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Connecting Learning Spaces Using Mobile Technology

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The use of mobile technology can help extend children's learning spaces and enrich the learning experiences in their everyday lives where they move from one context to another, switching locations, social groups, technologies, and topics. When students have ubiquitous access to mobile devices with full connectivity, the *in-situ* use of the mobile devices in different contexts may allow students to make connections to what they learn in the classroom with their daily life experiences outside the classroom. This article proposes mobile technology-supported seamless learning to illustrate how learning occurs seamlessly across time and places mediated by mobile devices. The authors' approaches to nurturing a seamless learning environment are also discussed.

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Introduction

The field of the learning sciences is concerned with understanding how people learn and with designing learning environments to help people learn better. This article seeks to examine how primary students learn in their daily lives where they move between locations, switch from one topic or context to another, and interact with different social groups. We aim to design learning activities to extend students' learning spaces and enrich their learning experiences with the use of mobile technologies and appropriate pedagogical designs.

While there is growing recognition that learning can take place anywhere and anytime beyond the walls of classrooms, until recently learning across spatial and temporal spaces has remained an under-researched area. By exploring the design spaces and the roles of mobile technologies for realizing seamless learning, this article makes a contribution to the learning sciences research.

Designing for seamless learning is a challenging task. Guided by the seamless learning framework, the article presents learning scenarios to illustrate how learning occurs seamlessly across time and places mediated by mobile devices. We hope this article will stimulate further discussions on how to design and study seamless learning environments that can foster 21st century knowledge and skills among the young generation of learners.

School Learning Spaces and Everyday Life

When thinking about school learning spaces, people often conjure up images of classrooms with students seated row by row facing a teacher. The presumption here is that learning happens at fixed times and fixed places. Recently, educational researchers have challenged this by mapping out a new landscape of learning—the learning space is no longer defined by the 'class' constrained by scheduled class hours or specific locations, but by 'learning' across spaces as students harness ideas and learning resources gained in one location or context, and apply or develop them in another (Looi, Seow, Zhang, So *et al.*, 2009). They learn across time, by revisiting knowledge that was gained earlier in a different context. They learn by moving from topic to topic, managing a range of personal learning projects, rather than following a single curriculum (Sharples, Taylor, & Vavoula, 2007). They learn across social groups, by co-constructing knowledge with another student, a small group, or a large online community, with possible involvement of teachers, friends, relatives, experts, and members of other supportive communities.

Therefore, learning is interwoven with students' everyday life activities. Technology that is used to support learning should be integrated with everyday life in the

same way that learning occurs in everyday life: seamlessly. Mobile technologies offer the potential for a new phase in the evolution of technology-enhanced learning, marked by a continuity of the learning experiences across different contexts. Chan, Roschelle, Kinshuk, and Sharples *et al.* (2006) use the term "seamless learning" to describe situations where students can learn whenever they want to in a variety of scenarios, and they can switch from one scenario to another easily and quickly using their personal mobile device as a mediator.

While learning can indeed take place anywhere and anytime beyond the walls of classrooms, until recently learning across spatial and temporal spaces has not been very well researched. We would like to investigate how we can design mobile-technology supported seamless learning environments that can promote students' 21st century knowledge, skills, and positive attitudes towards learning. This article proposes mobile technology-supported seamless learning to illustrate how students' learning occurs seamlessly across time and places mediated by mobile devices.

Seamless Learning and Mobile Technology

The basic premise of seamless learning is that it is not feasible to equip students with all the knowledge and skills they need to have for lifelong learning based on snapshots of episodic time frame, location, or scenario. Therefore, students will need to continually enhance their knowledge and skills, in order to address immediate problems and to participate in a process of continuous learning. We consider student learning as moving beyond the acquisition of content knowledge to developing the capacity to learn seamlessly.

Our research attempts to design and investigate a seamless learning environment that allows students to learn at any time and at any location, and provides children with multiple ways of learning throughout the day. This is consistent with what Pea (2009) argues: "we need to treat the activities and life experiences of the learners throughout the day as our units of learning design, description and explanation." The matrix in ***Figure 1*** shows the students' learning spaces from two dimensions: (1) in class vs. out of class, and (2) planned learning (planned by teachers) vs. emergent learning (not planned by teachers, but occurring unexpectedly, driven by student self-interest/motivation).

