Educational Technology International
2008, Vol. 9, No. 2, 97-121

Seamless Mobile Learning: Possibilities and Challenges Arising from the Singapore Experience

Hyo-Jeong SO*
Nanyang Technological University
Singapore

Insu KIM
Seoul National University
Korea

Chee-Kit LOOI
Nanyang Technological University
Singapore

The purposes of the present study are to describe the design of mobile learning scenarios based on learning sciences theories, and to discuss implications for the future research in this area. To move beyond mere speculations about the abundant possibilities of mobile learning and to make real impact in K-12 school settings, it is critical to conduct school-based research grounded on the learning sciences theories. Towards this end, this paper describes school-based mobile learning projects conducted by a research team at the Learning Sciences Lab in Singapore, and then discusses the possibilities and challenges of mobile learning to further inform future research. Specifically, this paper explores the affordances of mobile technology, such as portability, connectivity and context-sensitivity, to design seamless learning scenarios that bridge formal and informal learning experiences. The authors present a framework for re-conceptualizing different types of learning based on physical settings and intentionality, and then describe two seamless learning scenarios, namely 3Rs and Chinatown Trail, which were implemented in one primary school in Singapore. In conclusion, the authors discuss the affordances of seamless mobile learning for enhancing one's lived experiences to build a living ecological relationship between the person and the environment, and how mobile technology can play a critical role for enabling such lived experiences.

Keywords : mobile technology, seamless learning, informal learning, knowledge building, location-based learning

* National Institute of Education, Nanyang Technological University
hyojeong.so@nie.edu.sg

Introduction

The recent development and adoption of mobile technology in education provides an opportunity to redefine the conception of learning. From traditional perspectives, learning is defined as an interaction between instructors and learners in a classroom setting. Through the use of desktop computers with network functions, it became possible to overcome the limitations of fixed physical settings and to extend the opportunity of learning at anytime and anywhere, which is the significance of e-learning. Furthermore, the recent trend of mobile technology for learning provides another possibility to design learning environments across spaces and time. Now, portable mobile devices such as cell phones, PDA (Personal Digital Assistant), Tablet-PCs, and UMPC (Ultra Mobile PC) are recognized as essential tools for our daily lives. In the areas of education, with the assumption that such devices would lead to the realization of one-to-one computing towards the future of seamless learning, there has been an increasing body of research that investigated the potential of learning in Korea and other countries.

While the previous research studies in mobile learning focused on the impact of one-to-one computing in school settings (Norris & Soloway, 2004), the recent research trend is to explore broader contexts such as: the possibility of mobile learning in informal settings (e.g., museums, science centers) (Hsi, 2003), situated learning in real physical settings (Facer et al., 2004), and design of augmented reality and game-based environments using mobile devices (Squire & Klopfer, 2007). In Korea, mobile learning has been applied in school curricula to promote self-directed and creative learning through the use of mobile devices (Han & Kim, 2003). Such mobile devices can support more productive use of time by enabling learners on the move to search for and store necessary information (Park, Han, & Lee, 2005). Therefore, it is expected that the use of mobile devices as a tool for knowledge building and sharing can bring about improvement of learning quality and effectiveness.

With the growth in significant interest in the pedagogical implications of mobile learning, we need to redefine our conception of learning, learning activities, and teaching strategies to fully realize the pedagogical potential of one-to-one computing and seamless mobile learning (Swan, Kratcoski, & Hooft, 2007). Thus, our research aims to bring pedagogical changes not from the newness of the technology itself but from the innovative practices that fully utilize the affordances of mobile technology to engage students in their learning processes.

Despite the realization that mobile technology has the potential of leading the future of learning for the 21 century learners, there has been lack of in-depth longitudinal research based on school environments. When reviewing recent research on mobile learning, it is apparent that most studies used short-term interventions, focused on usability and attitude issues, or examined the application of mobile tools to adult users. Finn and Vandenham (2004) argue that “the time has come to move beyond the simplistic question of whether or not handhelds have a place in the classroom, and begin focusing on the more detailed questions concerning how this technology might affect teaching practice in the long term” (p.28). To move beyond speculating about the abundant possibilities of mobile learning and to make real impact in K-12 school settings, it is critical to conduct school-based research grounded on the learning sciences theories. For this end, the present paper describes school-based mobile learning projects conducted by a research team at the Learning Sciences Lab in Singapore, and then discusses the possibilities and challenges of mobile learning to inform future research in Korea and other countries.

Literature Review

Essential Features of Mobile Learning

Learning can be enhanced through the portability, connectivity, and context-sensitivity of mobile devices. In theorizing mobile learning, Taylor and Vavoula (2007) argued that it is important to consider the semiotic perspective which analyzes learning as a cultural activity mediated by technological tools. In addition, they suggest that future research in the area of mobile learning should test the following five questions for the tight coupling of pedagogy and technology: (1) is the research significantly different from the theories of classroom learning, workplace or lifelong learning?; (2) does the research explain learners' mobility?; (3) does the research include both formal and informal learning aspects?; (4) does the research theorize learning as a socio-constructivist process?; and (5) does the research analyze learning as an individual and situated activity? In this section, previous research on mobile learning, including research conducted in both Korea and other international countries, are discussed based on these five questions.

