Guest Editorial: Powering Up: Insights from Distinguished Mobile and Ubiquitous Learning Projects across the World

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Recent progress in mobile and wireless communication technologies has led to new development of technology-enhanced learning, enabling students to learn in the way that encompasses formal and informal learning across locations and time with supports or guidance from learning systems (Hwang, Wu, Zhuang, & Huang, 2013). The field of mobile learning and ubiquitous learning exemplifies such a trend in developing innovative learning approaches (Frohberg, Göth, & Schwabe, 2009; Wong & Looi, 2011; Wu, Hwang, & Chai, 2013). This trend is probably also reflected by the evolution of the definitions or expositions of mobile learning – from “e-learning using mobile devices and wireless transmission” (Hoppe, Joiner, Milrad, & Sharples, 2003, p. 255) (i.e., e-learning through mobile devices) to “any sort of learning that happens when the learner is not a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies” (O’Malley et al., 2003, p. 9) (i.e., the mobility of the learning devices) to “increasing a learner’s capability to move their own learning environment as they move” (Barbosa, Geyer, & Barbosa, 2005, p. 1) (i.e., the mobility of learners). In a related vein, ubiquitous learning is explicated as an an a learning approach that where the ubiquitous technology is leveraged to support the learners in the right way, in the right place, and at the right time, based on the personal and environmental contexts in the real world (Hwang, Tsai, & Yang, 2008).

In the past decade, various issues concerning mobile and ubiquitous learning have been widely discussed. In the meantime, researchers have reported the effectiveness of adopting mobile and ubiquitous learning approach in various learning contexts (e.g., Kukulska-Hulme, Sharples, Milrad, Arnedillo-Sánchez, & Vavoula, 2009; Milrad et al., 2013; Shih, Chuang, & Hwang, 2010). Recognizing such an emerging trend, the educational authorities of many countries have identified the development of mobile and ubiquitous learning as one of the strategic thrusts in their national educational policy. Consequently, more international, national, regional or institutional-scale mobile and ubiquitous learning initiatives have been embarked on across the globe in recent years (e.g., Buckner & Kim, in press; Cochrane & Bateman, 2010). The common aim is to seek efficient and effective ways of harnessing mobile and wireless communication technologies to create scalable and sustainable learning environments to nurture a new breed of learners with 21st century skills.

In spite of articles reporting on short-term, episodic empirical studies, this special issue seeks papers that trace, summarize and reflect upon individual research programs that may have spanned through several research cycles or consist of multiple sub-projects. Each of the accepted papers covers (the evolution of; if applicable) the background objectives, design rationales of the learning systems/environments, pedagogies and/or learning scenarios, empirical studies and the findings of their projects or studies. In addition, the discussion/conclusion sections of the papers are placing greater emphasis on informing fellow researchers, educators or policy makers about the nuances of translating and sustaining the reported innovative solutions.

This special issue features ten of such papers from ten different countries or economies, which would collectively offer a global perspective in the opportunities and challenges in bridging the research and practice in mobile and ubiquitous learning. From Taiwan, Hwang, Hung, Chen and Liu report a four-year national research project known as “Mindtool-Assisted In-field Learning” (MAIL), with a series of ubiquitous technology-assisted learning and assessment models being developed and evaluated, which has eventually informed and been incorporated into a government initiative of nationwide scaling up of mobile and ubiquitous strategies. From Spain, Laborda, Royo, Litzler and López address two intertwined projects for development and applications of a mobile language testing platform in a university setting. In Korea, Kim, Lee and Kim investigated the effects of mobile instant messaging on collaborative learning, and draw implications to its practical applications. From Sweden, Vogel, Kurti, Milrad, Johansson and Müller present the overall lifecycle and evolution of a mobile learning system developed in relation to the “Learning Ecology through Science with Global Outcomes” (LET’S GO) research project, thus provide deeper insights into the importance of properly addressing the interoperability and extensibility issues in order to develop sustainable solutions for future learning practice. In United Kingdom, Scanlon, Clow and Woods ventured into
informal participation in science by developing and deploying the iSpot system through design-based research; the system has over 31,000 registered users (learners) from within and beyond the UK, according to the paper. From Singapore, Looi and Wong report a two-year one-mobile-device-per-student program conducted in a primary school, which provides a good example of doing research that addresses multi-term, multi-pronged, multi-level and systemic aspects of school-based innovations for benefiting schools, deriving and refine scientifically and empirically theoretical frameworks, and designing principles, resources and strategies for learning. From Japan, Ogata et al. present a four-year project for developing a ubiquitous learning log system, which is able to record students’ daily life learning experiences and benefit them in language learning via a log sharing mechanism. From Canada and Taiwan, Lu, Chang, Kinshuk, Huang, and Chen present a context-aware mobile role playing game, which is one of the outcomes of a 5-year program aiming to provide learners with a ubiquitous learning environment that facilitates personalized learning. In United States, Liu, Navarrete and Wivagg present the effectiveness and challenges of using iPods in English language learning at elementary and middle school based on the experiences and findings of conducting a two-year project. Finally, from Hong Kong, Kong and Song present a framework for principle-based pedagogical designs for inquiry-based learning in a seamless learning environment and demonstrate how the approach benefit the students in their knowledge gains and inquiry skills.

From these projects, it is found that the studies and applications of mobile and ubiquitous learning has been shifted from merely using mobile and wireless communication technologies in educational settings to the lead-in of various learning strategies or tools, such as inquiry-based learning, collaborative learning and Mindtools. In addition, some countries, such as Taiwan and UK, have started to popularize mobile and ubiquitous learning approaches to nationally wide or regionally wide scales, implying the rapid growth of mobile and ubiquitous learning applications in recent years. As indicated by Tsai and Hwang (2013), it can be foreseen that mobile and ubiquitous learning will be one of the main trends of technology-enhanced learning in the coming years.

References


Mindtool-Assisted In-Field Learning (MAIL): An Advanced Ubiquitous Learning Project in Taiwan

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ABSTRACT

Scholars have identified that learning in an authentic environment with quality contextual and procedural supports can engage students in thorough observations and knowledge construction. Moreover, the target is that students are able to experience and make sense of all of the learning activities in the real-world environment with meaningful supports, such that their learning motivation can be promoted, knowledge can be sensibly constructed, and skills can be fully developed. To develop potential tutoring strategies and learning activity models using mobile, wireless, and sensing information and communication technologies (ICT) in a real-world learning environment, a four-year national e-learning research project entitled “Mindtool-Assisted In-field Learning (MAIL)” has been funded by the National Science Council of Taiwan since 2008 in an effort to lead the development and innovation of Learning Technology. The integrated project aimed to develop Mindtool-assisted knowledge construction models, assessment models, guidance models, and reflection strategies for cutting-edge context-aware ubiquitous learning. Moreover, a series of learning activities has been conducted to examine the effectiveness of the proposed learning strategies and models. Each year, more than 1,500 students have participated in the in-field learning activities with the designed approaches. Based on the results of a series of experiments, it was found that the students’ learning performance as well as their in-field inquiry ability was significantly improved, showing the effectiveness of the Mindtool-assisted ubiquitous learning approach and the success of the MAIL project. In this paper, the background, objectives, theoretical foundations, systems, research issues, applications, and findings of the MAIL project are presented. Finally, the scaling-up plan for applying these research-proven learning models to all levels of educational settings in Taiwan is also addressed.

Keywords

Mobile learning, Ubiquitous learning, Mindtools, Concept maps, Repertory grid

Background and objectives

Learning Technology (LT), as a trans-disciplinary, professional field of leading human developments and innovations in various situations, disciplines, settings, and industries with advanced technological uses, is always in need of creative applications of hard and soft technologies in order to bring about positive changes (Jonassen, 2004; Liu, 2008). Many educators have identified the importance of situating students in real-world contexts for developing and acquiring knowledge and skills (Brown, Collins, & Duguid, 1989; Lave, 1991; Wong & Looi, 2011). In the meantime, researchers have also pointed out the importance of providing personalized learning supports or knowledge sharing facilities during in-field activities (Sharples, Milrad, Arnedillo-Sánchez, & Vavoula, 2009; So, Seow, & Looi, 2009). The popularity of mobile and wireless information and communication technologies (ICT) has provided good opportunities which match this emerging trend in LT; moreover, the advancement of sensing technology has further enabled learning systems to detect real-world information with various types of information-generating e-readers and e-tags. With the help of these technologies, students are able to learn anytime, anywhere. That is, they are encouraged to learn in various real-world environments with supports from and access to the digitalized world (Hwang, Tsai, Chu, Kinshuk, & Chen, 2012; Looi et al., 2009; Wong, 2012); moreover, dynamic learning systems are developed for the user to engage in more active interactions with other learners as well as the learning system itself (Ogata, Li, Hou, Uosaki, El-Bishouty, & Yano, 2011; Okamoto & Tseng, 2008). Generally speaking, this kind of learning strategy has been called “context-aware ubiquitous learning,” and is a state-of-the-art, particular form of ubiquitous learning (u-learning) as defined by Hwang, Tsai and Yang (2008).

Recently, context-aware u-learning has become a popular issue and research topic in the area of e-learning (Ogata & Yano, 2004; Sollervall, Otter, Milrad, Vogel, & Johansson, 2012; Sylven, Beale, Sharples, Ahonen, & Lonsdale, 2005). Researchers have attempted to conduct context-aware u-learning activities for various courses; however, it
has been found that, without effective learning strategies or tools, students’ learning performance could be
disappointing (Chu, Hwang, & Tsai, 2010; Chen & Li, 2009; Liu, Peng, Wu, & Lin, 2009). Several studies have
pointed out that u-learning scenarios could be too complex for most students without some proper guidance or
supports, because the students need to make use of both real-world and digitalized world learning resources at the
same time (Shih, Hwang, Chu, & Chuang, 2011). Therefore, it has become an important and challenging issue to
provide effective learning supports in mobile or ubiquitous learning activities.

Among the various learning strategies and tools, Mindtools have been recognized as an effective way of assisting
students to learn in complicated learning contexts with all kinds of ICT. Educators have indicated that “technologies
should not support learning by attempting to instruct the learners, but rather should be used as knowledge
construction tools that students learn with, not from” (Jonassen, Carr, & Yueh, 1998, p. 1). Mindtools are cognition
tools that are able to assist students to think and learn in a meaningful and constructive way through stimulating them
to expand their cognitive ability in interpreting, analyzing, synthesizing and organizing their knowledge. Jonassen
(1999) defined Mindtools as “a way of using a computer application program to engage learners in constructive,
higher-order critical thinking about the subjects they are studying” (p. 9). With the assistance of Mindtools, students’
knowledge can be constructed to reflect what they have learned and realized, instead of merely memorizing or
recalling content taught by their teachers.

Mindtools and their logical learning design have been widely developed and used with various computer-based
application programs, which include database systems, spreadsheets, expert systems, semantic nets (e.g., concept
maps), video conference systems, multimedia and hypermedia editing tools, programming tools, and Microworld
environments (Jonassen, 1999). In the past two decades, scholars all over the world have paid much attention to
using Mindtools in various practical applications related to in-class learning, blended learning, and totally online
learning; nevertheless, using Mindtools in u-learning activities remains an important but challenging issue (Lee, Lee,
& Leu, 2009).

To develop Mindtool-supported u-learning approaches and to investigate their effectiveness, a four-year national e-
learning project was initiated in Taiwan in 2008. The aim of the project was to develop Mindtool-assisted u-learning
environments and strategies. Numerous experiments were conducted to evaluate the effectiveness of applying the
Mindtool-assisted u-learning approaches to various in-field activities in terms of students’ learning achievement,
motivation, attitudes, cognitive load and technology acceptance. Moreover, the students’ in-field observation and
question-raising abilities were measured as well.

Mindtool-assisted ubiquitous learning approaches

To facilitate in-field learning within context-aware u-learning environments, two kinds of Mindtools were developed
to support u-learning activities in the integrated, collaborative project; that is, the grid-based approach which
originated from a knowledge elicitation method for developing expert systems and the concept mapping approach
that has been widely adopted in in-class learning, blended learning and totally online learning environments.

Grid-based Mindtools for ubiquitous learning

An expert system is a computer system that simulates expert-level reasoning based on the knowledge elicited from
domain experts. The process and know-how of acquiring and organizing knowledge from domain experts for
building knowledge bases of expert systems is called knowledge engineering (Feigenbaum, 1977). Jonassen (1999)
indicated that such a process of collecting and organizing domain knowledge for constructing knowledge bases could
engage students in critical thinking; that is, an effective way of employing expert systems as Mindtools is surely to
engage students in collecting and organizing knowledge related to the course/learning content they aim to learn
following a knowledge acquisition approach.

Among various knowledge acquisition approaches, the repertory grid method originating from the Personal
Construct Theory proposed by Kelly (1955) has been widely adopted and discussed (Aranda-Mena & Gameson,
2012; Canning & Holmes, 2006; Boose & Gaines, 1989). A repertory grid can be viewed as a matrix whose columns
are element labels and whose rows are construct labels. Elements could be decisions to be made, objects to be
identified, or concepts to be learned, while constructs are traits for featuring the similarities or differences between the elements. A construct consists of a trait (e.g., "Long") and the opposite of that trait (e.g., "Short"). Meanwhile, a five-scale rating mechanism is usually used to represent the relationships between the elements and the constructs, where "1" represents that the element is inclined to have the trait and "5" represents that the element is inclined to have the extreme opposite characteristic of that trait.

Referring to the "Expert systems as Mindtools" conception proposed by Jonassen (1999) and the repertory grid method, a repertory grid-oriented Mindtool was developed in the MAIL project for supporting in-field ubiquitous learning in several ways. In the earlier stage of this project, the repertory grid-based ubiquitous learning system was used as a guiding system for helping students observe learning targets in the field, collect data based on their observations, and develop repertory grids for organizing the collected data. Since 2008, a series of learning activities has been conducted with the tool to help students identify and classify a set of learning targets (e.g., plants on a school campus, butterflies in ecology gardens, or rocks in laboratories) via guiding them to observe the learning targets and organize what they have found in a repertory grid using mobile devices (Chu, Hwang, & Tsai, 2010; Wu, Hwang, Su, & Huang, 2012).

Before the learning activities, teachers were asked to develop an objective repertory grid (i.e., a repertory grid with correct ratings for each <element, construct> pair) to guide the students to make observations in the field and develop their own repertory grids. In such a learning-guiding approach, the elements and constructs were provided by the teachers; therefore, the students only needed to fill in the rating for each <element, construct> entry based on their observations in the field. Users were encouraged to consider the objective repertory grid in Table 1, in which the elements were "Lalang Grass," "Arigated-leaf croton," "Cuphea," "Indian almond," "Money tree," "Crown of thorns" and "Pink ixora," and the constructs were "leaf shape," "leaf point," "leaf edge," and "number of leaf vein branches." For example, the value of the <Lalang Grass, Leaf-shape> entry is 1, indicating that the leaf shape of Lalang Grass is "Long and thin." On the contrary, the value of the <Indian almond, Leaf-shape> entry is 4, implying that the leaf shape of Indian Almond tends to be "flat and round."

