dillon (1988) found that students asked very few questions during class, and of those, most regarded instructional clarifications, rather than knowledge-seeking questions (Dillon 1988). Similarly, through observations in urban American classrooms, Becker (2000) actually finds that student questions are subtly discouraged, stating that: "Overall, I found that, when elementary students asked questions, they were shut down. Students were not gaining the kinds of critical-thinking and literacy skills fundamental to academic enjoyment and achievement at all levels" (262). There are many reasons to believe that traditional learning environments and didactic pedagogies inhibit student questioning. In fact, some teachers may actually have a philosophy of teaching that views teaching as a transmission of facts and knowledge, with little place for student questioning. Unfortunately, this may be particularly true in developing countries, where memorization is highly prioritized over creative thinking or creativity.

Moreover, even student-centered pedagogies, which aim to promote student engagement in learning, can also fail to result in student questioning due to larger structural issues in schooling. Teachers tend to adopt the techniques of their own teachers – those exposed to didactic pedagogies during their own schooling are probably less likely to adopt student-centered pedagogies or invite student questions. Additionally, Woodward (1992) explains that teachers who are unsure of the material or knowledge may actually prevent student questions, as a way of avoiding the gaps in their knowledge. In the developing world, teachers are often poorly prepared to teach – many have not attended specialized teacher education programs or obtained an advanced education. In fact, primary school teachers many developing nations may never have gone to secondary school, or secondary school teachers not completed a four-year college degree. This means that their training as teachers is often limited somewhat narrowly to content, as opposed to pedagogical practices. This tendency to stifle questions could be exacerbated when new technologies are introduced, if teachers themselves are not comfortable with technology.

Additionally, the need to maintain teacher authority and control tends to reduce questioning. Dillon (1988) found that many students do not ask questions because they fear negative reactions from classmates and teachers (Dillon 1988). Cultural norms governing relations between adults and students, and socialization into situational authority roles may also inhibit student questioning (Chin and Brown 2002). In short, there is significant evidence that most students learn in didactic environments, as opposed to those that are rich with opportunities for inquiry, and dominant pedagogical practices are unlikely to alter this reality.

The many advantages of mobile devices make them particularly apt for supporting student-centered learning. Prior studies have documented how mobile devices can facilitate experimentation in real-world settings, help students collect and record information, and allows learners to share their experiences and information with peers (Looi et al. 2010; Squire and Klopfer 2007). According to Looi et al. (2010), “the portability and versatility of mobile devices has significant potential in promoting a pedagogical shift from didactic teacher-centered to participatory student-centered learning” (156). Yet, few concrete technological tools or applications have been designed to support inquiry-based pedagogies. This is an area in need of further research, and Looi et al. (2010) argue for more academic studies to advance our “understanding of how students engage in inquiry-based learning, experiential learning and knowledge building in mobile learning environments” (167). This need is particularly apt in the developing world, as much of the research on technologically enhanced inquiry-based learning has been conducted in the developed world thus far. In the next section, we respond to this need by exploring how mobile devices can promote inquiry-based learning in classrooms, and whether mobile devices are a practical development solution in under-resourced communities in the developing world.

Integrating Technology and Inquiry-Based Learning

This section conceptualizes an educational innovation design that utilizes mobile technology to promote inquiry-based learning. It presents the Stanford Mobile Inquiry-based Learning Environment (SMILE) as a prototype of how mobile technology can promote inquiry-based learning in the developing world. SMILE combines a mobile-based question application for students, with a management application for teachers. Together, SMILE allows students to create multiple-choice questions on mobile phones during class and share these questions with their classmates and teacher. The classroom management software allows students to share, respond, and rate questions on criteria such as creativity or depth of analysis. This section provides a brief overview of SMILE.

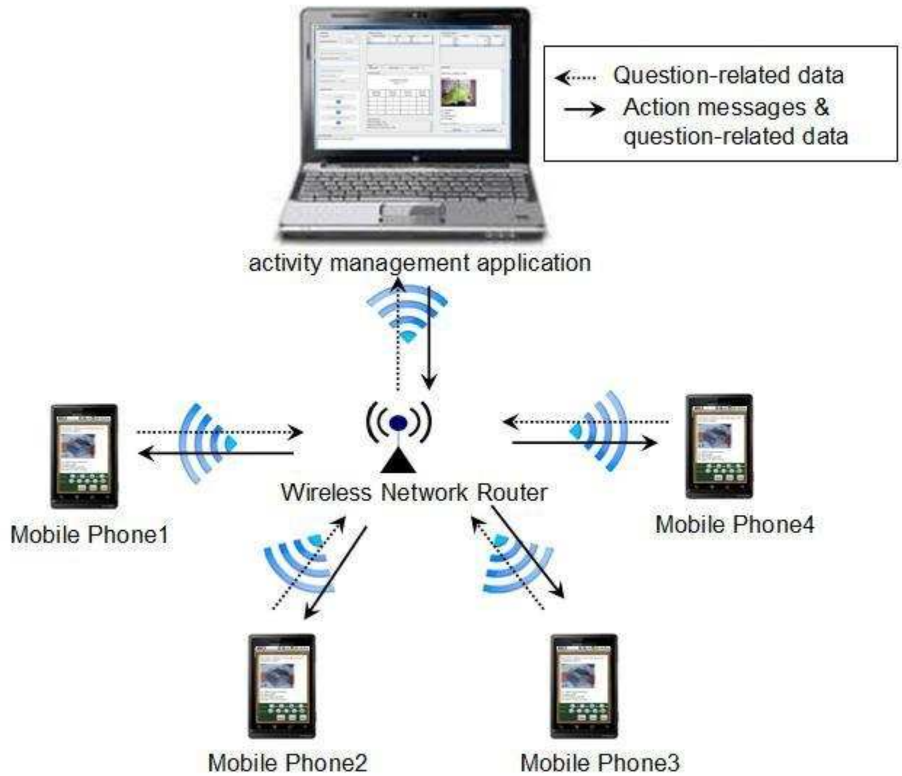


Figure 1: Schemata of SMILE's ad-hoc network

SMILE consists of two software elements: a student mobile-based application and management server application. These applications can communicate via either local ad-hoc network or Internet. The local ad-hoc based mobile learning network (Ad-hoc SMILE, Shown in Figure 1) is for developing regions where there is absence of any type of network and the Internet version (SMILE Global) is for areas where there is mobile network linked to Internet. The Ad-hoc SMILE enables students to engage in SMILE activities and exchange inquiries with peers in their classrooms or own school. SMILE Global enables students around the world to exchange their inquiries regardless of their location. Both SMILE Ad-hoc and SMILE Global allow students to incorporate multimedia components in their questions (Images for SMILE Ad-hoc and mages, audio, and video for SMILE Global).