First, the portability and versatility of mobile devices has significant potential to promote a pedagogical shift from traditional teacher-centered to learner-centered and participatory learning environments. Learners can participate in learning scenarios that utilizes the mobility, portability, and context-sensitivity of mobile devices. They can act as active self-directed learners, rather than passive learners following one single path of learning. Participatory simulation, designed at the MIT Media Lab, is an example of such learning scenarios that apply the affordances of mobile technology for active learning. Colella (2002) examined how learners interact with other learners in a virus game environment that utilized the Thinking Tag technology which changes information depending on who the learner is interacting with. Colella (2002) explored how the participatory simulation could create experiential learning experiences to help students learn high-order scientific concepts. Later, research on participatory simulation moved from Thinking Tag technology to mobile technology. The Savannah project by the Future Lab, UK, examined how to design a virtually-augmented learning environment in which learners interacted with other human agents to learn about animal ecology and behavioral patterns. This line of research on participatory simulation shows the synergetic effect of coupling real and virtual environments, and the importance of mobility for active learning.

Second, the nature of mobility as a continuous attribute should be a critical element of mobile learning scenarios. Mobility enables a shift from one-to-one to many-to-many communication, individual to collaborative interaction, and centralized to de-centralized systems (So & Kim, 2008). A key question is how to utilize the nature of mobility to design a space where learners "on the move" are shifting between various communication and interaction modes in a seamless way. Squire and Klopfer (2007), for instance, examined the effect of augmented reality simulation games mediated by mobile computing. In this study, students used Pocket PCs to participate in the immersive simulation game called the Environmental Detective designed for environmental engineering education. The mobility of devices enabled students to collect, analyze, and share data in situ across settings, thereby creating a balance between physical and virtual learning for lived experiences.

Third, another significance of mobile learning is that it challenges our conception of learning to move beyond a dichotomy between formal learning and informal learning, for the design of a seamless learning space linking the two modes of learning. From traditional perspectives, school learning emphasizes individual cognition, mental activities without the use of tools, and learning in general contexts (Resnick, 1987). Recently, educational research increasingly recognizes the fact that a significant amount of learning is happening in informal settings outside of school. Barron (2006) adopted a learning ecology lens to analyze how learners with diverse backgrounds learn about technology skills in various formal and informal settings. Other studies explored the effect of mobile learning in informal settings such as museums and science centers. For instance, Hsi (2003) investigated the behaviors and experiences of museum visitors using a mobile device. Chen and Kinshuk (2005) designed and evaluated a learning system for bird watching in outdoor settings where students could use wireless PDAs to record their observations.

Fourth, mobile CSCL is an area that focuses on the role of mobile technology to support collaborative learning. Earlier research on CSCL is grounded on socio-cultural constructivism, and the mediating role of technology to support collaborative meaning-making processes. According to Roschelle, Rosas and Nussbaum (2005), the meaning of an activity in mCSCL refers to two aspects, namely content and relation, which mediate both technological and social relationships. The essence question in mCSCL is about how to make the tight coupling of technological and social dimensions of learning. In mCSCL, some research studies have been conducted for creating learning scenarios to support interaction and collaboration among multiple users through the mediating role of mobile tools. For example, Zurita and Nussbaum (2004) investigated how seven-year old children with low linguistic abilities used networked mobile devices to construct words collaboratively. Their study reported that children who participated in mobile collaborative learning activities achieved significantly more word acquisitions than those in a paper-based group.

Finally, mobile learning research emphasizes the socially situated nature of learning and practices. In activity theory, one of the theoretical and analytical frameworks in mobile learning research, an activity is a basic unit of analysis to understand human cognition and interaction situated in a certain context (Engestrom, 1999). Thus, activity theories view the relationship between subjects and objects as a mediated phenomenon through the use of tools, which can be either invisible such as signals and rules or tangible such as computers, mobile devices, and other tools (Zurita & Nussbaum, 2007). Activity theory in mobile learning has been used as an analytical lens to disentangle the complex relationships of subjects, tools, relationships, and other socio-technical infrastructure manifested by the use of mobile devices.

Mobile Learning Research in Korea

Interests in mobile learning have increased rapidly in Korea. To review research studies about mobile learning in Korea, the search of relevant research was conducted in the electronic database (http://www.riss4u.net), using key words such as "mobile", "PDA", "Tablet", "hand-held", "learning", and "education". Results showed that mobile learning research in Korea has been focused on three areas: (1) how teachers and students use mobile technology for classroom learning; (2) how mobile learning content can be developed; and (3) how mobile technology supports learning activities.