### Table 1. Example of a repertory grid for guiding students to observe plants on a school campus

<table>
<thead>
<tr>
<th>Trait</th>
<th>Lalang grass</th>
<th>Arigated-leaf croton</th>
<th>Cuphea</th>
<th>Indian almond</th>
<th>Money tree</th>
<th>Opposite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf-shape long and thin</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>Leaf-shape flat and round</td>
</tr>
<tr>
<td>Perfectly smooth leaf edge</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>The leaf edge has deep indents</td>
</tr>
<tr>
<td>The leaf vein has few branches</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>The leaf vein has many branches</td>
</tr>
</tbody>
</table>

During the learning activities, the students were asked to complete their own repertory grids by filling in the rating for each <element, construct> pair based on their observations in the field. If the students failed to give the correct ratings in comparison with those given by the teachers in the objective repertory grid, the learning system would guide them to observe a comparative learning target with the "incorrect main-feature" and would ask them to compare it with the original learning target. For example, if a student observed the plant (learning target) “Lalang Grass” and described its “Leaf point” as “round with a blunt tip” (by giving rating "4"), by comparing the student’s answer with the rating given by the teacher (i.e., “tapering to a long point” with rating "2"), the learning system detected that the student’s answer was incorrect. Accordingly, the learning system tried to find a comparative plant with “round with a blunt tip” leaf points from the objective repertory grid. In this case, “Indian almond” met the condition; therefore, the student was guided to observe the “Indian almond,” and compared its “Leaf point” with that of “Lalang Grass,” as shown in Figure 1. Having made the comparison, the student was then asked to answer the question again. If the student still failed to correctly answer the question, the learning system then provided supplementary materials and the teacher’s rating to the student.

In addition to the guidance from the learning system, the students were able to browse their own repertory grids via the mobile device during the field trips, which was helpful to them in identifying and distinguishing the learning targets via comparing the corresponding ratings of the features of the targets in the grid.
The student is asked to observe the leaf shape of “Indian almond” and compare it with the leaf point of “Lalang Grass.” The answer “Round with a blunt tip” to the “leaf point” of “Lalang Grass” is incorrect.

To engage students in higher-order thinking during the in-field learning activities, the repertory grid-based Mindtool has further been used to support collaborative knowledge construction in context-aware ubiquitous learning activities in the MAIL project. For example, one of the applications conducted in 2010 aimed to engage students collaboratively in a more challenging learning task; that is, the teacher only showed them the learning targets/objects (i.e., plants on the school campus) without providing any other guidance during the in-field learning process, meaning that the students needed to determine the constructs for identifying and differentiating the plants themselves as well as observing the plants and collecting data. To enable the students to share their repertory grids and make reflections after referring to the repertory grids developed by their peers, a knowledge-sharing system was developed. Through this knowledge-sharing system, the students could upload their repertory grids to the system, browse others' repertory grids, receive feedback from teachers, and discuss with their peers. The experimental results showed that the quality (i.e., completeness and correctness) of individual students' knowledge structure (i.e., the constructs they used and the ratings they gave to represent the relationships between elements) was significantly improved after the ubiquitous learning activity.

Concept mapping as Mindtools for ubiquitous learning

Concept mapping is a well-known learning tool for helping students organize and visualize knowledge and learning experiences (Chiou, 2008; Fischer, Bruhn, Grasel, & Mandl, 2002; Hwang, Wu, & Kuo, 2013; Novak & Cañas, 2006). It is also an effective assessment tool for helping teachers evaluate students’ cognitive levels and knowledge structures (Ingeç, 2009; Liu, Don, & Tsai, 2005; Peng, Su, Chou, & Tsai, 2009; Trent, Pernell, Mungai, & Chimedza, 1998). In the past decades, many studies have shown the effectiveness of concept mapping in engaging students in meaningful learning, and hence their learning achievements could be improved (Amadieu, Tricot, & Mariné, 2010; Anderson-Inman & Ditson, 1999; Horton et al., 1993; Markham, Mintzes, & Jones, 2006).

In the MAIL project, concept mapping has been employed in context-aware ubiquitous learning activities in several ways. For example, one of the learning activities was conducted for butterfly ecology observations. Before the learning activity, the students were asked to develop a concept map about butterfly ecology based on what they had learned from the textbook. During the in-field observations, the students browsed their concept map when observing the butterflies in the ecology garden. They could modify the concept maps if something different or interesting was observed. Alternatively, they could take notes and modify the concept maps when they went back to the classroom. Figure 2 shows the scenario of the in-field learning activity. The students were situated in the butterfly ecology garden with wireless communication networks. The garden consisted of 25 ecology areas in which particular kinds of butterflies and the related host plants of the butterflies are raised. In this earlier study, an RFID (Radio Frequency Identification) tag was placed in each ecology area and each student held a PDA (Digital Personal Assistant) with an RFID reader. When the students walked into an area, the learning system could detect the information within the tag in that area via the RFID reader and confirm individual students’ locations, such that corresponding learning guidance or support could be provided.
In recent studies of the integrated MAIL project, smartphones and the QR-code sensing technology have been used to support extensive self-directed learning in the field. A series of large-scale and long-term activities has been conducted in Chiku Ecology Park in southern Taiwan, where various species of mangroves grow. Figure 3 shows the plan for one of the learning activities. In this activity, the students were equipped with a smartphone to interact with the learning system as well as a telescope for long-distance observations. The learning system provided online instant feedback (e.g., hints to remind the students that part of their answers to the questions raised by the learning system were incorrect) and learning guidance (e.g., clues to find the correct answers to the questions) to the students via wireless communications. Moreover, an e-library was developed to provide supplementary materials for the field-based activities.

A series of concept mapping tasks was developed to scaffold the students’ knowledge construction during the field trips in a progressive manner. In the first stage, the learning tasks included multiple-choice questions, short-answer questions, and a structured two-level concept map in order to help the students clarify their knowledge about the basic features of individual mangrove species. In the second stage, the learning tasks were designed to encourage the students to describe the advanced features for classifying different species via the use of developing multiple-level concept maps. In the third stage, the learning tasks aimed to guide the students to compare the species and find the relationships among the species based on what they had learned and observed via developing the multiple-level and cross-relationship concept maps.
Figure 4 shows an illustrative example of a student’s emerging concept map while working in the field. The title of the concept map is “the life of Idea leuconoe clara,” which is a species of butterfly found in Taiwan. Before the field trip, the student developed an initial concept map consisting of four stages (i.e., egg, pupa, larva and imago) to describe the life of Idea leuconoe clara. Later, he went to the butterfly garden to complete the learning tasks. When observing the butterfly ecology in the field, the student browsed the initial concept map and found several facts to be added: (1) In stage 1 of the Idea leuconoe clara, he had only described the egg as being “white or lemon yellow;” however, in the field, he noted that the egg was also “translucent.” Therefore, this new feature was added to the concept map, as shown in block A of Figure 4. (2) In stage 2 of the Idea leuconoe clara, he had not described the features of the larva. When learning in the field, he noted two of its features, that is, “red spots on the sides of the body” and “black and white;” therefore, these two features were added to the concept map, as shown in block B of Figure 4. (3) In stage 4 of the Idea leuconoe clara, he had not given examples of food plants. When observing in the field, he found that the Idea leuconoe claras were acquiring honey from magnolias; therefore, the proposition “magnolia is an example of food plants” was added to the concept map, as shown in block C of Figure 4.

Applications and research items

From August 1, 2008 to September 30, 2012, the research team conducted 73 u-learning activity-based studies to try out the learning system, Mindtools, learning models and strategies, evaluation scales, and the design of the learning content and activities. The in-field learning environments included the Chiku Mangrove Conservation Area, the Chiku Black-faced Spoonbill Conservation Center, the butterfly ecology garden in Cheng-Kung Elementary School, the science parks and museums in several cities across Taiwan, and the campuses of several educational settings in Taiwan. The learning content of the in-field activities not only focused on natural science, but has also been extended to various academic disciplines. So far, there are 38 natural science studies, 19 social science studies, 5 computer science studies, 2 nursing training studies, 7 language learning studies, 1 mathematics study and 1 Art learning study conducted as part of the MALL project.

The total number of participants has increased each year, from about 500 participants in 2008 to nearly 3,000 in 2012, as shown in Figure 5. To date, the total number of participants in this integrated LT project has reached more than 6,000 students. Most of these experiments have been conducted by comparing the learning performance of experimental groups and control groups; moreover, the students’ pre-and post-test scores as well as their perceptions collected based on several measures have been analyzed. It is evident that based on these experiment results, both the
quantity and quality of this integrated, collaborative research project are satisfactory in terms of academic rigor and knowledge innovation.

![Number of participants](image-url)

**Figure 5.** The number of students participating in the MAIL ubiquitous learning studies in 2008-2012

**Achievements and implications**

In the early experiments, we aimed to investigate the students’ perceptions of learning with the ubiquitous learning approach in comparison with their past experiences of learning with the traditional one-to-many in-field instruction. In the meantime, the teachers’ perceptions of conducting u-learning activities were also investigated. For example, one of the experiments was conducted to collect the feedback from 30 elementary school students and 9 teachers after they experienced a u-learning activity in the butterfly ecology garden (Peng et al., 2009). From the questionnaire survey, it was found that, in comparison with the traditional instruction, the students’ learning motivation and interest were significantly promoted with the help of the personalized guidance and feedback provided by the u-learning system in the field. The average rating given by the students was 4.53 in a five-point Likert rating scheme. Moreover, from the interviews, it was found that the teachers highly accepted the u-learning approach owing to several reasons: (1) it provided the students with better access to online resources during the field trip; (2) it enabled the students to make observations and collections with learning guidance without being constrained by time or location; (3) the u-learning activities engaged the students in learner-centered activities seamlessly across locations and contexts; and (4) the u-learning approach was able to provide step-by-step expert advice and record the students’ learning portfolios.

To improve the students’ learning achievements, in the second stage of the MAIL project, we aimed to compare the effectiveness of the Mindtool-assisted in-field learning approaches with that of the conventional tour-based u-learning approach, which guides individual students in the field, providing them with supplementary materials and giving feedback to them based on their observations and input. It was found that, with the assistance of the Mindtools, the students’ learning achievements, as well as their learning attitudes, were significantly improved. Moreover, it was also found that via the sharing of the constructed knowledge (e.g., repertory grids or concept maps), the knowledge structures as well as learning achievements of the students were further improved. For example, in an experiment for conducting a “plant identification” activity at an elementary school campus, the repertory grid method was implemented in the u-learning system to serve as a Mindtool to help the students summarize the features of the plants observed in the field (Chu, Hwang, & Tsai, 2010). From the experimental results, it was found that the Mindtool-integrated approach not only enhanced the learning interest (the average rating changed from 4.85 to 5.31 in a six-point Likert rating scheme), but also improved the learning achievements in comparison with the conventional u-learning approach via ANCOVA analysis ($F = 9.573$, $p = 0.011$ and $d = 1.39$) for the two groups of students. Another experiment was conducted in the butterfly ecology garden with embedded concept mapping in the u-
In the third stage of the MAIL project, Mindtool-integrated u-learning was included in the formal science curriculums of several selected schools in Taiwan. Accordingly, several long-term activities were conducted in field trips to observe the growth of students’ inquiry competences with the u-learning approach, such as problem-posing and problem-solving abilities. For example, in one of the activities conducted in the Chiku Ecology Park, the participating students were forty-nine elementary school students aged 11.5 years old on average. The students experienced the field trips within four months to complete a series of learning tasks. Twenty-five of them who were assigned to the experimental group learned with the u-learning approach. Another twenty-four students who were the control group learned with the traditional in-field instruction; that is, they were guided and instructed by the teacher on the field trip. The students’ inquiry performances were evaluated by the teachers based on several criteria, including the quantity and accuracy of the descriptions of the learning targets for completing the learning tasks, the number and quality of the questions raised and the responses to the peers’ questions during the field trip, and the relevance and correctness of the features and relationships used to describe their findings in the learning diaries. It was found that through the assistance of Mindtools, the students’ inquiry behaviors, such as the quantity and quality of the questions they raised and the depth of their descriptions of their observations in the field, were significantly increased in comparison with traditional in-field learning based on the ANCOVA result ($F = 4.72$ and $p < 0.05$); in the meantime, the students’ learning performances were significantly improved.

Another three-month experiment was conducted to compare the learning performance of 18 gifted students and 30 average students who were 11.5 years old on average. The participants were scheduled to learn with the concept map-based u-learning approach in the Chiku Ecology Park. Within the three months, the two groups of students showed remarkable progress in ecology observations based on the Computerized Ecology Observation Competence Assessment (CEOCA) developed by Hung, Hwang, Lin, Hung and Wu (2010). The CEOCA consisted of three facets, that is, knowledge, observations and conceptual relationships. The test items were presented with real pictures, films or concept maps. In the pre-test, the average performance of all of the participants was close to the norm (0.04 vs. 0.00) of the students of the same age in Taiwan. After the learning activity, the post-test scores showed that the average growth slope of all of the participants was significant ($\mu = 0.27, p < .01$) in comparison with their pre-test scores with effect 0.53; however, there was no significant difference between the two groups. By conducting a follow-up test one month later, a significant difference was found in the CEOCA scores between the two groups. The gifted students revealed positive performance growth, while the performance of the average students decayed after the learning activity, showing the need to provide continuous supports to average students after field trips (Hung, Hwang, Lin, & Su, 2012).

Furthermore, some experimental results also showed that the Mindtool-assisted u-learning approach can help students improve not only their learning achievements, but also their higher-order critical thinking competences. For example, in one of the u-learning activities conducted in the butterfly ecology garden, the students were asked to develop repertory grids based on what they observed on the field trip (Hwang, Chu, Lin, & Tsai, 2011). The experimental results showed that the students who learned with the Mindtool-based u-learning approach showed better learning achievements than those who learned with the conventional u-learning approach. By comparing the students’ answers to the learning sheets before and after participating in the repertory grid-based u-learning activity using a t-test, it was found that the students’ ability of determining the characteristics for differentiating the butterflies and their competence for identifying and differentiating the butterflies had significantly improved with $t = 7.13$ ($p < 0.001$) and $t = 9.23$ ($p < 0.001$), respectively. This implies that their higher order thinking (i.e., analysis and evaluation) performance was improved.