When all students have finished writing and submitting their questions to the server management application (See Figure 2 for the SMILE activity process), all of their aggregated questions are sent back to their student application. In a classroom of 30 students, one student or one group may generate one question, but one student gets to solve 30 questions or multiple questions generated by their peers or peer groups.

While responding to each question, students rate each on a five-point scale from 1 (poor) to 5 (excellent) based on some predetermined criteria, such as creativity or depth of analysis.

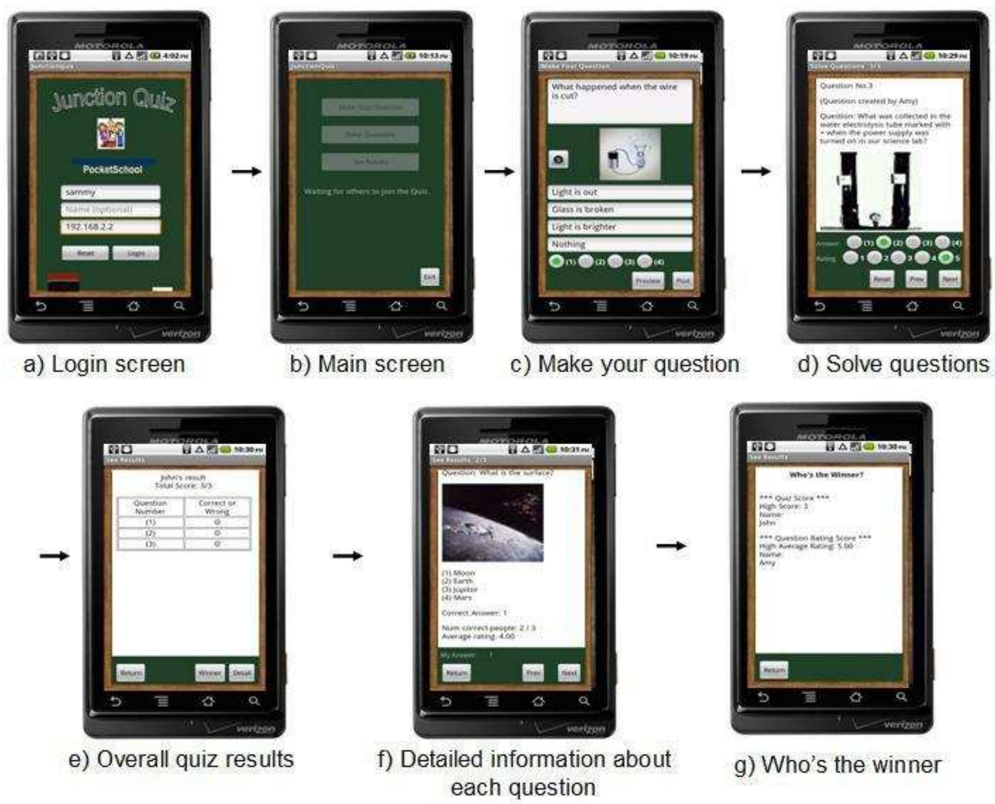


Figure 2: The Junction Quiz application

Their responses and time-to-response are gathered by the data management software and saved for further analysis by the teacher. Once all students have responded to (See Figure 3) and evaluated their peers' questions, the teacher is able to display the results through the "See Results" button. At this point, students can view a summary of their results and see which questions they answered correctly or incorrectly. They can also view detailed information about individual questions including how many students answered each correctly and average ratings. Finally, students can view which student answered the most questions correctly and whose question received the highest ratings.

a) Logging in to application b) Creating a question c) Solving and rating peer-created questions

Figure 3: The student-question generation process

In addition to student-generated questions, teachers are also able to input questions from their mobile device, which can serve as evaluative assessments for crucial information. In this way, both students and teachers alike are actively involved in generating questions, assessing student knowledge, and offering feedback.

Figure 4 provides a schema of the activity management application, with important features labeled. The activity flow window (A) allows the teacher to activate the various stages of the questioning process (creation, response). This allows the teacher to maintain control over class-time and ensure that students are only creating questions at a designated time if intended to. The Student Status window (B) displays the status of each student on the present activity (i.e. who has joined the activity, who has submitted questions, and who has submitted answers). The Scoreboard window (C) displays individual student’s responses and ratings for each of the questions. The Question Status window (D) displays which student created each question, what the average rating was for that question, and the percentage of the students who answered it correctly. The Question window (E) displays the question itself and its predetermined correct answer. The Top Scorers window (F) shows which student achieved the highest score and which question received the highest ratings. This can be used for class-wide reflection on the quality of inquiry. Finally, the Save Questions button (G) allows the teacher to save the data from a given exercise to the server, which can be accessed at a later date.