First, in research about how teachers and students use mobile technology in classroom, Lee (2005) investigated teachers, students and parents' perceptions about the educational use and potential availability of Tablet PCs. Teachers applied Tablet PCs in their classes mainly in three ways: (a) students read online textbooks and solve problems, (b) students search the Internet and find solutions for their project-based learning, and (c) students take exams using the Tablet PCs. The findings show that the amount of learning, various learning activities, and computer literacy of learners increased and that students' attitudes toward the project was changed more favorably. For teachers, they spent more time designing learning activities. For parents, they expected that learning experience with Tablet PCs would positively affect their children's learning in the future.

Second, in research of mobile learning content, Kim and Kwan (2007) developed a handheld learning tool based on the design principles drawn from the cognitive load theory. They pointed out that most studies about PDA in education focused on the font size and the navigation design to overcome the problem of small screen sizes. Five principles applied to developing the learning program, for minimizing the extraneous cognitive load, include modality, redundancy, split-attention, multimedia, and worked-out examples. Park, Han, and Lee (2005) developed a crossword puzzle mobile game for computer learning, and evaluated the effect of this program on academic achievement, learner satisfaction and interests. Mobile games are the wireless Internet content that young learners often access through their mobile phones. However, mobile games currently available in the market are mostly simple entertainment packages, and there are hardly any educational game programs for mobile learning. The research divided the middle school computer education curriculum into five parts and implemented a crossword puzzle mobile game. The mobile game designed in this research places emphasis in allowing the access of school lesson content anywhere and anytime through the mobile telecommunication networks, so that the students might experience fewer barriers to enjoy more entertaining educational content. Ninety-six percent of the students expressed that the game was very fun, and ninety-three percent thought that the game was very helpful for learning.

Regarding systemic design of learning environments, Min and Choi (2006) developed a web-based mobile system to support three stages of field learning to maximize learning effectiveness. The three stages include the preparation, the actual field activity (mission, resource, question and answer), and the post-evaluation. Field learning provides opportunities to construct knowledge in real situations. Their proposed Web-Mobile system supports an integrated approach to effectively manage the three steps of field-learning, including functions such as searching for the activity plan, exploring necessary information, and managing and sharing information. In another study, Ryu and Lee (2005) examined the effectiveness of providing information in web discussions to increase interactions among group members through the use of mobile SMS. The result of the study showed that providing SMS functionality significantly affected the frequencies of uploading messages to the discussion board. The researchers suggested that SMS could increase learners' awareness of the discussion process and had a positive influence on increasing the interaction among students during the web discussions.

There are also some attempts to evaluate the overall effectiveness of mobile on a large-scale. Han and associates (2007) conducted a research study about analyzing the effectiveness of u-learning in the research schools sponsored by the Ministry of Education, Science and Technology for 3 years. In this study, the participating schools were categorized into three types: Type 1 based on the use of Tablet PCs

(TPCs) and Ultra Mobile PCs (UMPCs), Type 2 based on the application of cyber-home education systems, and Type 3 based on the use of Macintosh notebook PCs and iPod for ubiquitous-based learning (i.e., u-learning). The analysis of academic achievements revealed that, only Type 3 had a significant difference between the research class and the comparison class. Regarding learner satisfaction, self-directed learning and ICT literacy, Type 3 had a positive effect due to the mobility and immediate feedback. However, it was also reported that the teachers were reluctant to prepare classroom activities for u-learning.

When summarizing mobile learning research in Korea, it appears that teachers and students needed various teaching and learning methods to apply mobile technology for the effective design of instruction (Han et al., 2007; Lee, 2005). To move beyond the use of mobile technology for content delivery centered learning, it is necessary to develop more various learning activities integrating mobile technology and other supporting systems.

Mobile Learning in Singapore: Designing Seamless Learning Environments

In Singapore, the Ministry of Education initiated the Master Plan in Information Technology in 1997 to build an infrastructure for the application of information communications technology (ICT). Historically, mobile learning in Singapore can be traced back to the eduPAD project in 1999. The eduPAD is a small mobile device, 80g with 18cm screen and 16MB storage space, designed as a collaborative project among the Ministry of Education, schools, and industry sectors. The eduPAD project attracted international attention as an early effort to build a learner-centered constructivistic tool for bridging school learning and home learning (Lourdusamy, Chun, & Wong, 2001). However, it failed to lead a sustainable effect in school after one-year of the implementation due to various reasons, including the stability and maturity of the technologies used in building eduPAD, and that the ideal concept of its use was ahead of its time with the social infrastructure of the schools in those years.