In addition to the lead-in of various Mindtool-based u-learning strategies, it should be noted that some of the participating schools of the MAIL project have already included such Mindtool-assisted u-learning approaches as part of their regular curricula. For example, a nursing school in southern Taiwan not only prepared their own u-learning equipment (i.e., mobile devices, wireless networks and sensing devices) after participating in one of the
experiments of the MAIL project, but also started to use the repertory grid-based u-learning approach as a standard way of teaching some clinical nursing courses.

Another issue raised in the MAIL project was the cognitive load of the students who participated in the u-learning activities (Hwang, Wu, Zhuang, & Huang, 2013). As the students needed to interact with the real-world learning environment as well as the e-learning system simultaneously, there was a concern that their cognitive load might be too great in some cases; therefore, several experiments of the MAIL project measured the students’ cognitive load using the measures developed by Paas (1992) and Sweller, van Merriënboer, & Paas (1998). It was found that, with a proper learning design, the Mindtool-assisted u-learning approach could significantly decrease students’ cognitive load; on the contrary, students were likely to meaningfully expand their cognitive capability after the practice of integrating in-field observation and technology-driven knowledge construction into situated learning. This decrease could be due to the fact that the Mindtools were able to assist the students in organizing the collected data from the field by linking the chunks of information in a well-structured form, which eased their load in interpreting the data (Verhoeven, Schnotz, & Paas, 2009). For example, the repertory grid-based Mindtools can help students organize the observed features of the learning targets in a unified form (i.e., ratings ranging from 1 to 5), which is very helpful to them for comparing the learning targets and identifying the significant features that can be used to distinguish the targets. Consequently, students’ cognitive load could be decreased; in the meantime, their learning achievements could be improved owing to learning in a more efficient and effective way.

From the series of related studies conducted in the MAIL project, it is found that technologies are not the key or solution to cope with in-field learning problems. Without proper learning supports in the field, students might feel helpless, frustrated and aimless, and hence their learning attitudes or motivations could be affected. Moreover, their cognitive load can be high owing to the strategies or tools used to link what they have learned and observed together, and hence their learning achievements could be disappointing. On the other hand, from the experimental results, it is also suggested that grid-based tools are effective in helping students identify and differentiate a set of learning targets, while concept mapping tools are helpful to students in linking and organizing what they have observed in the field and have learned from the textbooks. That is, grid-based tools help students observe the learning targets with a "micro view," while concept mapping enables them to see things with a "global view." For example, if the aim of a context-aware activity of a language course is to help students learn to use vocabulary, phrases and sentence patterns related to the contexts, concept mapping could be useful; similarly, if the aim of a social studies course is to let students have a whole picture of a cultural asset, concept mapping is also a good choice. Nevertheless, if the aim is to foster students’ ability of identifying or differentiating the artifacts from different historical periods, grid-based Mindtools are good candidates.

Therefore, when designing Mindtool-based u-learning activities for different subjects, the following procedure is suggested:

1. Review the nature of the learning content to see if the aim of the subject unit is relevant to identifying and differentiating a set of learning targets based on their features, or organizing the relevant concepts by finding the relationships between them. Accordingly, the Mindtools to be employed in the learning activity can be determined.

2. Design the learning tasks based on the aims of the activity. For the learning activities with grid-based Mindtools, both problem-based and inquiry-based learning tasks are recommended, depending on the level of learner control. For novice or younger learners, problem-based learning with instant feedback would be preferable; for experienced or older ones, inquiry-based learning with supplemental materials in e-libraries or on the web would be better. On the other hand, for the activities which incorporate concept mapping strategies, inquiry-based learning is recommended.

3. Determine the technologies used in the learning activities. It is suggested that at least mobile and wireless communication technologies are required, while sensing technologies are optional. One of the reasons for adopting sensing technologies is to provide students with learning tasks, learning supports or supplementary materials at the right place and at the right time, which not only reduces the load of students in searching for the information, but also makes the learning process more efficient.

4. Determine the way to measure the learning performance of students and provide feedback to them. For the activities using grid-based Mindtools with the problem-based learning approach, automatic scoring and instant
feedback can be provided. For inquiry-based learning, scoring rubrics need to be defined by teachers in advance for measuring students’ findings, dialogs, learning sheets, and learning behaviors; moreover, a knowledge sharing mechanism could be helpful to the students in making reflections.

Conclusions and future work

In this paper, an advanced u-learning project entitled “MAIL” with various dimensions of research design, issues and contributions, has been presented. The integrated project has aimed to develop Mindtool-assisted u-learning environments to improve the in-field learning performance of students. A total of 73 u-learning activity-based studies have been conducted in the past five years to investigate the effectiveness of the Mindtool-assisted u-learning approach in terms of improving students’ learning achievements, learning motivation, learning attitudes, and technology acceptance degrees, among other aspects. The experimental results show that the research-proven approach with multiple practices in various settings is both promising and appealing.

In terms of LT innovation, the findings of the MAIL project provide several new contributions to the field of mobile and ubiquitous learning. It has been demonstrated that simply adopting new technologies for students to learn in a real-world learning environment is not good enough. What is more important is for us to design appropriate pedagogical strategies as Mindtools for providing better support to students in an authentic in-field ubiquitous learning environment with procedural and contextual components. It is expected that the accomplishments of the MAIL project can provide research-proven LT know-how of Mindtool-assisted ubiquitous learning as well as references for those researchers and practitioners who are interested in conducting in-field activities with instant supports from technologies.

The various designs and experiments described in this paper can serve as a good reference model for practitioners and researchers who are interested in this emerging field of LT. This paper also reveals several essential future research topics, which are summarized as follows:

• Track students’ learning activity logs as a way to support learning analytics studies in mobile and ubiquitous learning environments. For example, it would be interesting to analyze the students’ learning patterns and investigate the relationships between the patterns and their learning performance. Moreover, it is important to further examine the effects of the Mindtool-based u-learning on students’ higher order thinking based on the learning logs of students’ in-field learning behaviors.

• Provide instant and personalized learning supports based on the learning logs and profiles of individual students. Although Mindtools are theoretically helpful to students in constructing and organizing knowledge, students might find it difficult to effectively use Mindtools during the in-field learning activities. For example, some students might have difficulty in developing concept maps without appropriate assistance. That is, while learning with Mindtools in the field, students might require instant and personalized supports. Therefore, it is important to provide instant learning supports by analyzing the learning logs and profiles to identify their problems and needs in the field.

• Develop seamless learning environments by integrating front-end in-field learning experiences with the backend support of Learning Management Systems (LMS) by using the cloud technology so as to apply versatile Mindtools in more courses. In addition to the concept map and grid-based Mindtools developed in this paper, other Mindtools reported by Jonassen (2004) could be included for helping students learn in more effective and constructive ways. For example, spreadsheets could be an effective Mindtool for helping students infer the relationships between variables in Mathematics and Physics courses; database management systems could be Mindtools that engage students in analytical tasks; simulation software could be helpful to students in associating abstract theories with real-world scenarios. Therefore, it is worth investigating the possibility and effectiveness of applying those Mindtools to different u-learning activities.

These cutting-edge research topics and issues are worth our efforts to shed more light on this ever-changing, promising field of context-aware ubiquitous learning in Learning Technology. Recently, the Ministry of Education in Taiwan has initiated a large-scale program for applying mobile and ubiquitous strategies and tools in all levels of schools. In 2012, one hundred schools were selected as demonstration sites, and the number of schools participating in the program will be increased each year. In those schools, each student in the selected classes is equipped with a
mobile device. In each city or county, a cloud-based educational service system has been established to support the anywhere and anytime learning. Moreover, a series of training programs has been proposed to train teachers in how to design in-class and in-field activities with the strategies and tools developed based on the experiences and findings of MAIL and some other studies. It is expected that mobile and ubiquitous learning will become a regular form of learning in the coming five years in Taiwan.

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References


Mobile Phones for Spain’s University Entrance Examination Language Test

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ABSTRACT

Few tests were delivered using mobile phones a few years ago, but the flexibility and capability of these devices make them valuable tools even for high stakes testing. This paper addresses research done through the PAULEX (2007-2010) and OPENPAU (2012-2014) research projects at the Universidad Politécnica de Valencia and Universidad de Alcalá (Spain) to provide a powerful but low cost delivery system for the foreign language paper of the Spanish College Entrance Examination (henceforth PAU). The first project, PAULEX, intended to create a robust mobile platform for language testing while the second, OPENPAU, examined the specific applications of ubiquitous devices to create more dynamic forms of assessment. This paper focuses on the projects’ design, testing theory, and technical evolution including visual ergonomics. The current results demonstrate the technical and didactic feasibility of mobile-based formal assessment that aligns student needs with the kind of inferences that the mobile based language test should provide academic authorities.

Keywords

Mobile learning, High-stakes testing, College entrance examination, Foreign language, Higher education

Introduction

Mobile phones have been playing an increasingly significant role in education in the last years, and although until recently very few tests were delivered through them, their flexibility and capability to do so have suggested their potential even for high stakes-testing. High-stakes testing can be defined as those tests with important consequences for the test taker such as acceptance to university, a scholarship, or a license to practice a profession, all of which may have a great influence of the testee’s life. Using mobiles beyond their traditional uses such as podcasts, mp3 applications, and even learning apps seems to be a real challenge at this point, yet they have already been used for language testing as in PhonePass, previously called SET-10 (http://www.7act.net/7ACT_files/set10.pdf) test. The validity of the test has repeatedly been supported (Downey, Farhady, Present-Thomas, Suzuki & Van Moere, 2008) but little evidence has been provided of its operativeness in real educational contexts. As a consequence, the potential opportunities for mobiles for language testing are still open (Valk, Rashid, & Elder, 2010) but sound projects need to be implemented. This is the kind of research that the Ministry of Education started to support in 2007. By that year, the Spanish and regional educational authorities responsible for the high stakes University Entrance Examination (“Prueba de Acceso a la Universidad”, henceforth PAU) had determined the need to design a new test with greater validity than the current paper-based test, which only included the traditional tasks of reading and writing along with grammar questions. The new test had to include listening and speaking activities. However, budget cuts reduced the chances of implementing a new exam that could include speaking and listening activities unless a low-cost possibility could be found. With a view toward designing a modern test in the hopes of saving the possibility of including the two skills, the Universidad Politécnica de Valencia obtained funds for the development of an online testing system (PAULEX, “PAU en Lenguas Extranjeras”) project from 2007-2010 and the OPENPAU (“PAU abierta”) later on between 2012-2014 whose results were described by García Laborda (2012). After testing over 150 students online it was concluded that implementation of the computer test would save human resources and be economically feasible in a period of two to three years. As a subproject, the PAULEX project addressed the use of mobile phones (García Laborda & Giménez López, 2010), which is the main focus of this paper.

Literature review and theoretical approach

When addressing this sub-project, the research team felt that the use of mobiles phones, like any other delivery system, could not challenge three main testing features: validity, reliability, and practicality (Bachman & Palmer, 1996, among others). Validity here means that if a student gets a score of X on the test, it means that he should be
able to study using that foreign language at university; reliability provides information on the “the precision of the test measurement” (Salmani-Nodoushan, 2009, p. 1); and practicality implies that the test can be implemented in real life. In addition, the test construct in which mobiles are to be applied has taken into account current theories in language testing and Communicative Competence (Canale & Swain, 1980; Canale, 1984; Bachman & Palmer, 1996). Thus, the questions considered were (1) why use mobile phones for language testing? (2) How can the basic testing features be assured? (3) What learning theories are implicated in their use?

For most part, the collection of evidence in both projects was based on Weir’s validation framework and the Evidence Centered Design (Mislevy, Steinberg, & Almond, 2002; Mislevy & Haertel, 2006). Weir (2005) feels that the reliability of a test depends mostly on its conditions for validation. For him, it is necessary to have warrants that there will be two main types of validity in implementing a test: context validity and theory-based validity. Both are interrelated and need to be considered interdependently. Context validity is divided into three parts: task, setting and administration, and task demand (similar to test construct), while theory-based validity includes executive processes and executive resources. Given this framework, the theoretical application for the mobile application of the PAU took into account the aspects included in figure 1.

![Figure 1. Delivery framework (based on Weir, 2005)](image-url)
As indicated in figure 1, the theoretical aspects that needed to be considered in the implementation of the mobile-based test were grouped into three main phases: design, delivery, and consequential. The limitations and scope of this paper only allow for a discussion of the most important aspects of the design phase. Within this framework, this paper will mostly focus on contextual validity because this is where Weir places the delivery system factor. However, there is no question that the implications of using certain delivery systems - whether pen-and-paper or mobiles - are present in all the aspects presented in figure 1. This approach is based on performance-oriented tasks, which intend to resemble communicative acts of the language. In designing the test process in the test, two main options were included: a cognitivist and a social constructivist intervention. While the cognitivist approach supports the notion that students bring knowledge at the time of testing and this is represented by observable behaviors, the social constructivist approaches in language testing are very much related to the development of the Zone of Proximal Development (ZPD) (for further discussion see Poehner, 2008) through the examiner’s intervention and moderation. The Zone of Proximal Development is defined as “...the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky, 1978, p. 86). Based on the development of the ZPD, Poehner (2008) also suggests that Dynamic Assessment includes both approaches. Both PAULEX and OPENPAU projects follow the principles of Dynamic Assessment (DA). This approach considers that students have a current level of language knowledge (the one they show without test moderation) and a potential level (the one that they show when their output is computer or human-based moderated and improved through this interaction). According to DA, both can be included in a two-part assessment if the first is moderated (socio cognitive approach) and the second just serves to obtain current language evidence (cognitivist approach) without any tester’s intervention. This can be seen the process shown on figure 2.

According to these principles and given their experimental nature, the PAULEX and OPENPAU projects placed more emphasis on achieving a sound design based on experimental evidence than on potential achievement scores through the use of the test. In practice, evidence was collected and recorded through the use of mobiles. There were five main benefits that justified the decision: (1) the lower cost of mobile based hardware; (2) immediacy of rating and results; (3) ease of recording during oral interviews (hence, data available for further revision of the test and research); (4) the candidates’ familiarity with the delivery means; (5) possibilities for students to rehearse; and (6) ease of rating and administration. Additionally, accessibility for schools and/or official testing centers would enable the optimization of space.

Evidence obtained from the tests, which was moderated, was processed through the Evidence Centered Design (figure 1) (Mislevy, Steinberg, & Almond, 2000; Mislevy & Haertel, 2006) after the first interview, and implied the design of adequate tasks that considered all the linguistic requirements (as seen in figure 1) and could be delivered though mobile phones. According to the cognitivist approach, used in the second testing session, tasks had to be automatically delivered and recorded without moderation to provide current real data. Then the responses were rated (and the scores validated) and with a view toward having an impact on decisions for teaching and high stakes decisions.