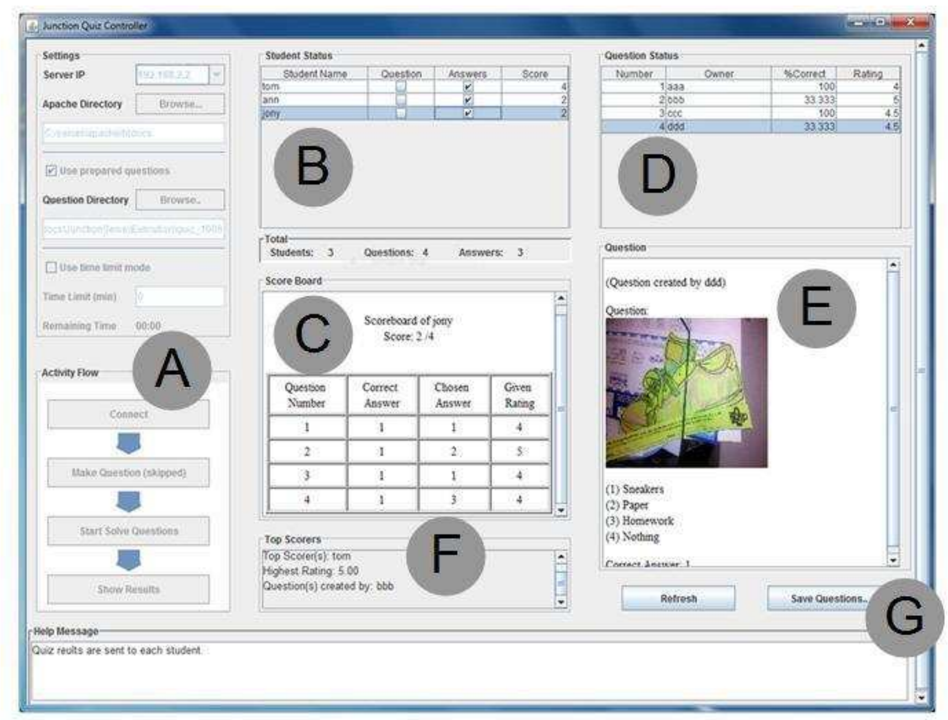


Figure 4: The activity management software

The SMILE application affords myriad benefits to teachers and students, namely that it creates a highly interactive learning environment; it engage learners in evaluating and analyzing their own learning; it promotes inquiry and critical reasoning, and allows students to synthesize acquired concepts. SMILE also allows students to generate, share, and evaluate multimedia-rich inquiries. Its mobile-platform allows students to learn, study and inquire anytime/anywhere, and it can be used to promote both a collaborative and/or a competitive classroom environment, as needed to motivate students. SMILE allows for both teamwork and competition between students when asking and answering questions.

The cost of implementing a SMILE activity depends on the infrastructure available in the school. The minimum resources required for a SMILE workshop include the cost of the phones, one laptop and a router. The costs for the following workshops were: $300 for a notebook laptop computer, $100 for a local router, and the required number of mobile phones (1 per every 2-3 students), which are estimated at $80 each.

Data and Methodology

To assess the effectiveness of SMILE as an educational intervention, we carried out a series of studies in diverse country contexts. Our methodological design is comparative in nature, as we seek to compare advantages and limitations of mobiles for inquiry-based learning in various settings. In this sense, we draw from the research agenda advocated by Looi et al. (2010), who explain that "by collaborating across the globe, researchers could take advantage of different student device preferences, exchange curriculum ideas, understand cultural differences and better address issues of scale" (167). The specific implementation method involved a network of researchers and non-profit organizations collaborating to carry out a series of studies using SMILE. The research team varied in each context, but researchers were trained on SMILE and its implementation before carrying out the studies.

Sample

The findings for this article are drawn from a series of seven studies, carried out in California, USA (2 pilots), India, Argentina, Indonesia, South Korea and Tanzania. A number of factors shaped the sample of countries studied. First, a major goal of the study was to understand the advantages and disadvantages of a mobile inquiry-based learning model using mobile applications and mobile devices in varied country contexts, and among learners of different backgrounds. We wanted to understand what factors shaped project feasibility, and how these factors varied by context. As such, we employed purposeful sampling and intentionally sought out opportunities for implementation in very diverse settings. The major dimensions of interest were: urbanicity (urban/rural); national economic development; student population (age and school type); world region (West, Asia, Africa, Latin America), and school subject. Therefore, we chose sites that would offer new insight into the effects of each of these dimensions.

In addition, in line with the applied nature of our study and the importance of strategizing with local partners in carrying out applied research in international contexts, site locations were also chosen based on feasibility and interest of local partners. Table 1 provides details the site locations and their characteristics.

TABLE 1: PILOT STUDY LOCATIONS AND FEATURES

Site Location	**Urbanicity**	**National Economic Development**	**School Level**	**World Region**	**Substantive Discipline**
Sunnyvale, California	Suburban-Urban	Developed (mixed income, ethnically diverse student population)	Primary	North America	Science
Stanford, California	Suburban-Urban	Developed	Undergraduate post-secondary	North America	Social sciences
Nellore, India	Rural	Lower middle-income	Primary	Southeast Asia	Math and Science
Misiones, Argentina	Urban	Upper middle-income	Primary	South America	Civic and social sciences
Pesatren, Indonesia	Rural	Lower middle-income	Primary	East Asia and Pacific	Math
Seoul, South Korea	Urban	Developed	Graduate post-secondary	East Asia	Medicine
Newala, Tanzania	Rural	Low income	Secondary	Sub-Saharan Africa	Language

Methodology

The SMILE project is part of a larger model of educational intervention that aims to think about how mobile technology can be designed and implemented to meet the future needs of developing and under-resourced nations. This model to educational interventions has been classified as educational design research. Plomp (2009) defines educational design research as: "the systematic study of designing, developing and evaluating educational interventions (such as programs, teaching-learning strategies and materials, products and systems) as solutions for complex problems in educational practice, which also aims at advancing our knowledge about the characteristics of these interventions and the processes of designing and developing them" (13). This approach to research differs substantially from traditional models of research that prioritize description, hypothesis testing or analysis of singular or multiple variables (Van den Akker 1999). Rather than simply describing a problem or parsing out the effect of a single variable, educational design research is more appropriate for understanding how to improve real-world problems.