With funding from the Ministry of Education, the Learning Sciences Lab was set up in 2005 with the belief that a stronger framing of the research from the learning sciences perspective, and stronger designs for research work, which address issues with a systemic approach on both the research and the practical implementation front, can enjoy sustainability. There is realization that we can learn much from all the research that over the years has accumulated much wisdom about what we know of learning now. There is an overall increase in our understanding of how people learn (Bransford, Brown, & Cocking, 2002). The learning sciences emerges as a multidisciplinary field which attempts to understand learning or rather "how we learn," and this question requires multiple perspectives and fields of understanding. Researchers from multiple disciplines have been engaged in this question for decades, and fields such as education, computer science, neuroscience, linguistics, anthropology, and others have been interested in this issue. Learning sciences researchers not only study learning in formal settings such as classrooms, but are also concerned with learning in and out of schools, including after-school care, museums, and other learning spaces. Over the last few years, thelab has conducted mobile learning research using Tablet PCs, UMPCs, and cell phones in school settings. This section describes two projects conducted by the research team in the Learning Sciences Lab as examples of seamless mobile learning scenarios.

Formal Learning and Informal Learning

In discussing mobile learning, it is important to understand the potential of creating a seamless learning space linking formal and informal learning modes. Traditionally, formal learning is defined as learning that happens at a fixed time following pre-defined curricula. Informal learning, on the other hand, means a mode of learning driven by self-interest and intention outside of school environments. Cross (2006) views informal learning like riding a bicycle while formal learning is parallel to riding a bus. When riding a bicycle, a person can direct a way to go and stop while a person riding a bus has to follow a fixed and limited path. Generally, when reviewing the literature on informal learning, it is apparent that many researchers do not agree with the idea of defining formal and informal learning solely based a physical setting (i.e., in school or outside of school). Barron (2006) argued that regardless of physical settings, formal learning may happen when didactic instructional activities are posed to learners, like parents teaching drill-and-practice skills to their children at home.

Therefore, in this paper, we view different types of learning based on two factors: physical setting and intentionality as shown in Figure 1. Type I refers to intentional learning in classrooms, like students using digital textbooks loaded in a Tablet PC. Type 2 means intentional learning outside of school environments. Field trips are an example of this type of learning. Type 3 refers to unintentional learning happening outside of school. In this type, learning is mainly driven by learners' interests and initiatives, rather than by teachers or school curricula. Finally, Type 4 means an unintentional learning in class, such as unplanned teachable moments and serendipitous learning (Bowles, 2004).

In general, learning refers to Type I that is intentional learning in classroom. Recently, there have been increasing interests in the importance of Types II and III learning. While Type II learning such as field trips focuses on experiential learning in real settings, there has been lack of research on how to link Type I and Type II learning in a seamless way to create rich experiences of integrated learning. Below are two mobile learning scenarios, designed and implemented in one primary school in Singapore, which aims to integrate Type I and Type II learning.

Physical Setting	Out class	**Type II** **Intended learning out of class** e.g. field trip to an art museum which is part of a school curriculum	**Type III** **Unintended learning out of class** e.g. using mobile phones to capture pictures and video clips of animal behaviors in a zoo and share them with friends, driven by self-interest
	In class	**Type I** **Intended learning in class** e.g. browsing digital textbooks on a Tablet PC	**Type IV** **Unintended learning in class** e.g. teachable moments, not planned by teachers
		Intended	Unintended

Intentionality

Figure 1. Types of formal learning and informal learning

3Rs (Reduce, Reuse, & Recycle) Learning Scenario

The purpose of the first learning scenario, the 3Rs, is to help learners understand concepts in environment education and apply those concepts into their daily life. Understanding that environmental education in school often focuses on abstract concepts separated from real applications, the 3Rs learning scenario aims for the transfer of learning from conceptual understanding of the 3Rs' concepts, namely Reduce, Reuse, and Recycle, learning in school, to applications in real-life situations like home and supermarkets. To bridge formal learning and informal learning experiences seamlessly, mobile devices (HP RX3715 Pocket PC) was used as a learning tool. In addition, the Windows-based mobile program was designed to facilitate learning processes. The design of the software program is grounded in the learning sciences theories that emphasize the iterative process of inquiry learning and the importance of gradual scaffolding. As shown in Figure 2, the program is based on the Challenge-Experiential Approach, including five interrelated stages: Challenge-Experience-Reflect-Plan-Apply.

Figure 2. Pocket PC software: Challenge-Experiential learning cycle

The purpose of the challenge stage is for students to recognize the environmental problem and formulate pre-requisite knowledge. Specifically, the teacher helps students understand the recycling problem, and the students record their ideas in the KWL (What I Know, What I want to know, & What I Learned) charts. Based on the ideas built in this stage, students move to the next stage "Experience" in a supermarket where they collect necessary data in situ. As shown in Figure 3, students at this stage engage in the three main tasks individually and collaboratively:

- *Task 1 Packaging*: After observing the different materials and size of packaging of products displayed in the supermarket, students use the Pocket PC to take pictures of objects and store in the photo album.
- *Task 2 Storage bags*: For 5 minutes, students observe how many plastic bags are used by consumers, and record the data in the program installed in the Pocket PC.