![Figure 2. Development of test process](image)

Overall, the research team felt that the use of mobile phones was strongly founded but they recognized that the advantages and disadvantages needed to be weighed. Table 1 presents the pros and cons of their use:
Table 1. Use of mobile phones according to test characteristics

<table>
<thead>
<tr>
<th>Test characteristics</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place and time circumstances</td>
<td>Convenience of location and time because they require no external human presence</td>
<td>Security and technical assurance of full functionality required; otherwise test is at stake</td>
</tr>
<tr>
<td>Test rubric and process for responses</td>
<td>Tasks are consistent and delivered exactly in the same way to all testees</td>
<td>Testees may have different levels of understanding of the instructions according to proficiency levels</td>
</tr>
<tr>
<td>Test delivery</td>
<td>Current developments in mobile phones increasingly enable the inclusion of audio and image, thus enhancing contextualization and richness of responses</td>
<td>Standardization of mobile phones used for the test is needed; otherwise significant differences in responses can be found even by the same speaker.</td>
</tr>
<tr>
<td>Construct, rating, and scoring</td>
<td>Automated rating validates the equanimity in multiple choice items; separation of the rater from the testee enables rating protocols to be followed without the influence of contact with the testee. Thus assessments are more objective.</td>
<td>Human protocols do not assure complete equanimity (Baldwin, Fowles, &amp; Livingston, 2008).</td>
</tr>
</tbody>
</table>

Mobile phones in high stakes testing: The PAULEX project (2007-2010)

Since the implementation of the originally planned computer-based language testing platform was costly - albeit assumable in the long term -, one of the suggestions for the researchers was the use of mobile phones for the Speaking test only until the online platform could be used. However, while mobiles were originally thought to support student training, almost from the beginning the project management felt that they could also have a very positive effect on learning and they could encourage after-test washback effects. The main reasons to implement mobile phones were that the hardware was less costly than for computers, their use could be more accessible as they can easily be delivered and collected to and from each school, and their use could facilitate rapid assessments by testing units (which would resemble calling centers in their functioning and organization). These testing units could potentially organize and deliver a large number of tests in a limited time. The tests could be delivered automatically; the students’ responses could be recorded and assessed later by human raters.

From the beginning of this three-year project, it was clear that a well-trimmed double design project was needed for the delivery, ergonomics, and content inclusion. Figure 1 describes the organization of the PAULEX project.

![Figure 1. Organization of the PAULEX project](image1)

Figure 2. Organization diagram of PAULEX project
As can be seen in figure 2, two branches were organized: one devoted to the linguistic and validation aspects, and the other focused on the technological design of the online and mobile platforms. From the beginning it was clear that most of the significant difficulties were associated with the test design since the technology group had already been involved in similar projects before. Because the validation process was central to the project, the mobile application was designed and tested considering a variety of students and also bearing in mind that the PAU project served to obtain inferences of whether students would be able to use English for university work. Furthermore, the mobile technology branch considered that not all students have the same ability in using mobile technology so the technological specifications were relevant and accessible to students with special needs.

The development of the mobile phone subproject within the larger PLEVALEX project was intended to provide information on three aspects: (1) student adaptability to the new environment, (2) content and test validity for the listening/speaking tasks, and (3) delivery reliability. As mentioned above, mobile phones have been thought to foster learning more than to be used to assess students. Learning would take place by providing them with test samples that could be used anywhere and at any time. In this way mobile phones would bring to the fore the required testing skills in combination with similar listening and speaking tasks along with affective considerations but in a more interactive and usable manner. This process would also provide opportunities for authentic learning and the elimination of test fear would probably favor motivation. In this sense, the mobile phone sub-project sought to engage students in terms of motivation, high stakes test practice, and language learning. The results for this project were obtained through triangulating linguistic achievements, field notes, and a usability analysis carried out through a 20-item questionnaire computer delivered to all the students who took part in the research (García Laborda, Giménez López, & Magal Royo, 2011).

Validation method

We used five types of validation analysis for the PAULEX project. First, we did a Delphi analysis (Custer, Scarcella, & Stewart, 1999) to foresee potential issues in the mobile phone test with experts and then a reduced number of regular users (3). Second, we observed the intended scores of the mobile phone users and compared them with those obtained with the online platform (Sariola, 2003). Next, we analyzed the video recordings from the pilot studies. After that, inspection techniques were followed to do a usability analysis (Nielsen & Mack, 1994). Finally, the students’ attitudes toward mobile phone use for the test were analyzed (as seen above).

Usability analysis

As discussed above, the first test was conducted as a pilot test with a small sample of students, to detect faults in the design of the application and to debug and test the viability. After making some corrections such as adapting some aspects of the content and navigability, a second review of the application was made using potential users. In this second test the number of the sample was expanded to 144 individuals in the last year of high school (aged from 17-18 years), all of whom lived and studied in the area of La Oliva-Gandia (Valencia, Spain) (see table 2).

<table>
<thead>
<tr>
<th>High school</th>
<th>Frequency</th>
<th>Valid percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  IES Tirant lo Blanc</td>
<td>20</td>
<td>13,9</td>
</tr>
<tr>
<td>2  IES Monduver</td>
<td>22</td>
<td>15,3</td>
</tr>
<tr>
<td>3  IES Veles e Vents ,</td>
<td>33</td>
<td>22,9</td>
</tr>
<tr>
<td>4  IES Maria Enriquez</td>
<td>29</td>
<td>20,1</td>
</tr>
<tr>
<td>5  IES Ausias March</td>
<td>40</td>
<td>27,8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>144</strong></td>
<td><strong>100,0</strong></td>
</tr>
</tbody>
</table>

To evaluate the usability of the interface, a likert scale questionnaire ranging from 1 to 4 (to avoid indecisions) was used.
Results of the second test

Once collected, the data were processed using the SPSS statistical program. The first part of the test, which related to knowledge of the environment, focused on aspects to justify routine use and availability of phones, adaptation to the environment of the test items, and utility-satisfaction.

Table 3. Students’ attitudes toward the mobile-based tool operability

<table>
<thead>
<tr>
<th>Responses</th>
<th>Frequency</th>
<th>Percentage</th>
<th>Valid Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally disagree</td>
<td>9</td>
<td>6,3</td>
<td>6,3</td>
</tr>
<tr>
<td>Disagree</td>
<td>35</td>
<td>24,3</td>
<td>24,3</td>
</tr>
<tr>
<td>Agree</td>
<td>89</td>
<td>61,8</td>
<td>61,8</td>
</tr>
<tr>
<td>Totally Agree</td>
<td>11</td>
<td>7,6</td>
<td>7,6</td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td>100,0</td>
<td>100,0</td>
</tr>
</tbody>
</table>

Table 4. Students’ attitudes toward the mobile-based tool usefulness

<table>
<thead>
<tr>
<th>Responses</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally disagree</td>
<td>9</td>
<td>6,3</td>
</tr>
<tr>
<td>Disagree</td>
<td>16</td>
<td>11,1</td>
</tr>
<tr>
<td>Agree</td>
<td>100</td>
<td>69,4</td>
</tr>
<tr>
<td>Totally Agree</td>
<td>19</td>
<td>13,2</td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td>100,0</td>
</tr>
</tbody>
</table>

Table 5. Students’ attitudes toward the mobile-based tool time facilitator

<table>
<thead>
<tr>
<th>Responses</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally disagree</td>
<td>10</td>
<td>6,9</td>
</tr>
<tr>
<td>Disagree</td>
<td>21</td>
<td>14,6</td>
</tr>
<tr>
<td>Agree</td>
<td>69</td>
<td>47,9</td>
</tr>
<tr>
<td>Totally Agree</td>
<td>44</td>
<td>30,6</td>
</tr>
<tr>
<td>Total</td>
<td>144</td>
<td>100,0</td>
</tr>
</tbody>
</table>

Once the descriptive data had been surveyed and the group statistics had been examined, it was determined that the results were satisfactory as a whole. The results are above 1.5 on average (on a 0-3 scale).

Table 6. Students’ attitudes toward other factors in relation to mobile phone use for language testing

<table>
<thead>
<tr>
<th>Responses</th>
<th>Valid</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Mode</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A mobile-based task design helps me to perform better</td>
<td>144</td>
<td>1,71</td>
<td>0,058</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>A mobile-delivered test is useful</td>
<td>144</td>
<td>1,90</td>
<td>0,058</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Mobiles help to save time in taking this test</td>
<td>144</td>
<td>2,02</td>
<td>0,071</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Mobiles are adequate to cope with my needs for this test</td>
<td>144</td>
<td>1,74</td>
<td>0,060</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>I learned to use the application quickly</td>
<td>144</td>
<td>2,44</td>
<td>0,057</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>It is easy to remember how to use the application</td>
<td>144</td>
<td>2,45</td>
<td>0,053</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>I became familiar with the application easily</td>
<td>144</td>
<td>2,32</td>
<td>0,051</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>I think this is a good application</td>
<td>144</td>
<td>1,94</td>
<td>0,062</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>It is user friendly</td>
<td>144</td>
<td>1,94</td>
<td>0,060</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>The application works as I expected</td>
<td>144</td>
<td>1,92</td>
<td>0,059</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>I would recommend its use to other students</td>
<td>144</td>
<td>1,90</td>
<td>0,075</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>
As observed, in general the students valued the use of mobile phones for language testing very positively. The results of these tests have led us to continue with the research, which is still currently being developed.

**Advancing toward solutions for the PAU: The OPENPAU project (2012-2014)**

In the years between the PAULEX project and the beginning of the OPENPAU project, Spain started experiencing one of the worst financial crises in its history. In that context, the research team of the PAULEX project observed that mobile phones would be a valuable asset in testing oral skills (speaking and listening) and reading efficiently at a low cost. However, the team also considered that mobiles would be inappropriate for writing due to the intrinsic difficulty of keyboard use (García Laborda, Giménez López, & Magal Royo, 2011; Park, 2011). The design principles for developing a mobile phone application were the following (also Keskin & Metcalf (2011):

- Use of video communication with the examiner or a video delivery system if videos are used (possibly the most likely situation),
- Creation of a podcast library for student test preparation,
- Adequate real or deployed time access and adequate connectivity,
- Augmented reality possibilities,
- Mobile Blackboard or a similar platform for test preparation.

The first trials on a large scale are expected to begin by September 2013. The technology is designed to incorporate these conditions. The following sections address this concern. Thus far only the Delphi analysis and a very small sample of research have been complete.

**Significant results of the PAULEX and OPENPAU project for m-testing technology**

The results hereby presented are mostly related to the observations and research undertaken between the end of the PAULEX project and the beginning of the OPENPAU project. However, the ideas are based on the results from PAULEX and the triangulation of the Delphi method and focus groups. From their reactions and opinions, we concluded that the different kinds of interfaces for mobile devices favor tasks such as speaking and listening, even multiple choice tasks but are rather limited for reading and especially for writing. In the case of online exams with different kinds of tasks, adjustments must be made to navigation and content so that users can feel more comfortable when viewing and inputting information or data. The adaptation of user interfaces for certain tasks in a limited period of time requires prior understanding of certain determining factors such as the physical, functional, and formal accessibility of the application. For example, an interface with a hierarchical menu on a mobile phone is useful for beginning users because the appropriate options can be selected through the presentation of a series of menus. Hierarchical menus require relatively higher numbers of key clicks but this is acceptable for novel users who need help using unfamiliar navigation systems and thus leads to diminishing differences due to technology knowledge and serves to validate the use of mobiles as delivery system (Weir, 2005).

**Interface design**

The most recent interfaces developed have been designed with specific criteria for users taking the university entrance exam. The fundamental criteria studied in this period were accessibility, ergonomics, and the functionality or usability of the application.

**Accessibility**

Both projects followed the criteria for technical accessibility for interface design proposed by the World Wide Web Consortium, W3C, so that they reached the largest possible number possible of students as end users including those having visual or auditory impairments. This was achieved mainly by following the Web Content Accessibility Guidelines, WCAG 2.0 (http://www.w3.org/TR/WCAG20). In terms of accessibility of the contents of the university entrance exam, we considered the type of programming language used for navigation and also established guidelines for information access (Nelly et al., 2009). The first applications developed, PAULEX and OPENPAU, were created
in environments accessible on Internet with access to the contents delivered online by way of contextual menus for accessing the task management area and student management area. As for the exams created for the students, special attention was paid to visual and functional accessibility of navigation during the final exam tasks. The tests permitted us to determine the potential for mobile phones and the testees’ acceptance mobil phones (Magal-Royo, Fajarnes, Tortajada Montañana, & Defez Garcia, 2007). At the same time, they revealed the importance of two determining factors in the development of future applications: the present rate of technological progress of ubiquitous devices, and the adaptation of contents to the restrictive conditions imposed by them.

**Ergonomics**

The ergonomic aspects examined for the different applications created for mobile devices focused on the visual ergonomics that enabled students to focus easily and effectively on completing the different tasks. Various studies conducted after the experts’ research revealed the need to establish formal visual guidelines for the content of language learning tasks to enable navigation that is directed and transparent (Weining, Heng, & Guoping, 2007; García Laborda, Magal-Royo, de Siqueira Rocha, & Álvarez, 2010). Ubiquitous devices (mobiles, PDAs, smart phones, netbooks, etc.) can be small in size. That is, they have small screens that limit the space for user interface and the information available on them thus writing and reading tasks may have an additional difficulty due to the fact that a global vision of the read or written text is always desirable. In fact, the information shown must be carefully selected and presented so that it facilitates user interaction not only with the device but mostly with the task content. The major problem with the large variety of screens on ubiquitous devices is the direct impact on information access and visualization because no normalized standards have been established so far (Chae & Kim, 2004; Piolat, Roussey, & Thunin, 1997). This problem was of the most significant ones in test validity. In theory, if the test is implemented, the Ministry should provide all the testees with the same mobile phone to avoid biased or unfair testing conditions.

**Limited data input mechanisms**

These devices are also limited in terms of data entry procedures because of their reduced size. The methods used most often for mobile devices nowadays are the keypad, which has more than one function associated to each key, and the touch screen. Both methods require a high degree of attention on the part of users and can lead to errors, a situation that limits how they can be used.