Increasingly, scholars are recognizing the benefits of this prototype-development approach to educational reform, particularly in the field of educational technology. Reeves (2006) advocates for more educational design research, stating that the educational technology field has "a legacy of ill-conceived and poorly conducted research that results in no significant differences or, at best, in modest effect sizes" (57). To improve the field, Plomp (2009) explains that educational design research permits "systematic research supporting the development and implementation processes in a variety of contexts" (9). While more skeptical of design research as a methodology, Kelly (2009) argues that the purpose of design research should be oriented not to knowledge production per se, but to improving a specific outcome or product, explaining that: "design studies should produce an artifact that outlasts the study and can be adopted, adapted, and used by others (e.g., either researchers or teachers)" (Kelley, 2009: 116). Kelley also argues that educational design research is most appropriate for understanding how to improve an educational learning environment or specific educational technology.

Drawing on the work of prior scholars in educational technology, this article adopts a design approach that specifically is targeted to improving our understanding of how mobile educational technology can improve student inquiry, inside and outside classrooms around the world. Through a series of iterative research studies, the SMILE model aims to continually improve both the application and the implementation procedures, while also understanding in what contexts and with whom the SMILE model is most effective.[2] The research is not comparative in nature, in that we are not comparing sites to understand where implementation is most successful – rather, we are gathering insights from each site to further develop both the application and implementation of the SMILE model. In this sense, each site provides insights for how to implement the model in various contexts worldwide.

The SMILE Model draws on prior educational design research. Reeves (2009) outlines the four-stages of educational design research as: 1) Identify Stage 2) Prototype development; 3) Iterative Testing; 4) Reflection and evaluation. Similarly, we draw on Kim's (2009) model for action research in the developing world. Kim (2009) specifies four stages of designing educational interventions for under-resourced areas of the developing world. Kim's stages are: 1) Strategize;

[2] As Kelley advocates, the project has generated a specific educational innovation, a mobile phone application known as Global SMILE, which is open-source and publically available to all students, teachers, and researchers who have access to mobile phones and an Internet connection (through the iPhone or Android markets). The Global SMILE application is continuously being refined in light of pilot study findings.

2) Apply; 3) Evaluate; 4) Reflect. These four stages are similar to those proposed by Reeves (2009), however Kim's (2009) model is particularly appropriate for thinking about how academics, funding organizations and civil society organizations in highly developed countries can work with and support the work their peers are doing in under-resourced regions of the world. At all stages of the model, researchers are encouraged to strategize and test the technological innovation with academics and organizations working locally and globally to share resources and knowledge.

According to this design process, the SMILE project is currently in the iterative testing and research stage of the design process, and has begun testing the SMILE application in multiple countries and contexts. Seeds of Empowerment, a globally networked NGO that has helped develop SMILE, has piloted studies in the United States, India, Argentina, Indonesia, Korea and Tanzania. Working jointly with Stanford University, Seeds of Empowerment is working to refine the SMILE project application and better understand how it can enhance student learning and expand opportunities for student inquiry inside and outside of school. Together, we have carried out a series of experiential workshops in a wide range of contexts globally, and are continuing to research the design and implementation of SMILE by testing it out in a wide variety of classrooms worldwide.

Findings

This section provides an overview of the various studies carried out to assess the effectiveness of the SMILE model. In each pilot study, we asked: what elements of the SMILE approach are effective, and what are the limitations to the SMILE model?

1. Science Inquiry in Northern California

In a preliminary study, we implemented SMILE in a 5th grade science classroom in Sunnyvale, California, a mixed-income small city located in the Silicon Valley. Students used a prototype of SMILE to generate questions (See Figure 5., left); the students were familiar with mobile technology and with asking questions. They were able to ask media-rich questions without difficulty (See Figure 5. Middle and Right). However, their initial level of inquiry remained focused on recall of information, as shown below in their sample inquiries. This is largely due to the lack of inquiry making experiences in their traditional classroom setting. Nonetheless, students reported that the activity is not only enjoyable, but also helpful in reviewing material for tests (Seol, Sharp, and Kim 2011).

Additionally, the Sunnyvale teacher easily adopted SMILE into classroom practice, and further developed her own teaching strategies around SMILE. She taught students about Bloom's taxonomy and asked students to evaluate their peers' questions based on the Bloom's taxonomy classification. For example, if a question was designed to simply trigger simple recall, she advised students to give it a low rating. If a question required application of knowledge or synthesis of multiple concepts, she advised them to give a higher rating. This impressive local innovation on the part of teachers was an indication that teachers indicated that teachers could play an important and active role in linking technology and pedagogy within the SMILE model, and informed future studies' teacher trainings by encouraging teachers' creativity, experimentation, and ownership of the program.