- *Task 3 Interview customers*: Students conduct interviews with costumers regarding their attitude toward the 3Rs concepts and record the data in the program installed in the Pocket PC.

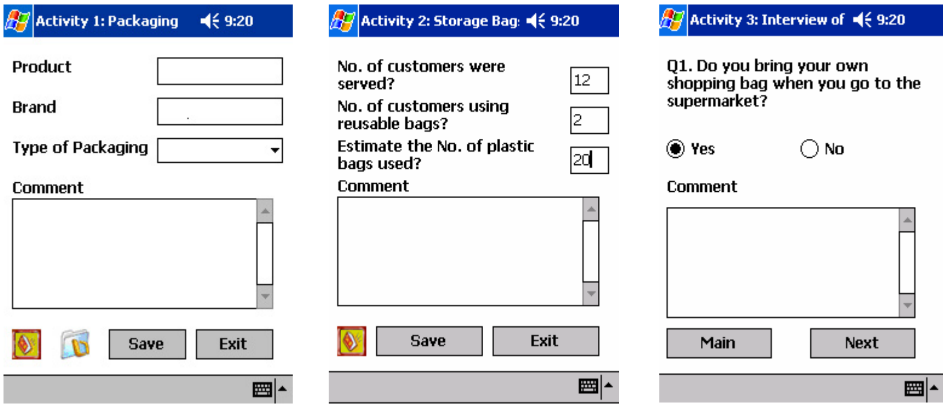
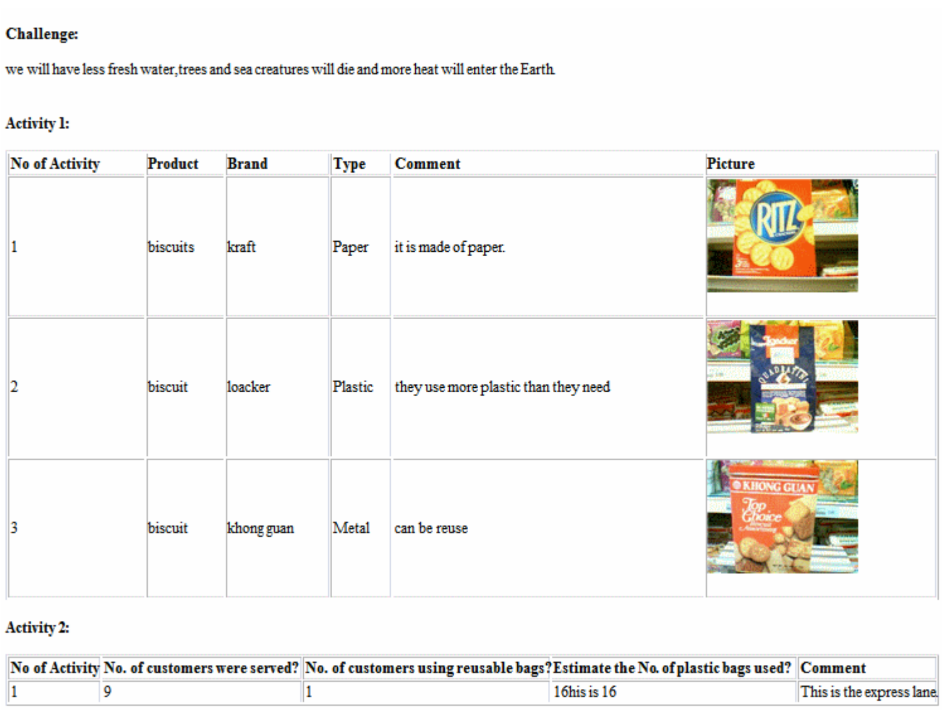


Figure 3. The interface of the 3 main tasks in the Experience stage



Challenge:

we will have less fresh water,trees and sea creatures will die and more heat will enter the Earth.

Activity 1:

No of Activity	Product	Brand	Type	Comment	Picture
1	biscuits	kraft	Paper	it is made of paper.	
2	biscuit	loacker	Plastic	they use more plastic than they need	
3	biscuit	khong guan	Metal	can be reuse	

Activity 2:

No of Activity	No. of customers were served?	No. of customers using reusable bags?	Estimate the No. of plastic bags used?	Comment
1	9	1	16his is 16	This is the express lane.

Figure 4. An example of the product package uploaded to the website

After completing all the tasks, students upload their collected data to the school portal using the wireless network function in the Pocket PC. Figure 4 shows an example of the product package uploaded to the school portal website. At the third stage "Reflect", students come back to the school setting and share their data and learning experiences. Finally, students present how they want to apply the 3Rs concepts in their daily life.