Thanks to improvements to user interaction mechanisms now found on ubiquitous devices, different channels can be used for data input, which can be simultaneous, synchronized, or combined for certain tasks. In the case of the mobile phones, which have different kinds of exercises (oral, comprehension, writing, etc.), data entry mechanisms can slow down or directly affect completion of the exam, for example, on the reading test, which can involve reading a long text or typing using a virtual physical (Giménez López, Magal Royo, Garcia Laborda, Garde Calvo, & Prefasi Gomar, 2009) (see figure 3). The approach to design this interfaces was taken from the socio-constructivist theory of language that uses images to trigger the testee’s output and the visuals to support and enrich the production. This can be also the case when the video clips are interrelated in semi-interactive conversation through short questions or even in connection to other user to make dialogues between two testees in which the potential knowledge is visible after reconstructing one’s production (Poehner, 2008). At the same time, a robust recording system and clear rubrics support the cognitivist approach that can be best seen in the long responses for descriptions or the multiple choice responses in which the students need to show evidence of knowledge without external mediation or support (what has been called current knowledge).

**Usability**

In terms of the usability and functioning of the applications adapted to mobile phones created for the PAULEX project, the results show that the students considered it to be useful because it enabled them to save time while taking an exam of this kind (see figure 3). It was also determined that the students learned to use the application for mobile phones faster and independently due to their familiarity through daily use of mobiles, which enabled them to adjust quickly to it and to its guided interactivity. Analysis of the data related to level of satisfaction with the use of the
application was very high when there was a sensation of predictability that leads to a fast understanding of the method and learning how to do specific tasks on the mobile phone.

The overall conclusion of these first trials was that the students felt comfortable with the format (bearing in mind the limitations of the devices. The oral tasks with video presentations were evaluated with the same degree of confidence and reliability as the analogous activities on the web platform for personal computers.

**Proposals for the design of an m-testing platform**

The proposals in this section were also applied to the OPENPAU project and any future project of a language testing m-platform and are strongly based on the findings from the PAULEX project. The OPENPAU project has incorporated the application to the HTC Desire model mobile device whose base technology allows multimodal use of different forms of data input and output (see figure 3). To do so, a study was carried out in advance to determine the initial conditions needed for completion of the tasks on an English language skills exam. These included the
The general format of the application contained the following visual sections:

- The program header area. The application name and official logo of the program participants appear in this section of the screen.
- The user data area. This area is fundamental for the final coding of the exam and student for initial correction and any future corrections, as well as any official reviews required by law at the national level.
- Area for viewing progression through the exam. This area has numbers indicating the different tasks that must be completed on the exam. This section will enable the students to know their progression throughout the exam from the point at which they enter their application access code until they send the completed exam. It starts with the reading of the student's data before the actual completion of the exam and provides information throughout completion of the exam including selection of the interaction mode, and completion of the different tasks on the exam, etc.
- Test area. This area shows the questions or exercises to be completed on each of the tasks. The content will vary depending on the functional and/or content characteristics of the exercises.
- Help area. This section will show general as well as specific information about how to complete the exam including the maximum score assigned to each section.

Project results and conclusions

As observed in the PAULEX project, in situations of high stakes tests with a large number of students, mobiles have some advantages that may put them ahead of other testing systems in terms of budget, accessibility, familiarity, and sound quality. Additionally, although the results in the PAULEX project were limited, the validation methods provided information about the ergonomics, usability, integration, and motivation of the application. According to the data obtained, it was observed that prospective research should include the following aspects:
• Task adaptation to new types of mobile phones;
• Multiplatform systems;
• User satisfaction;
• External validity as compared to other delivery systems and other tests including similar pen and paper versions;
• Technical advances in software design;
• Pedagogical benefits;
• Delivery reliability;
• Functionality.

The students were eager to use mobile phones for language teaching and learning, but they mostly wanted to use them for speaking and listening. Still, the multiple choice items for grammar were also well regarded. However, the students predictably indicated that reading and writing were too difficult to be implemented, with reading rated in a better position than writing (García Laborda, Giménez López, & Magal-Royo, 2011). The PAULEX project also showed that mobiles were excellent for test preparation and an even more encouraging finding is that they offer great opportunities for the real test itself because the students would accept using them for real testing tasks. All three teachers indirectly involved in piloting their use supported mobiles and liked the sequencing and delivery procedure for questions, but they claimed that they had no software up to that time to implement the teaching at a large scale. They also found that, although the testing system could, in fact, be valuable to assess oral skills in the PAU in the long term, phones with bigger screens were desirable. At the same time, they doubted that the Ministry of Education would spend large sums of money on the terminals. However, they believed that the listening and speaking sections could be done online while the rest of the test could be done with pen and paper in order to lower the cost. Additionally, they mentioned that one set of mobile phones could serve more than one high school and maybe more than one year given adequate hygienic measures. Finally, they mentioned the convenience for raters since they could work from a distance either on synchronous or asynchronous testing.

Our experience also determined that technologies for developing user interfaces should focus on the requirement to offer simple interaction modes that are highly natural and adapted to future terminals and communication networks (Oviatt & Cohen, 2000). It is in this area in which technologies face their biggest challenge: attempting to integrate different modes of communication (visual, oral, auditory, gestural, etc.) in order to offer more powerful methods of interaction with the user, grouped under the name of natural or multimodal interaction, thus overcoming the limitations of interfaces available today (Oviatt, 1999). The ultimate objective of natural interaction is to enable users to be able to use all the communication resources available to them, combining multiple modes of interaction and, therefore, creating a multimodal environment for information access (voice, audio, graphics, video, keypad, electronic pencil, pointer, mouse, etc.) (Oviatt & Larson, 2003). In this sense, the OPENPAU project is currently being driven by practical concerns. The current research is now exploring the potential for implementation and the pedagogical implications while extending the domains of the project to make it a multiplatform one. The study has shown the feasibility of using mobiles for the intended purposes and that the cost could probably be lower than the traditional face-to-face interviews while also permitting a better distribution of space for delivery and adequate rationalization of testing times. Most of the students might also engage in this testing means more easily than in a face-to-face interaction with the examiner. With the development of the OPENPAU application for ubiquitous devices, it has been found that technology has now progressed sufficiently to propose the offering of exams using multimodal access. The incorporation of new modes of interaction such as voice recognition for navigation, the use of touch screens, or synchronized use of the keypad will enable users more comfortable access in accordance with their needs and, thus, solve problems related to accessibility to the media (Magal-Royo, Giménez-López, Pairy, García Laborda, & Gonzalez-Del Río, 2011; Magal-Royo & Giménez López, 2012).

Progress in the use and research of mobile phones for language learning is receiving increased attention and their use in Mobile Assisted Language Learning (MALL) is an area of steady growth. Despite the advantages this area offers users in terms of the flexibility and ubiquitous nature of the device and environment, as well as advances in mobile applications and Internet access, it must still deal with the need to seek efficient adequate interfaces for user needs for information access and transfer. In the specific case of task completion or specific processes, it is important to evaluate the impact of functional environments that enable users to find comfort and accessibility in the information provided in order to favor this mode of learning.
Future lines of work

The potential of technologies adapted for multimodal interaction in language testing offers huge possibilities for development of innovative applications. In that sense, devices will enable users to select between using one mode or another exclusively (for example, using an online dictionary or making a voice call), to the possibilities of changing between modes of interaction in the same session (sequential multimodality, as in consulting the dictionary on occasions on a mobile during a test), to true freedom in combining and changing modes (simultaneous multimodality: talking, keying, dialing, viewing, etc.) on terminals or ubiquitous devices that enable simultaneous access to voice and data channels, and thus offers opportunities for new items that resemble more what speakers do with the language and how they use it.

In reference to the project impact in the Spanish educational system, it is believed that an inexpensive system to assess speaking skills may have two potential benefits: first, it will enable testing of this skill at a low cost; and second, the impact on the classroom of implementing speaking skills may lead to a great educational improvement in foreign languages. Thus, as a whole, the expected effect of the project if used in the near future is immense and certainly very significant for the educational system.

To conclude, while the use of mobile phones for high stakes testing may be feasible, it is necessary to obtain a commitment from all the stakeholders including the students and the administration authorities. Since the oral test is a social, professional, and educational demand, delivering the oral section of the PAU through mobile phones would require adequate facilities from all the high schools, a better understanding of technology from teachers and new ways to plan and prepare for the test on the part of students. Researchers should also seek ways to overcome the difficulties associated with hearing impairment or other restrictions. While mobiles could be a great asset in education, it is necessary to recognize that not all teachers may be equally prepared to face such as a technological change or eager to change their ways of teaching to cater to the students’ needs by facilitating them with the necessary strategies for taking the test. Thus, practitioners should also receive the necessary instructions and courses to facilitate their adaptation to the new context. Nevertheless, it is believed that this change would not be any more traumatic then others that they have seen in recent years. The ongoing work in the PAULEX project is expected to continue to address these issues. The information obtained so far, while initial, provides enough evidence for the potential of this innovation in both the national and international contexts in areas such as educational planning, course design, test delivery, specifications, and information and communication technologies development. It also takes the use of mobile phones far beyond their traditional perspective of mere supportive elements of courses or learning to enhance their role as high stakes testing facilitators.

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References


Effects of Mobile Instant Messaging on Collaborative Learning Processes and Outcomes: The Case of South Korea

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ABSTRACT

The purpose of this paper was to investigate the effects of mobile instant messaging on collaborative learning processes and outcomes. The collaborative processes were measured in terms of different types of interactions. We measured the outcomes of the collaborations through both the students’ taskwork and their teamwork. The collaborative learning processes and outcomes in the Mobile Instant Messaging group (Mobile IM) were also compared with the Personal Computer-based Instant Messaging group (PC IM) and the Bulletin Board System group (BBS). A total of 48 students participated in this study, and the main results show that more cognitive and metacognitive interactions were found in the BBS group while social and affective interactions were the major types of interactions in the Mobile IM group and the PC IM group. As a result of the collaborative learning outcomes, the Mobile IM group shows better teamwork than the other two groups. However, better taskwork was found in the BBS group and the PC IM group rather than the Mobile IM group. Finally, the researchers discuss the implications of this study from the perspective of the educational potential of mobile learning.

Keywords

Mobile-based collaborative learning, Mobile instant messaging, Collaborative learning processes, Collaborative learning outcomes

Introduction

Many researchers have claimed that mobile learning will greatly influence the future of teaching and learning in collaborative learning contexts (El-Hussein & Cronje, 2010; Huang, Yang, Huang, & Hsiao, 2010; Ryu & Parsons, 2012). The main reason behind many researchers’ enthusiasm about mobile based collaborative learning stems from its spontaneous, portable, personalized, ubiquitous and situated characteristics (Motiwalla, 2007; Patten, Arnedillo Sanchez, & Tangney, 2006; Rau, Gao, & Wu, 2008; Ryu & Parsons, 2012). Moreover, mobile learning has gradually become stable and mature (Huang, Yang, Huang, & Hsiao, 2010) and has attracted an increased number of learners in recent years.

Educators in South Korea are particularly fascinated by the concept of mobile learning due to its potential to overcome the limitations of traditional education and web-based learning. According to Korea Internet & Security Agency (2011), the infrastructure for mobile learning (e.g., WiFi networks, high-speed internet connection) is well established in South Korea. The Organization for Economic Cooperation and Development (OECD) also recently reported South Korea has the most mobile wireless broadband subscriptions of 34 OECD counties (OECD, 2012). South Korea has 104.2 subscriptions per 100 inhabitants. Additionally, several South Korean universities have distributed free iPhones or smart phones and encouraged students to utilize them to participate in lectures, to access library sources, and to access educational administration system (Lee, 2010). Students’ adoption of mobile technology is not surprising, given recent statistics on Internet usage. The Korea Internet & Security Agency (2012) finds that the internet usage rate for university students is almost 100% (99.9%) and among instant message users, 49.4% use mobile instant messaging services. The rapid diffusion and use of mobile devices suggests students may be receptive to educators’ incorporation of these tools for learning or ubiquitous learning in South Korea (Park, Nam, & Cha, 2012).

However, the true extent of the impact of mobile learning on education is still contested, both theoretically and empirically (Motiwalla, 2007, Ryu & Parsons, 2012). Moreover, previous research is limited to two specific themes – the effectiveness of mobile learning and the design of mobile learning systems (Wu, Wu, Chen, Kao, Lin, & Huang, 2012). Researchers have typically measured the effectiveness of mobile learning using learning outcomes rather than learning processes (Chen, Chang, & Wang, 2008; Hwang & Tsai, 2011). These outcomes comprise motivations, perceptions, attitudes, academic achievement, and satisfaction of students.
In this respect, various research topics that can uncover the potential of mobile learning are warranted to present more practical guidelines in this area. To address this gap in the literature, the present study explores how mobile learning affects collaborative learning processes and outcomes. Specifically, we examine the extent to which students’ cognitive, metacognitive, and social/affective interactions vary in mobile-based collaborative learning environments. We also examine the quality of cognitive messages and the level of team effectiveness in order to measure taskwork and teamwork, respectively.

**Theoretical background**

**Mobile-based collaborative learning in social and situated learning frameworks**

It is important to emphasize that the use of technology in educational settings must be in accordance with educational theories and specific pedagogical considerations (Patten et al., 2006). According to Ryu and Rarsons (2012), social and situated learning can be experienced through mobile-based collaborative learning since mobile learning facilitates seamless social interaction in learners by providing them advanced functions such as mobility and instant connectivity. Social learning theory emphasizes that learning occurs within a social context, which means people learn through observing and modeling other learners’ behaviors (Bandura, 1977; Hung, Looi, & Koh, 2004). Mobile-based collaborative learning can maximize the quality and quantity of interactions and observations through its rich communication channels. On the other hand, situated learning theory emphasizes authentic contexts and real learning activities (Lave & Wenger, 1991). Situated learning occurs in educational settings, which provide authentic contexts and activities to promote social interaction and collaboration (Herrington & Oliver, 1995; Lave & Wenger, 1991). Unlike traditional classrooms that decontextualize learners from authentic and practical situations, mobile learning provides a borderless context where learners can reach their goals and needs through real-time interactions. Thus, learners will experience enhanced social and situated learning through mobile learning. Also, mobile learning grounded in social and situated learning will provide learners with more updated learning environments.

**Mobile instant messaging for collaborative learning**

Collaborative learning is defined as ‘a situation in which two or more people learn or attempt to learn something together’ (Dillenbourg, 1999, p. 2). Collaborative learning can be mediated through many different tools, such as discussion boards, blogs, and instant messenger. Like computer-based collaborative learning, mobile-based collaborative learning is mainly text-based, which can enable students to express their opinions and to ask questions without the pressure or feeling of threat that can accompany traditional classrooms (Kitsantas & Chow, 2005; Rau et al., 2008; Ting, 2012). However, Chen & Huang (2010) note that computer-based collaborative learning has a limitation with respect to meeting learners’ educational needs, especially for students who want a more informal and flexible learning environment. In this respect, mobile-based collaborative learning can be more in accordance with their needs by providing ubiquitous and situated learning environments (El-Hussein & Cronje, 2010).