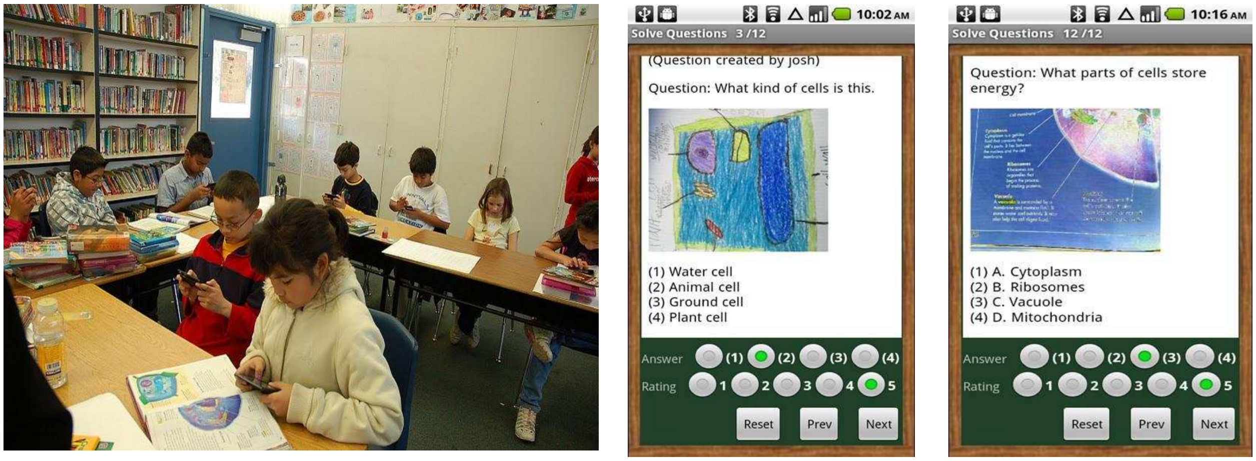


Figure 5. Left - 5th grade students in SMILE activity. Middle – Sample inquiry 1 incorporating a drawing. Right – Sample Inquiry 2 incorporating textbook figure.

2. Math and Science Inquiry in India

The second pilot study was conducted with students from Nellore, India, a southeastern rural area. These students were asked to generate questions using SMILE from any topic of their choice from the math and science textbooks they had. Students had hard time generating their own questions (compared to the first school) due to limited familiarity with experiences with strictly passive rote-memorization activities in classrooms. Students practiced several times on paper to get them familiar with questioning skills. Additionally, students had little experience manipulating the smart phones; however, after roughly 20 minutes of exploration, they adjusted to the technology.

Students were able to generate a variety of questions on motion, levers, static electricity, moon eclipses, and fractions (See Figure 6. Middle). There was no teacher involvement other than observing and minimal facilitating. The advanced students were asked to explain their questions to the rest of the class. Due to a lack of stable electricity connection, a car battery was used to power the notebook and the SMILE network (See Figure 6. Left). The class was highly heterogeneous in their achievement level, and the depth of inquiry varied substantially. It was clear that the questions of the more advanced students challenged the less advanced students (See Figure 6. Right. Advanced student question in English). This study raised important new questions about how SMILE can be best used in mixed-ability classrooms, and what the advantages and disadvantages are of grouping students by ability for various purposes of SMILE implementation, which is an area for future research.

Figure 6. Left – Student powering the SMILE network server with car battery. Middle – Students generating questions. Right – Sample student-generated question.

3. Undergraduate Classes at Stanford University, California

The third pilot study was carried out at the university level. In this study, students were asked to generate questions based on all the learning in the class to date (i.e., Summative assessment for the class). Interestingly, they were generating questions using Google search, Wikipedia. Some of the students used both notebook computers (if they had one available) and the mobile phone we provided (See Figure 7). Some of them took pictures of the screen from their notebook, textbooks, reading materials, etc. In one hour, students were able to generate, answer and rate at least three questions. The pace of the activity was fast because they were able to do quick research, use mobile phones without difficulty, and found the concept of generating questions quite comfortable. However, their initial questions were mostly simple recall questions.

Figure 7. Left. Students are using both notebook computers and mobile phones to generate inquiries. Right. Students are incorporating simulation graphics from their computers into their inquiries in Junction Quiz.

By studying each other's questions and understanding which question get higher ratings, the students' questions became more conceptually difficult; likewise, their motivation to generate higher quality questions also increased. While discussing the questions generated in the first round, the workshop facilitator gave students clear specifications on what constitutes high quality question (e.g., questions with multiple concepts, more effective media incorporation, triggering critical thinking, etc.). This study raised important questions on how to improve the quality of student-inquiry over time and what the role of the facilitator is in setting early guidelines for stimulation and multi-purpose class learning evaluations.

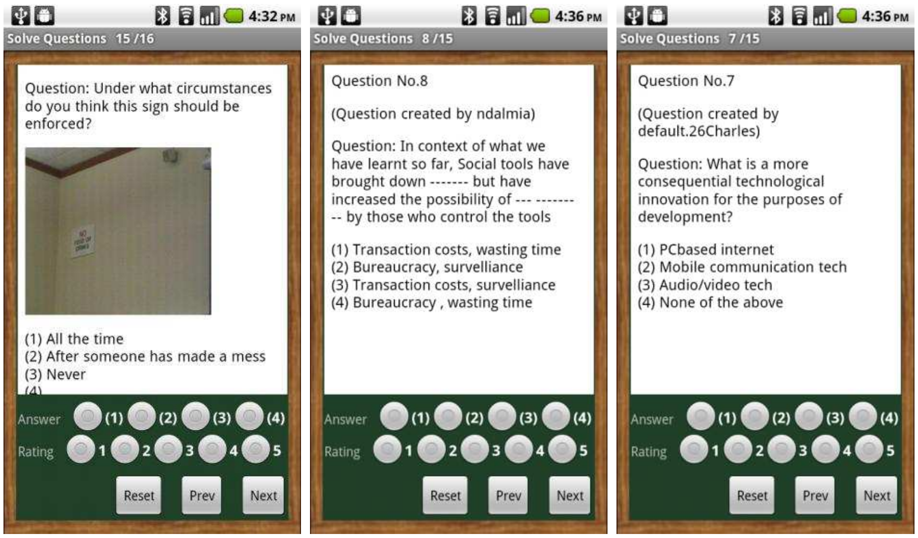


Figure 8. Sample questions generated by students.

4. Civic Engagement in Misiones, Argentina

The fourth pilot study was carried out in an urban high school located in Northern Argentina. In this adaptation of SMILE, students used SMILE to think critically about what it means to be an engaged citizen in their community. Specifically, students were asked to generate questions for their peers relating to moral dilemmas that might arise in their community. Students generated questions on homelessness, suicide, stealing, and school bullying and violence (See Figure 9). They were able to make interactive and media rich questions by acting out a skit to present the concepts of social issues and capturing their skits on video.