The characteristics of this 3Rs mobile learning scenario are to link learning in class and outside class intentionally through the mediation of mobile devices, and to enable learners to collect data in situ. The software program based on the Challenge-Experience cycle acts as a cognitive scaffolding tool that assists learners to be aware of the problem, to formulate a clear goal for learning, to organize pre-requisite knowledge, and to intentionally plan for their learning path before going to the field. When considering that students often participate in field trips without clear intention of learning, this challenge-experience cycle provides an important anchor point to direct more intentional and active learning experiences. In addition, the role of mobile devices in this learning scenario can be described as an integrated inquiry tool enabling students to learn in multiple locations. Since the students were able to store and share data in the website, the whole process of the inquiry process happened without much delay of time.

The results of the application of this 3Rs learning scenario showed that it was effective to use the handheld computers with appropriate software for students' authentic learning. Students' content knowledge on 3Rs concepts increased significantly after participating in this learning scenario. With the handheld computers, students' learning activities are more organized as a result of the complex processes made simple with the use of mobile devices (see Tan et al., 2007 for more detail of findings).

Chinatown Trail Learning Scenario

The purpose of the second learning scenario, the Chinatown Trail, is to help students engage in the knowledge building process in the field trips. Based on the pedagogical theories of knowledge building (Scardamalia, 2002) and location-based learning (Lim & Barton, 2006), this learning scenario was designed to help learners appreciate the social and cultural aspects of places that they visit in the Chinatown. According to Scardamalia and Bereiter (2006), knowledge building is grounded on the socio-constructivism which values the co-construction of knowledge by a community of learners. When learners build knowledge collaboratively toward a certain goal, what the community of learners can achieve is much greater than what the individual learners can do. In the theory of knowledge building, knowledge is viewed as a dynamic and improvable entity rather than a static and fixed one resided in one's cognition. Knowledge Forum is a technical tool that facilities the process of knowledge. For the past decade, knowledge building research has gained increasing interests in Asia-Pacific countries such as Hong Kong, Singapore, and Japan as well as the North America where the theory was originated from. A study conducted by van Aalst and Chan (2007) in Hong Kong found that knowledge building could lead to positive impacts in fostering higher-order thinking skills.

In the Chinatown Trail learning scenario, the connectivity and portability of mobile devices opens new learning experiences that are often limited in the desktop-based Knowledge Forum software. In addition, this learning scenario explores the potential of Web 2.0 tools for participatory learning in various locations, as seen in the application of the Google Maps for location-based learning (see Figure 5). In the area of mobile learning, GPS (global positioning systems) and context- or location-awareness programs have been used and recognizing the importance of situated locations and contexts for learning (Price & Rogers, 2004; Selwyn, 2007). In fact, significant amount of human knowledge is constructed and organized around topological (e.g., spatial) information. While Knowledge Forum primarily relies on textual ideas for knowledge building, the Web 2.0 environment supporting multi-modal learning can facilitate learners move beyond abstract text information to form concrete and in-depth knowledge.

Figure 5. Chinatown in the Google Maps (blue markers indicate that there are postings about a specific location)

Figure 6. Google Maps posting by a student about the Srim Mariamman Temple in Chinatown

The Chinatown trail learning scenario is based on the following guiding principles: 1) to engage the students in the environment by leveraging on their sense of place; 2) to facilitate collaboration between students to build and share their knowledge based on the places they have visited; and 3) to encourage the students in higher order thinking skills to reflect on their learning goals and experience. Figure 6 shows an example of the Google Maps posting by a student who visited the Srim Mariamman Temple in Chinatown. We found that the design makes it possible for students to create locative content using mobile devices, situated in the real environment of the field trip and enabling them to continue their learning journey and interactions in the virtual space after the field trip. The discourse analysis revealed that students' sense of place activated by the experiences in the Chinatown trail promoted knowledge building discourse and collaborative meaning making. This finding is consisted with the literature of science education that views the potential of places to become "pedagogical centers of experience and meaning making" (Gruenewald, 2003). This means that a sense of place emerges from one's lived experiences which is used to build a living ecological relationship between the person and the place (Cobb, 1977). Please refer to Seow, So, Looi, Lim and Wong (2008) for more detailed analyses and discussions of findings.

Discussion

Mobility Makes a Difference to Learning

The recent literature of mobile learning shows that mobile devices have been recognized as a promising learning tool due to the portability and connectivity. Mobile learning implies several possibilities for learning. Learners with a mobile device can go to a field to interact with other people, and participate in physical environments for gaining concrete knowledge, instead of sitting in front of a computer screen. As the two learning scenarios described in this paper, through the use of mobile technology, it is now possible to create learning scenarios bridging the gap between formal learning and informal learning. The 3Rs and Chinatown Trail examples suggest that the following facts should be considered for the design of seamless learning experiences:

- Learning is not bounded by a fixed time or location.
- Mobile devices are used in diverse subject areas for integrated curricula.
- Learners construct knowledge and skills individually and collaboratively.
- Mobile devices are used to support experiential learning experiences.
- Knowledge is applied in situated contexts.