As the use of the mobile technology such as Smartphones is becoming more pervasive in our lives, we envision learning to occur when a learner interacts with others and the environment across time and locations seamlessly through the use of the technology as a mediating tool. Stroup and Petrosino (2003) categorize educational technology into two types: vertical technology and horizontal technology. Vertical technology is mainly for teachers' needs in a confined setting, whereas horizontal technology is used to meet

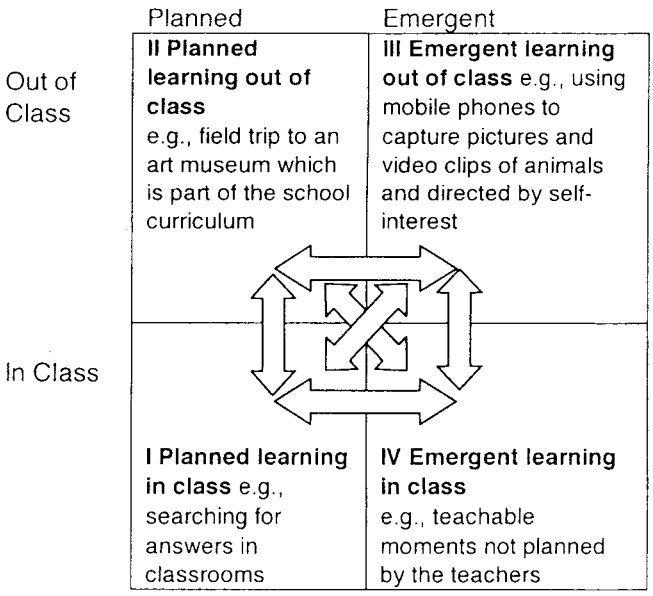

Figure 1. Matrix of students' learning spaces (adapted from So, Kim, & Looi, 2008).

students' personal needs across multiple physical contexts. Many of today's educational technologies are used as vertical technologies in the classroom. Seamless learning requires horizontal technologies that can meet students' personal needs. Mobile technology is exactly a horizontal technology because of its affordances shown in ***Table 1***. The characteristics of mobile technologies are well suited to support seamless learning.

The Seamless Learning Research

The work reported here is part of a three-year initiative to explore and design seamless learning environments to bridge Primary (Elementary) Grade Three (P3, with nine-year-olds) students' different learning spaces by equipping them with personal mobile devices. The choice of the mobile device for school use is a function of many considerations: the learning activities it will support, the cost, the connectivity (data, phone, broadband, etc.), the subscription plan, the range of available software, the weight and robustness of the device, and functionalities, such as a built-in camera or Global Positioning System. The affordance of a mobile device determines the type of learning activities that it supports. We must delicately balance the trade-offs between phone affordances to support learning activities and the cost of implementation, which may have an adverse impact on the scalability of phone usage for school-wide deployment. The mobile device that is used in this study is HTC Tytn II Windows Mobile phone that comes with photo-taking function, stylus pen, keyboard, 3G-enabled Internet surfing data plan, and educational applications (e.g., GoKnow applications such as KWL-table for organizing what the user wants to know,

Table 1. Matching affordances of mobile technology to seamless learning.

Characteristics of seamless learning	Ways mobile technology can support seamless learning
Learner-centered	*User-centered:* Students can actively use the devices to engage in learning activities by interacting with people, resources, and the environment. For instance, students with mobile devices can go out to the field, explore the world, and share their experiences with others (Roschelle, 2003; Squire & Klopfer, 2007). Gaining ownership of what and how they want to learn, they become co-producers of knowledge.
Everyday life experiences	*Useful:* Use of the device becomes a routine practice and is assimilated into everyday needs for communication, reference, and learning.
Across time	*24/7 access:* The technology is available anytime.
Across location	*Portable:* The small size and light weight of mobile devices mean that they can be taken to different sites or moved around within a site, so that they can be available wherever the student needs to learn.
Across social groups	*Networked:* The device enables students' data exchange, communication, and collaboration with teachers, experts, friends and family members, etc.
Natural flow across different situations	*Unobtrusive:* The students can capture and retrieve *in-situ* information without encroaching into spaces obtrusively.
Situated	*Contextualized:* As the mobile device can be turned on and off instantaneously, students can use it whenever they need to, enabling them to make rapid connections between ideas and observations. The mobile device can both gather and respond to information specific to the current location, environment, and time. For example, the students can refer to their device for stored information or resources or do a new search whenever their curiosity prompts them to do more inquiry.
Accumulative	*Promote learning resiliency:* The student's personal accumulation of resources and knowledge is persistent and can be immediately accessible.