For example, participants took pictures of ambiguous civic circumstances and created questions for their peers, such as "What would you do in this situation?" or "Who do you think is responsible for this?" Some students took pictures depicting homelessness and others captured bullying. Through the process of rating each other's questions, students came to the realization that better questions were those that divided the class in terms of responses, where less complex questions would yield unanimous answers. However, most topics drew various perceptions, attitudes, and dispositions. After three rounds of creating, answering and rating each other's questions, the high school students began to generate profound and challenging questions relating to local concerns. For example, one question addressed the fact that there had been an increasing incidence of suicide in the area and asked their peers what they thought was the leading reason for this. In this context, we realized additional benefits of SMILE. In other words, SMILE was not only a student learning and assessment management tool, but also a discussion-generation tool that opened up various opportunities to bring out numerous issues perceived as important by the participating students.

Figure 9. Top left – Students enact a skit on homelessness. Top right – Students act out a skit related to depression. Bottom left – Students act out the issue of school bullying. Bottom Right – Workshop facilitator discusses student questions and answers with whole class.

5. Math in Indonesia

The fifth pilot study was carried out 6^{th} grade students in Pesantren, an Islamic boarding school, in the rural village of Wanaraja, Indonesia, and focused on mathematics. The students were asked to generate questions related to math, and their questions covered a wide range of topics, from the triangle angle sum theorem, to fractions, areas and diameters. Teachers were surprised by the students' enthusiasm. They were also surprised by the students' ability to adopt the technology by themselves and their capacity to train each other and even their teachers with a great sense of achievement and pride. This pilot study suggested that SMILE supports teachers' in carrying out student-centered initiatives, by providing teachers a platform for student-initiated learning and activities, and demonstrating the immediate benefits with respect to classroom environment and student engagement.

For this project, we developed and refined an implementation method targeted to math inquiries, which consists of: 1) device exploration; 2) prompting students for problem generation in groups; 3) competition against other groups and class discussions; and 4) evaluation, reflection, repetition and enrichments. Using this model, questions covering a variety of topics were generated and shared. The format balanced collaboration within groups and competition between groups, ensuring scaffolding and evaluation among peers, however we also noticed that in nearly every group, one student tended to be dominant. During the share-out phase, students were excited to see their questions posted on the projector screen, suggesting that visualizing and sharing work with the entire class can be a motivating experience for participants, especially in classrooms where computers and projectors are rare. Future research is needed to understand the strength and limitations of having a dominant group member, and how the age, gender, and ability level of the dominant student might affect the effectiveness of student inquiry.

Figure 10. Left and Right. Students generating a variety of math questions on Junction Quiz. Students incorporate their own drawings into Junction Quiz through the phone's camera function.

6. AIDS Instruction in South Korea

Through our iterations of SMILE, we were prompted to develop additional software that can be used not only in class but outside of class as well. Unlike the ad-hoc version of SMILE, which is used for synchronous real-time sessions, SMILE Global works with a central server in an asynchronous mode, which aggregates all questions, generated from SMILE sessions around the world and lets participating schools share and exchange questions. The advantages of SMILE Global are that it allows students to generate questions using mobile devices without being in the same place at the same time. Moreover, it promotes the exchange of inquiries on common topics from learners of all ages and regions, while still allowing students to share experiences from their local contexts and cultures.

We tested SMILE Global with medical students at Chungbuk National University in South Korea. We first held a short discussion on the potential criteria needed to define and evaluate high quality questioning at the beginning of the session and the criteria rubrics, based on student feedback and our previous experiences with SMILE. Sharing sample questions with students prior to their interaction with SMILE highly impacted participants 'understanding of what is expected from them to do. Sample good and bad quality inquiries were shared and discussed with participants. This overview of question quality was initiated in response to prior iterations and seems to be an important component of promoting deep inquiry.

Students preferred using web based content (Naver – the Korean version of Google search, Wikipedia, etc.) instead of their textbooks to understand the topic, but then often used their textbook and group discussions for deeper understanding. Follow up studies showed that by the end of the activity, the students were thrilled with the activity and were pleasantly surprised by how deeply it required them to think about the topic.

During this iteration, we also began to include evaluation criteria for student questions, which allowed us to explore the possibilities of SMILE as an assessment tool in more depth. Participants' high level of technology exposure accelerated the process of inquiry generation and interaction with SMILE. Participants spent 60% of the time on inquiry making task; informing them that there would be global access to their questions was added motivational factor to encourage them to create high quality inquiries.

We found that participants used videos to support their SMILE inquiries, and that media richness was another highlight in this experience. However, the students' overall low-level of English proficiency negatively affected the process, as it slowed down student inquiry generation process. We concluded that automatic machine translation of questions would be beneficial for those who speak English as a second language. With easily accessible translation tools, students from all regions will be able to contribute and exchange inquiries freely. With recent advances in translation technology widely available, language should not be a barrier for SMILE Global. We believe that for medical students, exchanging inquiries on medical knowledge through a global inquiry exchange tool such as SMILE Global seems like a beneficial avenue for research, particularly for students attending medical schools in the developing world.

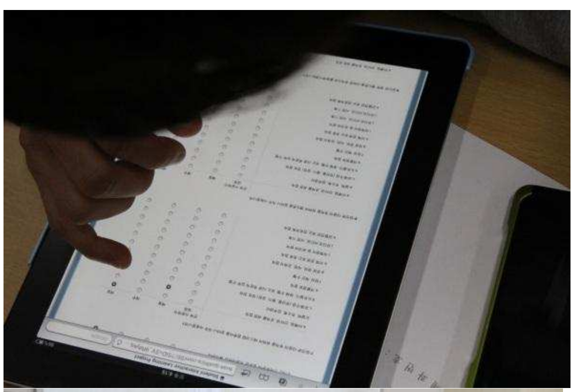


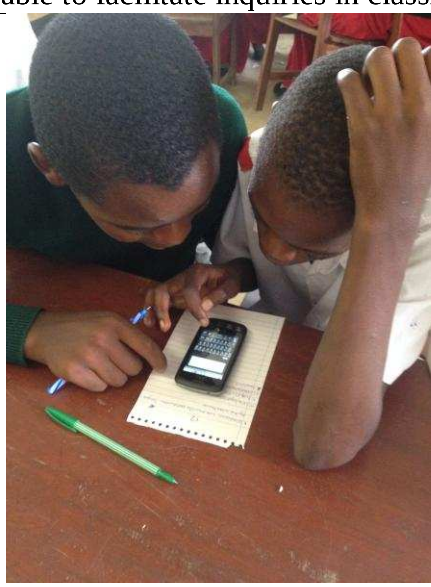
Figure 11. Figure Top Left – Students taking pre-test survey on iPad. Top- Right – Students learning about high quality question matrices. Bottom Left – Students presenting their question submitted with iPad. Bottom right – Students in groups generating questions.