In the two scenarios, since school learning is closely linked to learning in informal settings, learners were able to build more concrete knowledge in situ. When considering that conventional learning experiences usually rely on abstract textual information, such experiences providing a balance between abstract and concrete knowledge can lead to increase learner interest and motivation and cohesive knowledge schema.

Redefining Learning and Pedagogy in a Seamless Space

A conventional view of learning among parents, students and even teachers is that most learning activities are happening in a fixed physical space (i.e., classroom). New emerging technologies, however, are influencing our view of learning: how to re-conceptualize and re-design learning spaces to be more tightly integrated into the whole learning process. Research into seamless learning using mobile technology will inform how we can facilitate more effective use of flexible learning spaces not only to improve the learners' experience with traditional learning, but also to improve the opportunities for mobile learning in informal settings.

Much like unintentional learning, serendipitous learning (Bowles, 2004) recognises that the human search for knowledge may occur by chance, or as a by-product of the main task. For example, an inquiry or search for information may launch the user off on a tangent that ends up being more productive than the original search questions. Serendipitous learning often happens in exploratory or informal learning with no predetermined goals. While with our proposed framework, we can see some of it happening inside the classroom, we postulate most serendipitous learning will happen outside of the classroom.

Students tend to associate what they are learning from fun activities as drastically quite different from the more structured learning they experience in class. There are research challenges in exploring how to align and support the intended learning with predetermined goals with serendipitous learning without such goals, and vice-versa. Knowledge understanding, appropriation and application as a result of serendipitous learning tend to be high, because motivation remains with the learner. If we can channel such motivation back to the classroom and deepen the learning within class, the student can experience a more holistic process of learning that taps the rich affordances of different learning spaces and designs. It is with the switching between these spaces and designs that mobile technology can help mediate.

Conclusion

There is no doubt that the development and adoption of mobile technology continues to impact our society and education. To make sustainable impact in school, future research should consider not only the affordances of technology itself, but also the pedagogical aspects of learners, learning environments, and learning goals. To move beyond mere speculations about the superficial potential of mobile technology, future research should move the current focus of content delivery-centred mobile learning to learner-centred participatory mobile learning. For this purpose, more learning scenarios with innovative practices should be designed and implemented in school which can lead to sustainable impact and which can scale. Furthermore, it is critical to design and develop learning software programs supporting such seamless learning experiences.

References

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecologies perspective. *Human Development, 49*(4), 193-224.

Bowles, M. (2004). *Relearning to e-learn: Strategies for electronic learning and knowledge.* Carlton, Vic.: Melbourne University Press.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2002). How people learn: Brain, mind, experience, and school. In. Washington, DD: National Academy Press.

Chen, J., & Kinshuk. (2005). Mobile Technology in Educational Services. *Journal of Educational Multimedia and Hypermedia, 14*(1), 91-109.

Cobb, E. (1977). *The ecology of imagination in childhood.* New York: Columbia University Press.

Colella, V. (2002). Participatory simulations: building collaborative understanding through immersive dynamic modeling. In T. Koschmann, R. Hall & N. Miyake (Eds.), *CSCL2: Carrying forward the conversation.* Mahwah, NJ: Lawrence Erlbaum Associates.

Cross, J. (2006). *Informal learning: Rediscovering the natural pathways that inspire innovation and performance.* San Francisco: Pfeiffer.

Engestrom, Y. (1999). Activity theory and individual and social transformation. In Y. Engestrom, R. Miettnen & R. Punamaki (Eds.), *Perspective on activity theory* (pp. 19-38). Cambridge, UK: Cambridge University Press.

Facer, K., Joiner, R., Stanton, D., Reid, J., Hull, R., & Kirk, D. (2004). Savannah: mobile gaming and learning? *Journal of Computer Assisted Learning, 20*, 399–409.

Finn, M., & Vandenham, N. (2004). The handheld classroom: Educational Implications of mobile computing. *Australian Journal of Emerging Technologies and Society, 2*(1), 1-15.

Gruenewald, D. A. (2003). Foundations of Place: A multidisciplinary framework for place-conscious education. *American Education Research Journal, 40*(3), 619-654.

Han, S., & Kim, K. (2003). Research on the educational adaptability of mobile computing environments. *Korea Education & Research Information Service Report,* *KR 2003-2*. .

Han, S., Lee, C., Choi, S., Lee, S., Han, H., Seo, J., et al. (2007). The study on analyzing the effectiveness of and on developing the operating model of u-learning. *Korea Education & Research Information Service Report, KR 2007-8*.

Hsi, S. (2003). A study of user experiences mediated by nomadic web content in a museum. *Journal of Computer Assisted Learning, 19*(3), 308-319.