Instant messaging is one of the most widely-used mobile applications for education (Rau et al., 2008). Rau et al. (2008) found that mobile instant messaging supported social bonding between students and instructors. Additionally, Yengin, Karahoca, Karahoca, & Uzunboylu, (2011) investigate the potential of using mobile instant messaging for education, and they found the successful examples such as a quiz tool, an assessment tool and discussion tools in several previous studies (e.g., Attewell, 2005; Stone, Briggs, & Smith, 2002; Markett, Sánchez, Weber, & Tangney, 2006; Bollen, Eimler, & Hoppe, 2004; Holley & Dobson, 2008). Other studies suggested that when used as a discussion tool, mobile instant messaging can promote interactivity and led to more active collaboration (Markett et al., 2006; Bollen et al., 2004; Holley & Dobson, 2008). Despite positive findings from several studies, Ryu & Parsons (2012) and El-Hussein & Cronje (2010) point out that there is still a need to conduct additional research on how mobile instant messaging could facilitate collaborative learning beyond the ‘novelty effect’ of new mobile technology.

**Collaborative learning processes: Cognitive, metacognitive and social/affective interactions**

Mobile-based collaborative learning supports interactions among students as well as instructor-student interactions (Ting, 2012). Students can also enjoy the increased frequency of social interaction through mobile technology in group-based projects (Seppala & Alamaki, 2003). A number of researchers emphasize the quality of cognitive
interaction in learning environments, which is crucial for the success of collaborative learning. However, many researchers note that students’ metacognitive and social/affective interactions also play a fundamental role in collaborative learning (Efklides, 2008; Salonen, Vauras, & Efklides, 2005). Metacognition is defined as knowledge about knowledge or the regulation of cognition (Brown, 1987). Metacognitive interaction is regarded as the interactive activities that monitor, evaluate and revise other team member’s cognitive processes when they work as a team. They involve the sharing of metacognitive justification, evaluation and feeling (Efklides, 2006). Social/affective interactions are an inevitable part of human communication and play an essential role in collaborative learning (Shen, Wang, & Shen, 2009). Learners express a variety of emotional states (e.g., interest, curiosity and confusion) (Kort, Reilly, & Picard, 2001) as well as social expressions (e.g., greeting, complimenting, and expressing appreciation) (Rourke & Anderson, 2002) when they work together. Furthermore, Panitz (1999) argues that it is important to create an emotional environment that enables students to take initiative in expressing their opinions about any given topic while constructing a shared learning experience.

Interestingly, Ting (2012) suggests that mobile technologies can strengthen learners’ interactions and ultimately help learners achieve better collaborative learning outcomes. In addition, Rogers & Price (2006) indicate that mobile technology can change learners’ collaborative learning processes, particularly their cognitive, metacognitive and social/affective interactions. However, it is hard to find studies that focus on these specific types of interactions, even though much research has been done on the topic of computer-based collaborative learning (Guan, Tsai & Hwang, 2004; Hara, Bonk, & Angeli, 2000). In addition, Wu et al.’s (2012) meta-analysis on mobile learning using 164 published papers from 2003 to 2010 shows that evaluating the outcomes of mobile learning rather than processes was the most researched topic in the field of mobile learning. Thus, our study, which addresses how these interactions occur in mobile-based collaborative learning environments compared to collaborative learning via desktop computer or BBS, will be valuable to practitioners as well as researchers who are interested in facilitating students’ informal or seamless learning by applying mobile technologies to education.

Collaborative learning outcomes: Taskwork and teamwork

Unlike individual learning, collaborative learning not only needs task-related skills but it also needs team-related skills that enable team members to work together smoothly and effectively (Eccles & Tenenbaum, 2004). Moreover, a high performance team is characterized as a group of people that is effective in creating a balance between taskwork and teamwork (Johnston, Smith-Jentsch, & Cannon-Bowers, 1997). Mathieu, Heffner, Goodwin, and Salas & Cannon-Bowers (2000) describe taskwork as the skill necessary to accomplish a given task. Taskwork is identified by a learner’s cognitive activity. On the other hand, teamwork is described as the skills needed for effective team functioning such as proper role assignment/responsibility, using efficient communication channels and accurate decision making.

Although many researchers argue that teams develop both taskwork and teamwork through performing their team projects, the evaluation of collaborative learning tends to only focus on their task achievement in terms of how effectively and efficiently they accomplish their given tasks (Mathieu et al, 2000). However, Stott and Walter (1995) indicated that taskwork and teamwork are conceptually independent, but the nature of their functioning is intertwined and affects team performance. Therefore, it is more reasonable to measure both taskwork and teamwork as outcomes of collaborative learning instead of measuring taskwork by itself.

Research questions

To examine the extent to which learners’ cognitive, metacognitive and social/affective interactions vary in mobile based collaborative learning as well as the effects of mobile learning on collaborative learning outcomes in terms of taskwork and teamwork, the specific research questions are as follows.

First, are there any differences in collaborative processes in terms of learners’ three types of interactions when they use Mobile Instant Messaging in comparison to Personal Computer-based Instant Messaging and Bulletin Board Systems?

Second, are there any significant differences in collaborative outcomes in terms of learners’ taskwork and teamwork when they use Mobile Instant Messaging in comparison to Personal Computer-based Instant Messaging and Bulletin Board Systems?
Third, are there any differences in learners’ perceptions when they use Mobile Instant Messaging in comparison to Personal Computer-based Instant Messaging and Bulletin Board Systems?

Method

Participants

A total of 48 students in three classes from a large private Korean university participated in the study. All participants were enrolled in an introductory educational technology course which was a required course. Their average age was 21.57 (SD = 13). They participated in the study as part of their regular class activity. The three classes were randomly assigned to one of the following three groups: a mobile instant messaging group (Mobile IM; n = 22), a personal computer-based instant messaging group (PC IM; n = 12), and a bulletin board system group (BBS; n = 14).

Three communication media for discussion

Mobile Instant Messaging (Mobile IM): The Mobile IM group used the KakaoTalk application to conduct their discussion task. It is one of the most popular free mobile messenger applications in South Korea. It provides free text messaging and free calls. The students in the Mobile IM group can share various content and information such as photos, videos, and URL links. Group discussion is possible without the constraints of time and space.

Personal Computer based Instant Messaging (PC IM): The PC IM group used MSN Messenger in their desktop computers. The MSN Messenger is a form of communication over the internet on a PC that offers a quick transmission of text-based messages from sender to receiver. Computer instant messaging basically offers real-time online chat but students need to set a time and to log into the messenger for their group discussion.

Bulletin Board System (BBS): The BBS group used a discussion board system like Blackboard provided by the Learning Management System in a University. Through the BBS, students can do an asynchronous discussion while students can do synchronous discussion through Mobile IM or PC IM. Students in the BBS group are able to revisit their discussion board and post their message whenever they want.

To fairly compare the differences in the three communication media groups, both mobile and computer instant messaging groups are allowed to use only text-based messaging even though they can use voice chatting through their devices. Also, the BBS groups are only allowed to use the discussion board through their personal computer even though they can access it through mobile technology.

Task and procedure

The team task was an ill-structured problem describing a novice teacher who took on a very low achievement class with many troublemakers, and a school principal who directed her to increase student academic achievement within a year. Before students could solve the ill-structured problem, lessons on learning paradigms such as behaviorism, cognitivism, and constructivism were provided to the participants in a regular class. Then, they were randomly assigned to one of three communication media groups. Each group consisted of three or four students and they were asked to discuss a best solution to solve the given problem based on three learning paradigms within a week. All participants were required to discuss the topic using only an assigned communication medium. After the discussion week, participants answered an open-ended perception question which asked them what were the most and the least favorite aspects of the medium that they used for their discussion.

Measures

To examine the effects of Mobile Instant Messaging on collaborative learning, students’ interactions were measured as the learning processes of their collaborations, and taskwork and teamwork were measured as collaborative learning outcomes. The specific methods were described as follows.
Three types of interactions

The content analysis method was used to analyze the types of interactions. As Henri (1992) suggested, an individual theme or idea (thematic unit) was used as the unit of the analysis rather than a word, sentence or paragraph in order to maintain consistency in analyzing students' discussion messages that occurred in the three different media. For example, the Mobile IM group expressed their opinions in a short phrase or word instead of using a full sentence (e.g., "when?", "in this case") while the BBS group usually posted at least one paragraph to state their idea. Therefore, the individual theme or idea was used as the unit of analysis in this study, so the unit of analysis can be any size text from a single word to a paragraph as long as it expresses a theme or idea.

The types of interactions are composed of three categories: cognitive or metacognitive interaction, social or affective interaction, and other interaction. Cognitive or metacognitive interaction is a task-related meaning unit. Social or affective interaction is a non-task-related meaning unit such as personal talks or the expression of feelings. Other interactions are interactions about managing the discussion such as scheduling for the task and setting discussion rules. Two researchers then developed a coding scheme and classified each thematic unit into one or more of the aforementioned categories. The coding scheme is described in Table 1 with samples of thematic units. Inter-rater reliability for the classification of categorical variables was determined by Cohen's Kappa, which measures the agreement between two raters who each classify thematic items into mutually exclusive categories. Cohen's Kappa for the inter-rater reliability was 0.96 for the agreement of thematic unit and 0.94 for the classification of interaction. The two raters discussed until they reached a consensus, and a total of 1,850 messages were analyzed in this study.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive/metacognitive interaction</td>
<td>• Talking about key concepts of learning theories</td>
</tr>
<tr>
<td></td>
<td>• Talking about learning theories’ principles</td>
</tr>
<tr>
<td></td>
<td>• Talking about implication of learning theories</td>
</tr>
<tr>
<td></td>
<td>• Sharing learner’s opinion on learning theories and application</td>
</tr>
<tr>
<td></td>
<td>• Speculating some issues on learning theories</td>
</tr>
<tr>
<td></td>
<td>• Questioning something about learning theories</td>
</tr>
<tr>
<td></td>
<td>• Summarizing what they discussed on learning theories</td>
</tr>
<tr>
<td></td>
<td>• Reflecting what they discussed on learning theories</td>
</tr>
<tr>
<td>Social/affective interaction</td>
<td>• Praising the other student’s utterances</td>
</tr>
<tr>
<td></td>
<td>• Chatting about student’s private lives</td>
</tr>
<tr>
<td></td>
<td>• Chatting about non-task-related topics</td>
</tr>
<tr>
<td>Other interaction</td>
<td>• Talking about scheduling for the task</td>
</tr>
<tr>
<td></td>
<td>• Talking about taking turns</td>
</tr>
<tr>
<td></td>
<td>• Talking about setting discussion rules</td>
</tr>
</tbody>
</table>

Teamwork

A survey was used in order to measure teamwork. The survey consisted of five questions about team effectiveness: Efficiency of team management, Observance of team schedule, Conviction of team output quality, Adequacy of team output quantity, and Satisfaction with team output (e.g., “Our team management was efficient,” “Our team members kept our team schedule,” “we think the quality of team output was excellent,” “we think the quantity of team output was appropriate,” and “we are satisfied with our team output.”). Students responded on a five-point Likert scale ranging from “Strongly Agree” to “Strongly Disagree,” depending on how well they thought that the statement described their team effectiveness. The responses were coded in the following manner: strongly agree = 5, agree = 4, not sure = 3, disagree = 2, strongly disagree = 1. The reliability of the survey was .80 for the pilot test and for this study it was .78.

Taskwork

To examine how well learners discussed a given topic, we evaluated the quality of their group discussion. Specifically, we measured their cognitive messages based on four criteria: novelty, importance, relevance, and ambiguity. Among the 10 criteria in Newman, Webb, & Cochrane’s (1996) study, four criteria which measure the
quality of cognitive messages were selected for this study. Two researchers who specialized in educational technology scored each cognitive message as 1 or 0 based on the four criteria described in Table 2. The inter-rater reliability through Cronbach alpha analysis was 0.92.

Table 2. Four criteria for rating taskwork

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Descriptions</th>
<th>Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novelty</td>
<td>New information, ideas, solutions</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Repeating what has been said</td>
<td>0</td>
</tr>
<tr>
<td>Importance</td>
<td>Important points/issues</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Unimportant, trivial points/issues</td>
<td>0</td>
</tr>
<tr>
<td>Relevance</td>
<td>Relevant statements</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Irrelevant statements, diversions</td>
<td>0</td>
</tr>
<tr>
<td>Ambiguities</td>
<td>Clear, unambiguous statements</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Confused statements</td>
<td>0</td>
</tr>
</tbody>
</table>

Perception on communication media

For a more in-depth understanding of the characteristics of each communication medium, students’ perceptions on medium were measured by a survey which contained one open-ended question. The question asked students what was the most and the least favorite aspects of the medium in their discussion. One piece of paper was given to each student, and they described their thoughts about the given communication medium for 30 minutes.

Data analyses

Content analysis was conducted to examine how the types of interactions were different across the three groups. For the analysis of the comparisons of the three groups in terms of taskwork and teamwork, one-way ANOVAs were conducted. The perception survey data was analyzed qualitatively based on the main themes that students addressed as characteristics of the communication medium they used.

Results

Collaborative process: Types of interactions

This study was designed to discover if there are differences in the types of interactions such as: cognitive or metacognitive interactions, social or affective interactions and other interactions (not included in the two categories) among the three communication media groups. The interactions were analyzed by a content analysis and the percentage of each interaction compared to the total number of messages from each group was discerned. The results are shown in Table 3.

Table 3. Frequencies of Interaction Types by Communication Media Groups

<table>
<thead>
<tr>
<th></th>
<th>Cognitive/metacognitive interaction</th>
<th>Social/affective interaction</th>
<th>Other interaction</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile IM</td>
<td>614(50.00%)</td>
<td>449(36.56%)</td>
<td>165(13.44%)</td>
<td>1,228(100.0%)</td>
</tr>
<tr>
<td>PC IM</td>
<td>205(45.15%)</td>
<td>166(36.56%)</td>
<td>83(18.28%)</td>
<td>454(100.0%)</td>
</tr>
<tr>
<td>BBS</td>
<td>123(73.21%)</td>
<td>32(19.05%)</td>
<td>13(7.74%)</td>
<td>168(100.0%)</td>
</tr>
<tr>
<td>Total</td>
<td>942(50.92%)</td>
<td>647(34.97%)</td>
<td>261(14.11%)</td>
<td>1,850(100.0%)</td>
</tr>
</tbody>
</table>

From the results, it was found that cognitive/metacognitive interaction accounted for approximately 50%, social/affective interaction 37%, and other interaction 13% in the group utilizing Mobile IM in their discussion. A similar tendency was found in the group utilizing PC IM with results that showed that cognitive/metacognitive interaction accounted for approximately 45% of the total number of messages, social/affective interaction 37%, and other interaction 18%. On the other hand, cognitive/metacognitive interaction accounted for more than 73%,
social/affective interaction 19%, and other interaction 8% in the group utilizing BBS for interaction.