7. High School English in Tanzania

The most recent pilot study was carried out in Newala, Tanzania through a joint initiative between Stanford University, Seeds of Empowerment (a globally networked NGO) and Jiamini, a local NGO based in Newala. This pilot study is the first long-term investigation of SMILE as a regular pedagogical practice in a pilot school in rural Tanzania. The objectives of the pilot study are to understand how SMILE is used in classrooms in very under-resourced educational settings, and whether students' abilities to pose and respond to self-created inquiries develop over time.

Teachers and administrators alike were enthusiastic about integrating computers and mobile phones into their classrooms, and eagerly adapted to inquiry-based techniques into SMILE lessons. Nonetheless, the pilot also faced important challenges, which shed light onto the feasibility of SMILE projects in under-resourced areas. Findings from the initial study found that it took two weeks for students and teachers alike to be comfortable with the computer and mobile devices. Although many students were familiar with mobile devices, manipulation of smart phones was difficult at times, and took a period of adjustment. Additionally, implementation of the program was hampered by frequent electricity outages.

Since February 2012, researchers have been receiving sample student questions roughly every two weeks from participating teachers in Newala, Tanzania. The depth of inquiry indicated by student questions is improving over time, moving from memorization-based to some application of knowledge and manipulation of facts. The project has generated important insights into the SMILE implementation model; first, we recognize the importance of having committed and creative teachers to serve as "technology experts" in their schools. Second, we note that these teachers need an initial training period, and some follow-up mentoring to ensure that they are able to facilitate inquiries in classrooms.



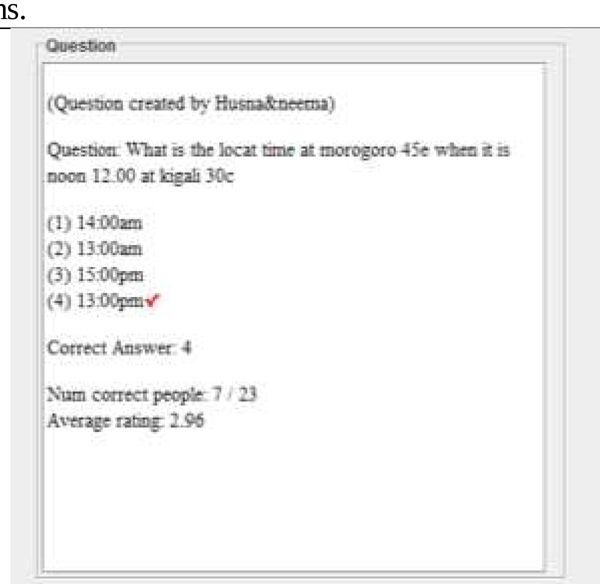


Figure 12: Tanzanian students using SMILE in groups; sample question from

Tanzania (right)

Major Findings
Our studies suggest that mobile devices can be implemented in a wide range of classroom settings with relative ease, and can clearly increase inquiry-based pedagogies. A number of similarities emerged across all contexts that suggest support for the SMILE implementation model, namely: the ease of implementation model, the relatively quick adoption of mobile devices in classrooms, efficient uses of technological resources. In terms of the effects of SMILE on classroom practices, we also found that during SMILE workshops, relationships between students and teachers changed.

In all sites, teachers adapted quickly to the inquiry-based practices used in the demonstration workshops, and were able to run workshops themselves easily. Similarly, mobile devices were not foreign to students; in all contexts, students were able to experiment with the phones and various applications, and were able to manipulate the SMILE app. Even in the most under-resourced site (i.e., Tanzania), the adoption time for use of inquiry-based methods through SMILE was under two weeks. In the developed country contexts, and at higher levels of schooling (university), students were already fluent with the mobile technology and the time learning to manipulate the SMILE app was negligent. This suggests that worldwide, mobile phone applications can be implemented in a wide variety of educational settings, with relatively quick learning curves.

Additionally, in our follow-up correspondence with teachers in Tanzania, we find that one set of mobile devices can be shared throughout a school, much like a computer lab is a school-wide resource. This “mobile” computer lab is an efficient use of the technological resources, and allows devices to be shared among many students and teachers in the same school.

In terms of pedagogy, initial studies suggested that the relationships between students and teachers changed quite dramatically during the SMILE sessions. As expected, teachers were not simply transmitting information to students; rather, students were drawing on written or digital resources to formulate their own questions. Students also worked together in highly collaborative small groups, in contrast to individual student work. The teacher played an important role in guiding students through the solutions to difficult questions, and in correcting any mistakes or elaborating on student-generated questions. In this sense, the studies did suggest that SMILE was able to transform typical relationships in class, at least for the duration of the SMILE workshop.

Nonetheless, the success of implementation also differed along important dimensions, depending on the context. First, as expected, we found that students in more developed countries had no technological learning curve, while those who had no familiarity with smart phones had a longer learning curve to use the phones. In terms of application design, even seemingly simple tasks such as putting in their name or group number actually requires a good bit of knowledge of the phones, such as how to delete a character or find the shift or space keys. Our pilot study from Tanzania suggested that students would be relatively competent users of the smart phones after roughly two weeks time, but that user interfaces should be as simple as possible, particularly for applications designed for the developing world.