Kim, D., & Kwan, S. (2007). Designing a handhelds learning tool based on the cognitive load theory. *The journal of Korean Association of Computer Education, 10*(1), 67-75.

Lee, Y. (2005). An analysis of the case study on Tablet computer-based mobile learning environments. *The Journal of Korean Association of Computer Education, 8*(1), 25-32.

Lim, M., & Barton, C. A. (2006). Science learning and a sense of place in urban middle school. *Cultural Studies of Science Education, 1*, 107-142.

Lourdusamy, A., Chun, H., & Wong, P. (2001). *Perceived benefits of eduPAD in enhancing learning.* Paper presented at the International Educational Research Conference, University of Notre Dame, Fremantle, Western Australia.

Min, Y., & Choi, B. (2006). Field-learning support system using web and mobile technology. *The journal of Korean Association of Computer Education, 9*(5), 53-64.

Norris, C., & Soloway, E. (2004). Envisioning the handheld-centric classroom. *Journal of Educational Computing Research, 30*(4), 281-294.

Park, M., Han, K., & Lee, Y. (2005). Development of puzzle type mobile game contents for computer education. *The journal of Korean Association of Computer Education, 8*(4), 87-95.

Price, S., & Rogers, Y. (2004). Let's get physical: The learning benefits of interacting in digitally augmented physical spaces. *Computers & Education, 43*, 137-151.

Resnick, L. (1987). Learning in school and out. *Educational Researcher, 16*(9), 13-20.

Roschelle, J., Rosas, R., & Nussbaum, M. (2005, July). *Towards a design framework for mobile computer-supported collaborative learning.* Paper presented at the Computer Supported Collaborative Learning Conference, Taipei, Taiwan.

Ryu, J., & Lee, Y. (2005). Applying mobile technology for improving learner's interaction in web discussions. *The Korea Journal of Education Methodology Studies, 17*(1), 103-124.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67-98). Chicago: Open Court.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 97-118). New York: Cambridge University Press.

Selwyn, N. (2007). *Web 2.0 applications as alternative environments for informal learning - a critical review*. Paper presented at the OECD-KERIS expert meeting.

Seow, P., So, H. J., Looi, C. K., Lim, G., & Wong, K. (2008). *Leveraging Knowledge Building in Seamless Learning Environments.* Paper presented at the International Conference on Computers in Education, Taipei, Taiwan.

Sharples, M., Taylor, J., & Vavoula, G. (2007). A theory of learning for the mobile age. In R. Andrews & C. Haythornthwaite (Eds.), *The Sage Handbook of E-learning Research* (pp. 221-247). London: Sage.

So, H. J., & Kim, B. (2008). Teaching and learning with mobile technologies: Educational applications. In M. Pagani (Ed.), *The Encyclopedia of multimedia technology and networking* (2nd ed.): Information Science Reference.

Squire, K., & Klopfer, E. (2007). Augmented reality simulations on handheld computers. *Journal of the Learning Sciences, 16*(3), 371-413.

Tan, N., Chen, W., Looi, C. K., Zhang, B., Seow, P., Chan, A., et al. (2007). *Handheld computers as cognitive tools: An environmental learning project in Singapore.* Paper presented at the International Conference on Computers in Education, Hiroshima, Japan.

van Aalst, J., & Chan, C. K. K. (2007). Student-directed assessment of knowledge building using electronic portfolios. *The Journal of the Learning Sciences, 16*, 175-220.

Zurita, G., & Nussbaum, M. (2004). Computer supported collaborative learning using wirelessly interconnected handheld computers. *Computers & Education, 42*, 289-314.

Zurita, G., & Nussbaum, M. (2007). A conceptual framework based on activity theory for mobile CSCL. *British Journal of Educational Technology, 38*(2), 211-235.

Hyo-Jeong SO
Assistant Professor, Learning Sciences and Technologies, National Institute of Education, Nanyang Technological University, Singapore. Interests: Computer Supported Collaborative Learning(CSCL), Designing Interactive Web-based Instruction, Virtual Learning Environment, Human Computer Interaction
E-mail: hyojeong.so@nie.edu.sg
Homepage: http://hjso.myplace.nie.edu.sg/

Insu KIM
Ph.D. candidate, Educational Technology, Dept. of Education, Seoul National University. Interests: Designing Learning Scenarios, Motivation and Fantasy, Digital Storytelling, Economics of Education
E-mail: kis00@snu.ac.kr

Chee-Kit LOOI
Associate Professor, Learning Sciences and Technologies, National Institute of Education, Nanyang Technological University, Singapore. Interests: Intelligent Educational Systems, Technology-Enabled Mathematics Education, Situated Cognition, Learning Sciences, Sustainability and Scalability of Educational Innovations
E-mail: cheekit.looi@nie.edu.sg
Homepage: http://eduweb.nie.edu.sg/lsl/drlooi.htm