In terms of the three types of interactions, the Mobile IM and PC IM groups showed similar results. However, the result reveals that the BBS group had more cognitive/metacognitive interactions and fewer social/affective interactions compared to the Mobile IM and PC IM groups. In addition, other interaction was also lower in the BBS group compared to the other two groups. The results are arranged into a pie chart as follows.

Collaborative outcomes

Teamwork

To identify if there are differences in teamwork scores across the three different communication media groups, the mean of the teamwork score was calculated as shown in Table 4. A one way ANOVA analysis was conducted to see if there were any statistically significant differences in the teamwork scores among the groups. The results are presented in Table 4.

From the results above, the Mobile IM group recorded the highest average points with 4.12 in the teamwork score, followed by the BBS group with 3.65, and the PC IM group with 3.47. As shown in Table 5, there were significant differences in teamwork scores between groups according to the type of media. From the results of the Scheffe verification, there was a significant difference between Mobile IM and PC IM at the \( p < .01 \) level, however, significant differences were not found between the BBS group and the other two groups (Mobile IM and PC IM). That is, the result reveals that the Mobile IM group showed higher teamwork at a statistically significant level compared to the PC IM group.

| Table 4. Teamwork scores by communication media groups |
|-------------|-----|-----|-----|
|             | N   | M   | SD  |
| Mobile IM   | 22  | 4.12| .65 |
| PC IM       | 12  | 3.47| .41 |
| BBS         | 14  | 3.65| .58 |
| Total       | 48  | 3.82| .63 |

| Table 5. ANOVA analysis of teamwork scores by communication media groups |
|-----------------|-----|-----------------|-------|-----|
|                 | Sum of Square | df | Mean Square | F  | Sig. |
| Between groups  | 3.929         | 2  | 1.965       | 5.803| .006|
| Within-groups   | 15.235        | 45 | .339        |     |     |
| Total           | 19.164        | 47 |             |     |     |
Taskwork

To identify if there was any difference in the taskwork score depending on the type of communication media, the total taskwork score was divided by the total number of cognitive/metacognitive messages in each group of communication media. The results revealed that the mean scores of taskwork were 1.89, 2.59 and 2.62 in the Mobile IM, PC IM and BBS groups respectively. The highest mean of taskwork score was found in the BBS group, and the lowest mean of taskwork score was found in the Mobile IM group.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Total # of cognitive/metacognitive messages</th>
<th>Total taskwork score</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile IM</td>
<td>22</td>
<td>614</td>
<td>1,160</td>
<td>1.89</td>
<td>.97</td>
</tr>
<tr>
<td>PC IM</td>
<td>12</td>
<td>205</td>
<td>530</td>
<td>2.59</td>
<td>1.00</td>
</tr>
<tr>
<td>BBS</td>
<td>14</td>
<td>123</td>
<td>322</td>
<td>2.62</td>
<td>1.09</td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
<td>942</td>
<td>2,006</td>
<td>2.13</td>
<td>1.05</td>
</tr>
</tbody>
</table>

The ANOVA analysis was conducted to determine if the taskwork score was statistically different across the three communication media groups. The results are shown in the following Table 7.

<table>
<thead>
<tr>
<th></th>
<th>Sum of Square</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>109.640</td>
<td>2</td>
<td>54.820</td>
<td>55.370</td>
<td>.000</td>
</tr>
<tr>
<td>Within-groups</td>
<td>938.589</td>
<td>948</td>
<td>.990</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1048.229</td>
<td>950</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 7, there were statistically significant differences in taskwork scores between groups. To identify which groups showed the difference, a Scheffe verification was conducted, and its results revealed that there was no difference between the PC IM group and the BBS group, but significant difference was found in the Mobile IM compared to the PC IM and BBS groups at the p < .001 level. That is, the taskwork score of the Mobile IM group was significantly lower than the other two groups.

Perception on communication media

Based on the results of the student perception survey, the following seven major themes were perceived to be the most or the least favorable aspects of each communication medium for their discussion.

Theme 1- Time Constraint: Mobile IM enabled students to contact their team members whenever they needed them. Most of the students using mobile devices said they liked that it did not have constraining time features of Mobile IM.

“I think our team discussed the topic all day long because we talked whenever we are available. Even though it’s short time…. So, I love it. One day, I had a lot of classes but I could read the members’ opinion between the classes and respond them. So, I could keep up with my team members’ discussion.”

However, the students in the PC IM group pointed out that it was difficult to find an available time for all team members to log into the PC IM, even though they did not need to be in the same place.

“It is hard to find the time which all the members can participate because of the differences time schedules. Some of the students wanted to night time and the others didn’t. A student was available on weekend only. It was so hard!!”

Theme 2 - Limitation of Location: The students in the Mobile IM group could participate in their group discussion while they were working or moving to another place. Many students in the Mobile IM group pointed out that this was one of the most favorable aspects of the technology.
“I am working at a café as a part time job. Sometimes when there were a few customers, I can respond to the team members’ opinion. It’s the most strong point of mobile IM because if I use BBS or PC IM, I cannot involve the discussion frequently.”

However, some of the students in the PC IM and BBS groups who used PC computers were limited by their location. Students could access chat rooms or discussion boards only where there was a computer available.

“It is hard to get the chance of using computer at the school because the number of the computer in the lab is not enough. So I can access the discussion board at home... sometimes when I came back home lately or I was so tired, I didn’t want to participate the discussion. It bothered me....”

Theme 3 - Availability for Searching Resources during Discussion: The PC IM group and BBS group reported that they could search the Internet to find any necessary resources related to their discussion topic while they were communicating. They could refer to any references and write their opinions for as long as they wanted without any sudden interruptions by other students. On the other hand, most of the students of Mobile IM felt it was inconvenient to locate necessary references such as textbooks or articles, especially when they participated in their discussion outside of the home or classroom.

“Sometimes I could not remember the detail of a theory which I learned. I really wanted to back up my opinion.... In that case, I want to search the Internet but it is little bit inconvenient through mobile chat. In a mobile chat, multitasking is exceedingly cumbrous.”

Theme 4 - Emotional Closeness: Most of the students in the Mobile IM group claimed that Mobile IM offered a more comfortable and friendly environment where they could talk about private topics as well as their discussion topic using various emotional and social expressions. However BBS and PC IM group students rarely addressed this point as an advantage.

“I usually start to say ‘Hello’ or ‘The weather is great’..... like my team members are besides me. Or sometimes I complain my headache or a lot of papers of the other classes to my team members. I feel free to talk to them about my private stories through mobile chat.”

Theme 5 - Chance for Careful Thought and Reflection: Most of the students in the BBS group commented that the BBS enabled them to post their opinions or responses after having enough time to think about the given discussion topic and to review other team members’ postings. Also, Mobile IM students had enough time to review other team members’ messages and provide thoughtful feedback as compared to offline discussion. On the other hand, some of the team members only focused on typing their opinion without reviewing or considering other members’ postings. Therefore, it was difficult for them to have a more convergent discussion in the PC and mobile IM environments. That point was addressed as a disadvantage of mobile and PC IM groups.

“Some members talk so long when we discuss at offline meeting. In that case, I am sure that I forget what he or she was talking about for the first time. However, in the mobile chat, I can review the full message, so I do not forget what I prepared for the comments”

Theme 6 - Participation of the members: The students in the BBS group reported that some team members did not frequently visit their discussion board, which resulted in delayed responses and disjointed group discussions.

“A group member didn’t visit the discussion board after his first posting. That was it... I was annoyed that we could not discuss anymore. However, there wasn’t any alternative because we had to discuss through BBS only.”

Theme 7 - Inconvenience of Using Communication Media: The most common problem voiced by Mobile IM students was that the relatively small keyboard and screen on their mobile phones constrained them when typing a lengthy opinion or response during their discussion.

“I hate typo but the keyboard of my mobile phone is so small. So, I cannot help mis-typing. Also, the screen is so small. When I read all the discussion, I have to drag the message for a long time. It so irritates me.”
Conclusion and suggestion

Our study contributes by extending the scope of research on mobile learning. Unlike previous research, our study focuses on the effects of mobile learning on collaborative learning processes and outcomes. Social and affective interactions as well as cognitive and metacognitive interactions were also considered as important factors in the collaborative learning processes. Moreover, teamwork that was often ignored as the outcome of collaboration was measured along with taskwork. Based on the results of the study, it is recommended that students use Mobile IM or PC IM in order to facilitate their social and affective interaction at the beginning of their team project when they need to invest in getting to know one another (Lee & Johnson, 2008). Once students have progressed beyond the initial stages of the project, BBS could be the best communication medium to promote students’ cognitive and metacognitive interaction. The results of this study suggest that BBS, PC IM and Mobile IM should be used for different purposes. The BBS and PC IM would be good communication media to improve students’ taskwork while the Mobile IM would be the best choice to facilitate their teamwork. Therefore, understanding the unique characteristics of each communication medium is pivotal to maximize the quality of instruction, and, ultimately, students’ performance.

Future studies are suggested in the following three directions. First, it would be interesting to examine the affective and social aspects of learning as the result of collaborative learning outcomes. In this study, we measured learners’ taskwork and teamwork by focusing primarily on their cognitive development and team effectiveness. However, it will be necessary to examine how much their motivation and attitudes are improved after using Mobile IM for their collaborative learning. Second, we measured learners’ interactions and outcomes that occurred in a one week discussion, but future study is needed to conduct the measurement at least three times to see the change in learner interaction patterns and how their teamwork and taskwork develop over time. According to Fiore, Salas, Cuevas, and Bowers (2003), a team as a cognitive community goes through three coordination phases consisting of pre-process, in-process, and post-process. Depending on each phase of the processes, learners’ interactions and their focus vary. Therefore, it would be a good research topic to examine the change in learner interaction patterns and the development of teamwork and taskwork along with the three coordination phases. Third, from a more practical standpoint, future study also needs to focus on the design of mobile based collaborative learning environments with consideration of the results of this study and provides specific guidelines for effectively and efficiently launching mobile-based collaborative learning in online and offline classrooms. Specifically, it would be interesting to design and develop online instructions using a combination of mobile IM and other online communication tools depending on types of team activities and expected interactions for students’ informal or seamless learning.

References


Mobile Inquiry Learning in Sweden: Development Insights on Interoperability, Extensibility and Sustainability of the LETS GO Software System

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ABSTRACT
This paper presents the overall lifecycle and evolution of a software system we have developed in relation to the Learning Ecology through Science with Global Outcomes (LETs GO) research project. One of the aims of the project is to support “open inquiry learning” using mobile science collaboratories that provide open software tools and resources, and participation frameworks for learner project collaboration, mobile data and media capture, publishing, analysis, and reflection. The primary focus of this paper is to report on our technical development, insights and knowledge gained during the past four years. Technical implementations and the prototypes developed in this project have been tested across several educational trials conducted in Sweden and abroad with more than 400 learners. Insights and knowledge gained from these activities verify that learners requirements were adequately addressed while satisfying their needs. The outcomes and results of our efforts provided us with a better understanding with regard to which software engineering processes and approaches can be used to address and support the complex requirements that emerge in novel mobile learning scenarios. Thus, the results discussed in this paper provide deeper insights into the importance of properly addressing issues related to interoperability and extensibility in order to develop software solutions to support mobile learning that are sustainable and endurable over time.

Keywords
Mobile learning, Inquiry-based learning, Software lifecycle, User-centered development, Interoperability, Extensibility, Sustainability

Introduction
Web technologies are enabling Internet applications and services to become easily integrated in interactive systems (Holmberg, Wuenzsche, & Tempero, 2006). Thus, the web is gradually becoming a “central computer” that helps to connect diverse computing and data resources and people (Liang, Croitoru, & Tao, 2005; Giusto, Iera, Morabito, & Atzori, 2010). The evolution of these web developments combined with sensor and interactive technologies provide new possibilities for the implementation and deployment of software applications to support a wide variety of human activities.

Mobile and web technologies and applications provide new possibilities for augmenting learning activities. These are Technology-Enhanced Learning (TEL) activities that can be spatially distributed and can incorporate different physical and environmental sensor data (Wu, Yang, Hwang, & Chu, 2008). There are different mobile, web and sensor-based technologies that provide new perspectives on how learning activities can be embedded in different settings and across contexts (Chang, Wang, & Lin, 2009). One innovative aspect of these new learning landscapes is the combination of learning activities to be conducted across different educational contexts such as schools, nature and science centres/museums, parks, and field trips (Kukulska-Hulme, Sharples, Milrad, Arnedillo-Sanchez, & Vavoula, 2009). In these technology rich and dynamic learning environments learners make use of a wide range of devices and applications and the notions of system interoperability and extensibility, become central in order to successfully fulfill the requirements posed by the different educational activities and the learners. Especially, since these aspects directly influence learners satisfaction and experiences with regard to the applications and systems they use and also directly affect how tools and applications are adopted, appropriated and sustained over time.

In our Learning Ecology with Technologies from Science for Global Outcomes (LETs GO) collaborative international project (2008-2012), we have been developing, implementing, studying and scaling up novel ways for fostering secondary school student learning in teams for ecological and environmental sciences (Spikol, Milrad, Maldonado, & Pea, 2009). During the last 4 years we have been working with the design, development and implementation of web and mobile services that integrate geo-sensing, multimedia communication and interactive visualization techniques in specific ecology learning scenarios. Our goal has been to create mobile science inquiry
collaboratories (Pea, Milrad, Maldonado, Vogel, Kurti, & Spikol, 2012) with teachers, learners and developers and domain scientist on topics related to water and soil quality, ecosystems and biodiversity.

One of the main objectives of the LETS GO project was to develop a robust software system including a wide range of applications and services to support educational activities that promote collaborative scientific inquiry as students formulate questions and hypotheses, and collect, analyze, discuss and compare data while studying problem topics in environmental sciences. All our software solutions have been conceived having in mind how to support all these processes. In this paper we present and discuss the overall lifecycle and evolution of the software system we have developed during the last four years. Our choice to focus on these specific aspects is guided by the challenge of how to address those problems related to the scalability and interoperability of mobile learning applications. Thus, the main question we are trying to answer in this paper can be formulated as following: How can software engineering processes support the functional requirements posed by current mobile learning scenarios and applications? The insights and knowledge gained during our research efforts are closely related to the issues of interoperability, flexibility and extensibility of the LETS GO software system and were identified during iterative user-centred development cycles. Developing sustainable mobile applications that can cope with the changing demands of dynamic learning environments requires new knowledge and approaches. The results presented and discussed in this paper provide some new perspectives in this direction.