Table 1. Matching affordances of mobile technology to seamless learning (continued).

Characteristics of seamless learning	Ways mobile technology can support seamless learning
Personalized	*Individual:* The device can store, organize, and retrieve personal information, cases, events, knowledge structures, and processes. It can empower the students with more autonomy to chart their learning paths. *Adaptable:* The use of the device is adapted to the learner's evolving abilities, skills, knowledge, and learning styles, and is designed to support individualized learning, rather than general office work.
Accommodate versatile learning activities	*Multimodal learning:* The student can use a variety of learning applications that support different types of learning activities. Students can type, draw, take photos, or do audio or video recording, supporting their multi-modal expressions.

wonder, and has learned, Picomap for concept mapping, and Sketchy for creating animations).

In a seamless learning environment, students are 'on the move' across different modes of space and time. In this project, students have 24–7 access to the mobile device, so that they can use the tool to engage in a wide range of activities in and out of the classroom. We have developed and installed a log software program ,to capture all the data stored in students' phones. For the planned learning activities, we designed a series of "mobilized" lessons in class (Zhang, Wong, Seow, Chen, & Looi, 2009) to help students learn curriculum subjects better.

Many "mobilized lessons" have an "out of classroom" element, where the students interact with the environment outside the classroom and engage in activities in their everyday lives. For example, we designed an English mobilized lesson on prepositions (Looi, Wong, So, Seow *et al.*, 2009) to support students' multiple learning paths. In this lesson, students used mobile devices to draw and sketch their understanding of the prepositions, and took pictures outside the classroom to demonstrate their usage in an authentic context. Another example is a mobilized science lesson on digestive systems. At home, the students taught their parents what they learned in class about the digestive system, and the parents were asked to share and recount the parts and functions of the digestive system. The students then used their Smartphones to video or

Figure 2. Jeremy exploring Google Maps in class.

Figure 3. Roy taking pictures of marine life he observed from the transparent bottom of a boat.

audio record what the parents had shared. After they came back to class, they listened or viewed their classmates' recording and evaluated the parents' knowledge of the digestive system by using an evaluation checklist. Learning inside and outside the classroom becomes a participatory activity between students, teachers, and parents. The use of mobile technologies can facilitate students' classroom and home learning, such as children revisiting the artifacts in the mobile devices and recording conversation they have had with their parents at home.

Some ideas for learning design are inspired by the students' emergent learning spaces. For example, when the mobile devices were first introduced to the class, some students used Google Maps to find the location of their homes on the map (***Figure 2***) and compared the distances of their homes from school. The researchers and teacher noticed this and designed a math learning activity for the students to learn distances and length using Google Maps: Each student was asked to find the distances and directions from one point to another point (e.g., from the school to the swimming complex) by using Google Maps. Then they added up the length of the journey and converted the metric into meters.

In our research, we found that planned lessons on the inculcation of inquiry skills actually spill over to emergent learning practices out of class. For example, in one lesson on "which fish give birth to young live?" one of the students, Roy, actually taught his parents that certain fish give birth to the young instead of laying eggs. He gathered this insight by making observations of fish in his home aquarium. He even used his Smartphone camera to take pictures. On a family holiday trip, Roy recorded videos of the fish and marine life from the transparent base of the boat he was on (***Figure 3***). Since being equipped with the Smartphone, Roy has developed the habit of using it to search all kinds of information he would like to know, take pictures that interest him, and show the pictures and resources in his phone to his friends. As this example shows, mobile devices can function as tools helping students to develop and sustain inquiry across location and time scales, thus enriching whole learning experiences.

Some of the above-mentioned leaning activities can be carried out by using traditional tools such as paper and pencils, notebooks, cameras, etc. However, mobile technologies can supplement these activities by offering learners the opportunity to manage their learning over time, to engage in collaboration, and to relate information to situated problems. In sum, it is a *learning hub* for the students to engage in several learning activities across time and location by using the same devices.

Approaches to Fostering Seamless Learning

Our work on fostering seamless learning mediated by mobile technology is still ongoing. Based on our experience in co-designing lessons with teachers, implementing the lessons, and studying the outcomes of the lessons in the classroom, we have identified the following approaches to foster seamless learning via mobile technology. These approaches will be iteratively reviewed as our design evolves.

Extend classroom learning activities beyond school hours and premises (to support the notion of seamless learning). Learning activities were designed where the students engage in learning beyond the boundaries of the classroom. We encouraged the students to be more observant of their surroundings during the course of everyday activities and learning outside the classroom. For example, during a Zoo trip, they took pictures of the different plants they observed and uploaded them to a class blog. At home, the students conducted experiments and recorded the experiments on video with the Smartphone.