A second major finding was that students' abilities to generate their own questions differed substantially. Students from developed countries were more competent questioners generally, when assessed on dimensions of Bloom's taxonomy. The majority of student-generated questions relied on rote memorization in the early workshops in less-developed countries, such as Tanzania. In contrast, students who had more exposure to inquiry-based methods were able to generate analytical or application-based questions. In this sense, we conclude that teacher quality is another important component in the success of a SMILE workshop. Students and teachers who have been exposed to inquiry-based methods in their classes have an easier time bringing to the SMILE workshops. However, in our long-term follow-up projects in Tanzania, we do find that students' questioning skills have developed over time, which is the purpose of the SMILE activity. Training teachers to continue to carry out SMILE workshops, and facilitate student inquiry over time is an important component of the SMILE model. In this sense, our study confirms prior research that technology can never replace the importance of teacher training. Nonetheless, we do finds support for the idea that mobile device applications, such as SMILE, can serve as an effective platform for encouraging greater student-centered activities and practices in classrooms.

Additionally, we also note that the implementation process itself can be hampered by a lack of minimal technological infrastructure. Although it is not impossible to run a SMILE workshop in a school without electricity (as demonstrated in the India pilot), it is much more difficult, as the workshop requires a working laptop, router and charged phones.

Scaling Up and Future Research

How can the SMILE model scale-up its impact? We have witnessed a groundswell of interest in what SMILE offers, and have also tried to understand what factors make SMILE most likely to be successful. We have found that a SMILE project can be initiated by any sector -- universities, businesses, or educational officials. However, in order for technology-enabled inquiry-based pedagogies to take place in classrooms, and for it to be able to reach its maximum effectiveness, we have realized that local educational officials must be on-board. Obviously, SMILE works best when educational officials, civil society organizations, universities and local businesses work together to bring SMILE to classrooms, and each supports different elements of its implementation.

We believe that SMILE can serve as an effective pedagogical model for implementing technologically enhanced educational development projects in the developing world. The critical elements needed to incorporate SMILE into classroom teaching are:

1) Mobile devices, (i.e., not notebook computers). This increases the overall sustainability by reducing the cost, and increasing scalability, maintainability and opportunities for collaboration, especially in under resourced and under developed region. SMILE can also be highly effective with a ratio of one device per three learners.
2) Application localization and development (translation and development).

3) Facilitator workshop – in order for teachers or facilitators to experience SMILE. We found that students who are able to quickly pick up technology can be excellent resources for technology training both for themselves and for the teachers.
4) Monitoring and evaluation.

Implementing a successful educational innovation requires the thoughtful consideration and deep understanding of the local educational ecosystem. Given the many aspects needed to create a successful SMILE project, we believe that implementation necessarily requires collaboration with an educational ecosystem's many constituencies and stakeholders. In our model, we believe that the basic "educational ecosystem" consists of learners, teachers, parents, education governance structures, industry partners, universities, and NGOs, along with other potential stakeholders. An effective SMILE project brings together members of these varied constituencies to implement a project – for example, in most of our prior studies, the SMILE model bring together business leaders, who take charge of providing local telecom network infrastructure and equipment such as mobile devices and computers, local educational administrators to facilitate participation of local schools and offer SMILE pedagogy workshops, universities to conduct research on the strategies to enhance the model within the local context, and NGO partners, who can provide localized knowledge, programmatic oversight, and project coordination. This eco-systematic approach brings together many stakeholders, without overwhelming the limited resources of any one sector.

Conclusions

Asking questions and inquiring about how the world works is a natural human disposition and an important process through which people learn. Moreover, it is at the heart of a needed shift in classroom pedagogies around the world, transitioning away from dictating information towards student engagement with learning and problem solving. This article has discussed two associated projects – SMILE Ad-Hoc and SMILE Global, both of which aim to foster learning by promoting student inquiries. SMILE Ad-Hoc expands inquiry-based and multimedia-rich learning programs in both rural and under-resourced schools. SMILE Global builds off of SMILE Ad-Hoc to connect learners of all regions and ages around. We believe that technology can empower students to take their learning into their own hands, and make them active agents of their own learning.

Although many educational initiatives have aimed to bring technology to children, prior experience has shown us that a hardware-only model does not work. Innovative educational software and applications are also sorely needed. However, pre-made content that seems innovative in developed countries may not be useful in the developing world, if they are not contextualized. Until now, most innovations are developed and piloted in the developed world and then transferred to contexts for which they were not designed – we have a lot to discover about the potential power of mobile innovations by targeting their development to the specific needs and contexts of developing world schools and students. Even the open-source content movement, which seems innovative in the developed world, will not be benefit those in the developing world if there are not local developers to deliver and contextualize content. Open source content cannot reach rural villages without access to the Internet and reliable electricity, unless intermediaries deliver technology. Moreover, there is no way for educational technology to have a practical impact on disadvantaged communities if is not translated and contextualized to local needs.

Future educational technology innovations must continue to not only leverage local content and practices, but also nurture local creativity and entrepreneurship. Otherwise, such technological innovations may remain short-lived and expensive episodes that benefit no one. SMILE is an innovation that aims to take into consideration local materials and conditions in allowing teachers and students to create a more active learning environment. It can even work in places where the teacher is the only person with a textbook due to poverty or just poor infrastructure. For example, studies indicate that mobile devices with cameras and video recording can help duplicate and distribute scarce education materials within highly disadvantaged school settings, and also enable students to participate in inquiry-based activities. We must not forget that mobile technology of today can be put to help nurture digital and multimedia literacy among students in developing regions even they may not have reliable electricity or fixed infrastructure. Through inquiry-based learning such as that facilitated by SMILE, students are engaged in real-world problem solving, thinking, and skill building. This is where our focus should be, as these are the goals of truly liberating educational practices.

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