Provide an environment to integrate multiple

learning activities (students have a hub to launch or continue their learning activities). The affordances of the Smartphone make it a hub for the students to integrate their learning activities. The teacher downloaded the learning activities to the students' Smartphones. During the course of the activities, students uploaded their artifacts or work-in-progress to a Website for the teacher to review. The activities were centered on the use of the Smartphone, which allows them to search the Internet, download resources, collect digital artifacts such as pictures, record their observations, communicate with their friends, view the lessons, work on their assignments, etc.

Design for holistic and authentic learning (make learning meaningful). We designed activities that are authentic and related to everyday activities. In learning about fungi, the students were required to observe and take pictures of fungi they saw outside the school. A student took a picture of a moldy wallet and another of a mushroom in the supermarket.

Incorporate different learning modalities (to personalize learning). We made use of multi-modality affordances of the Smartphone to engage different learners. In learning about plants, the students were required to do a comparison table to understand the characteristics of plants, create an animation of a plant transport system, create a concept of the parts of plants, and record pictures of different types of plants they observed outside school. In our study, we observed that some students do better when they are engaged in certain forms of modality and representation as compared to other forms.

Design student-centered learning activities (to promote engagement and self-directed learning). In most lessons, we used the mobile devices to engage students in self-directed learning. The students share their prior knowledge and generate questions on things they would like to know about the topic. They are encouraged to use the devices anytime/anywhere to embark on their own research as well as to find the answers to any hanging questions they may have. They may use a search engine to find the answers, view videos, or take pictures to answer their questions. Subsequently, they review their own learning and synthesize what they have learned.

Make students' thinking process visible (so that they can be shared and subject to further refinement). We used tools such as animation and concept mapping software on the Smartphone to help students visualize their thinking processes. For example, the students drew an animation of the plant transport system, showing how water flows through the plant from the roots to the leaves and how food is transported from the leaves to the roots. The visualization tools are useful for teachers, as they are able to see the conceptual understanding of the students and help address students' misconceptions. We found that such a visualization tool is a good platform for learning, as the whole class can be engaged in meaningful science discussion on what they see.

Facilitate social knowledge building (to promote collaborative learning). Rather than relying on teacher and textbooks as sources of knowledge, students conducted their own research and shared what they had learned with other classmates. We encouraged the students to share interesting videos or pictures they had found. We designed a mobile forum for the students. By participating in the mobile forum, the individual student brought in sources of knowledge he or she had found from the Internet and other resources into the classroom. In addition, students shared knowledge on the use of the Smartphone. They learned amidst the process of using the tool, and they shared what they had learned with others in the classroom.

Ensure that the teacher plays the role of facilitator (to move away from didactic teaching). The designed learning activities using Smartphones changed the teaching practices from didactic teaching to student-centered learning facilitated by the teacher. The teacher facilitated class discussions after the students conducted their independent study or research. The teacher guided the class in constructing the knowledge of the subject through raising and answering questions and drawing out the students' understanding.

Assess formatively (through the learning activities, students can receive feedback for their own ideas from peers or the teacher). We created opportunities for the students to receive feedback from their peers or teacher. In some activities, students exchanged their Smartphones and gave feedback on their partner's work. The teacher reviewed the students' work formatively and assessed each student's understanding when that work was uploaded to an online site.

Facilitate participatory learning involving the family (to support seamless learning across social groups). The family plays an important role in students' learning. We designed activities where parents were involved in participatory learning activities with the students at home. Parents gave us feedback that they enjoyed the activity, as they become more involved in their child's learning in school.

Conclusion

This article discusses seamless learning research and has identified practical approaches of matching the affordances of mobile technology to the premises of seamless learning, as well as presented how we use the affordances of mobile technology to connect students' learning spaces for the continuity of learning experiences across different scenarios. Until recently, not many studies in the literature have made full use of the vast potential for learning spaces out of classrooms

to enrich school education. As discussed in this article, students' learning spaces can be enhanced or extended by mobile technologies which support learning across multiple contexts and time scales.

Understanding technology-supported seamless learning is important for researchers and practitioners who are interested in connecting classroom learning and out of classroom learning spaces in order to create rich and holistic learning experiences for the students. We hope this article will stimulate further discussions on how to design and study seamless learning environments that can foster 21st century knowledge and skills among the young generation of learners. □

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