The remaining of the paper follows with a presentation of the motivation behind our research efforts, as well as the initial requirements, to continue after with an overview of the LETS GO project and its related activities. The following section presents the details of our design, technical solution and the evolutionary stages that were carried out as a part of this development to continue with the Lessons Learned section where we reflect upon the activities we have conducted during these four years of development. At the end, we provide our main conclusions and discuss possible lines for future research.

**Motivation and initial requirements**

The initial requirements elicitation with stakeholders emerged from a workshop with teachers involved in the LETS GO project that took place in the fall 2008. Different activities in this workshop helped to identify the need to integrate geo-location and environmental sensing, visualization, and Web 2.0 mashup technologies, as part of a broader educational scenario. These requirements identified the need to support “open inquiry learning” for having access to diverse sensor data, live mapping tools, interactive data visualization and collaboration tools, and additional learning resources. Another requirements related to usability, include low cost, using open standards, multiple application support, and support for different types of collaboration modes and contexts (Spikol, Milrad, Maldonado, & Pea, 2009).

Trying to match these initial requirements brought up a number of challenges that concern software tools for supporting inquiry-learning activities. A survey of the literature and existing approaches to support inquiry science learning conducted at the beginning of the project indicated that there were no existing software solutions that could cope with all these requirements at the same time (Vogel, Spikol, Kurti, & Milrad, 2010). More recently, Sun & Looi (2013) report on a review of different web-based science learning environments for collaborative inquiry. The analysis of the results indicate that even those systems discussed in their paper do not cope with the kind of requirements we are addressing in our work. Already at the early stage of our project, those aspects related to the issues of interoperability and extensibility of the system to be developed were identified as one of the central challenges in terms of “building new technologies or further developing existing technologies to create novel possibilities for supporting human activities” (Tchounikine, 2011). Some of the processes that learners need to be actively involved during inquiry learning activities are to problematize, demand, discover and refine, and apply new knowledge and skills to solve complex problems (Edelson, Gordin, & Pea, 1999). Therefore, our primary focus in this project was to facilitate the integration of proper tools (both hardware and software) and services for supporting inquiry based learning activities.

According to Knapp and Barrie (2001), field trips are important to effectively learn about environmental science and they should be actively promoted. It is suggested that field trips can be helpful to generate relevancy to classroom learning when connected with the outdoor environment. For students, such an approach may raise the interest in and aspirations for science-related careers (Rudmann, 1994). The data collected in such field trips play an important role
for analysis, and hence should be saved and carried back to the classroom. Presenting and analyzing these data using visualization tools may help to increase learners’ understanding of complex subject matter.

Reflecting upon our current knowledge and experiences from the field of TEL, two important issues can be identified for supporting environmental inquiry science learning including outdoors and in classroom activities:
1. Providing technological support (in terms of portable instruments and sensors for data collection and software) for field trips activities that include collecting data, and
2. Providing technological support for classroom activities that include visualizing, exploring, analyzing, discussing and reflecting upon the data collected in the field.

Hence, the system support for these kinds of activities needed to include functionalities for mobile data collection and web-based tools and applications for interactive visualizations. These aspects were also in line with the theoretical aspects of scientific inquiry thinking that suggest that this kind of system support has the potential to increase learners’ engagement and curiosity (Pea, 2002). Thus, based on these different requirements we have developed a variety of software tools and solutions to address these different challenges. A detailed description of this work can be found at Vogel et al. (2010), Vogel et al. (2011) and Vogel (2012).

Figure 1 below provides an initial overview of the educational settings related to the LETS GO project and presents some of the initial requirements. Moreover, this figure maps the key processes of inquiry learning activities related to data collection and interpretation, exploration and reflection, drawing conclusions and communicating the results (Edelson, Gordin, & Pea, 1999; Linn, & Eylon, 2011).

As illustrated in this sketch, the initial requirements that guided our research efforts can be specified in terms of the following:

- Mobility of the users/learners
- Distributed environments,
- Service-oriented systems,
- The need for reflection on the collected data and activities, and
- Interactive collaborative technologies.

Some of these requirements are also in line with the current key technological trends identified in the field of TEL: mobile and cloud computing, visual data analysis, web technologies and geocoded data, smart objects and open content, as pointed out recently in the literature (Johnson, Levine, & Smith, 2009; Johnson, Levine, Smith, & Stone, 2010; Johnson, Smith, Willis, Levine, & Haywood, 2011). Indeed, the latest Horizon Report (Johnson, Smith, Willis, Levine, & Haywood, 2011) points out that many technologies used in the field of TEL are increasingly becoming

Figure 1. The LETS GO Educational Settings

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cloud-based and decentralized. From a pure technological perspective, Hoppe (2009) claims that one of the main challenges we are facing involves the need for integration of diverse technological resources in broader educational scenarios. Therefore, these trends once more reaffirm that the issues related to interoperability and extensibility become central for the integration of diverse technological resources for supporting educational activities. In the coming section we provide an overview of the LETS GO activity flow in order to better understand the interplay between the different learning activities and the technological support.

**LETS GO activities and testing**

During the four years of the project more than 400 students have been involved in different type of learning activities. These activities included classroom lessons, field trips and lab work and included data collection in the field, taking images and notes, as well as data visualization and discussions in the classroom (see figure 2).

Usually, the participants in the different activities were either students from K-12 schools in Växjö, Sweden or undergraduate students (the teacher training program at Linnaeus University). As part of the environmental science curriculum, they investigated topics related to soil quality (woodland ecology) and water quality in the surrounding lakes. None of the participants in all these activities had prior knowledge regarding how to use the technologies we developed. In our latest pilot activity that took place at the Potomac River in the USA (September 2012), teachers from both Sweden and USA were involved.

![Figure 2. Different learning activities and the technologies in use](image)

Figure 3 below gives an overview of the learning activity flow and how the different phases of the students’ inquiry process were supported. It should be noticed that these activities where designed according to the different stages of inquiry based-learning as suggested by Edelson, Gordin, & Pea (1999) & Linn & Eylon (2011). Furthermore, these different learning activities have been integrated with their regular curricula in Environmental Science courses at the different schools. A typical LETS GO learning activity usually included workshops for the students to get familiarized with specific subject matter and central concepts and ideas associated with the inquiry learning process. These activities usually comprised six to eight lessons over a period of five weeks starting with the introduction of inquiry process where basic concepts of the activity were introduced; students discussed the initial questions given to them about a specific topic (e.g., water quality). This activity was followed by the preparation for investigation and experiments to be conducted using different technologies (proves, data loggers, mobile applications for data collection in the classroom). Additionally, users conduct field experiments at a local environment and collect samples for lab analysis (see Figure 2a). The data collected using the mobile data collection tool were geo-tagged content and sensor data (usually pH, dissolved oxygen, temperature, conductivity, moisture, etc. depending on the type of the activity). The learning activity usually ended with a discussion about their findings from the field and lab work and an overall class discussion and reflection by using the web visualization tool (see Figure 2b), which tailored different geo-tagged sensor data and digital content collected using mobile data collection tool. In average, (depending of their course schedule) the entire activity was conducted over the period of four weeks across five lessons units. The logistics, as well as the time period of these activities are illustrated in figure 3 below. As it is presented, each one of these lessons units generated a set of functional requirements that the system should support, namely: sensor support, mobile data collection and interactive data visualization. Furthermore, since these activities (mainly for K-12 students) were part of the regular curricula, students were asked to submit short reports on the outcomes of their efforts and reflections after each unit, concluding with a final test at the end of the activity.
Throughout these activities, we videotaped different sessions for later analysis and some of the researchers from our group used a systematic observation sheet during field and lab sessions.

Figure 3. Overview of learning inquiry activity flow, the technological support and the learning outcomes

During the lifetime of the project, we actively tested all our developments with school students where we combined classroom and field trips activities. The user trials (prototype testing) allowed testing the software application throughout five development iterations on authentic settings and dynamically changing environments, while new requirements continuously emerged in these activities. These iterations include the release of a prototype and its active testing with the users/learners. The initial two prototypes have been of throwaway type with a single iteration stage each. The last prototype has been of evolutionary nature that evolved through three following iterations cycles. Details regarding these prototypes as well as development iterations are presented in the Table 1.

Table 1 below, provides a detailed overview of the LETS GO field activities conducted since May 2009 until our latest activity conducted in September 2012. This table provides an overview about learner generated content, and the records that were stored in our repositories. It provides a summarized view on how many samples/records learners collected during these activities, as well as number of pictures they stored in our database and server resources. Furthermore, it also provides a rough overview about the number of users that used our software system so far, including information about location of the trials, school they belonged, and type of the activity they were engaged.

<table>
<thead>
<tr>
<th>Prototypes</th>
<th>Development</th>
<th>Deployment and Testing</th>
<th>Organisations</th>
<th>Users</th>
<th>Location</th>
<th>Records in Database</th>
<th>Images</th>
<th>Activity</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Prototype</td>
<td>2009-May</td>
<td>Katedralskolan</td>
<td>11 near Katedralskolan, Visa, Sweden</td>
<td>24</td>
<td>outdoor/indoors</td>
<td>soil quality</td>
<td>16</td>
<td>48</td>
<td>outdoor/indoors</td>
</tr>
<tr>
<td>2nd Prototype</td>
<td>2010-March</td>
<td>Katedralskolan</td>
<td>12 near Katedralskolan and Visa, Sweden</td>
<td>25</td>
<td>indoor</td>
<td>water quality</td>
<td>17</td>
<td>9</td>
<td>indoor</td>
</tr>
<tr>
<td>3rd Prototype</td>
<td>2010-April</td>
<td>Kronberg Skola</td>
<td>60 Kronberg Skola, Visa</td>
<td>139</td>
<td>318</td>
<td>water quality</td>
<td>17</td>
<td>9</td>
<td>indoor</td>
</tr>
<tr>
<td>4th Prototype</td>
<td>2010-May</td>
<td>Telbing, Sweden</td>
<td>25 Telbing, Visa, Sweden</td>
<td>77</td>
<td>123</td>
<td>water quality</td>
<td>17</td>
<td>9</td>
<td>indoor</td>
</tr>
<tr>
<td>5th Prototype</td>
<td>2010-June</td>
<td>Telbing, Sweden</td>
<td>25 Telbing, Visa, Sweden</td>
<td>24</td>
<td>51</td>
<td>water quality</td>
<td>17</td>
<td>9</td>
<td>indoor</td>
</tr>
<tr>
<td>6th Prototype</td>
<td>2010-October</td>
<td>Tehran Students</td>
<td>20 Tehran Students, Visa, Sweden</td>
<td>20</td>
<td>52</td>
<td>outdoor</td>
<td>17</td>
<td>9</td>
<td>outdoor</td>
</tr>
<tr>
<td>7th Prototype</td>
<td>2011-March</td>
<td>Jongbing, Sweden</td>
<td>20 Jongbing, Visa, Sweden</td>
<td>31</td>
<td>55</td>
<td>soil quality</td>
<td>17</td>
<td>9</td>
<td>outdoor/indoors</td>
</tr>
<tr>
<td>8th Prototype</td>
<td>2011-May</td>
<td>Jongbing, Sweden</td>
<td>20 Jongbing, Visa, Sweden</td>
<td>31</td>
<td>55</td>
<td>soil quality</td>
<td>17</td>
<td>9</td>
<td>outdoor/indoors</td>
</tr>
<tr>
<td>9th Prototype</td>
<td>2011-October</td>
<td>Visa</td>
<td>20 Visa, near Katedralskolan</td>
<td>31</td>
<td>55</td>
<td>soil quality</td>
<td>17</td>
<td>9</td>
<td>outdoor/indoors</td>
</tr>
<tr>
<td>10th Prototype</td>
<td>2012-March</td>
<td>Kenedralskolan</td>
<td>75 Kenedralskolan, Visa, Sweden</td>
<td>130</td>
<td>261</td>
<td>outdoor</td>
<td>17</td>
<td>9</td>
<td>outdoor/indoors</td>
</tr>
<tr>
<td>11th Prototype</td>
<td>2012-May</td>
<td>Lars Sjöblom</td>
<td>25 Lars Sjöblom, Visa, Sweden</td>
<td>8</td>
<td>22</td>
<td>outdoor</td>
<td>17</td>
<td>9</td>
<td>outdoor</td>
</tr>
<tr>
<td>12th Prototype</td>
<td>2012-September</td>
<td>National Geographic Society</td>
<td>15 National Geographic Society, Visa, Sweden</td>
<td>18</td>
<td>44</td>
<td>outdoor</td>
<td>17</td>
<td>9</td>
<td>outdoor</td>
</tr>
</tbody>
</table>

Table 1. LETS GO Activities and related data
The evolution of our software system

The LETS GO software system has gone through an evolutionary prototyping approach through the past four years in order to become a stable and robust platform for mobile data collection, aggregation and data visualization. During the prototyping efforts, we extensively used two different development principles: evolutionary prototyping and throwaway prototyping (Sharp, Rogers, & Preece, 2007). The iterative user-centred development cycles of the software system are mapped to our developments, following these two principles of prototyping:

**Throwaway prototyping**–considers creating the basis of a final product, which is eventually thrown away; however, it remains valuable to construct further evolving ideas related to the final product (1st and 2nd prototype).

**Evolutionary prototyping**–considers the evolution of a prototype toward a robust final product (3rd prototype). We applied both these principles throughout our development process.

These two principles of prototyping led to the development of an application that was later used in testing. The design and implementation of the three prototypes was made possible by an evolutionary process through several iterations (as already introduced in Table 1 above). Two initial prototypes have been throwaway type while the last one has been an evolutionary prototype.

Figure 4 presents the timeline overview of the different iterative development cycles and stages of the three software prototypes. During these development efforts, we heavily utilized service-oriented approaches for supporting TEL activities in the context of inquiry learning. These prototypes of a software system evolved from being proprietary applications towards combining several Internet-based services to process and visualize the geo-temporal data collected using mobile data collection tools and web. In the first development stage, we mainly dealt with the integration challenges of different technological resources. In addition, the first software prototype has been mainly implemented using static forms for mobile and desktop enabled visualization features and did not provide real time data representation (and thus was throwaway prototype). During the second development stage, we continued with our integration challenges, however, due to the evolvement of requirements, the challenge of interoperability across diverse technological resources arose. Thus, the second prototype resulted in a combination between more dynamic forms for mobile (XForms), desktop and web technologies and included initial cloud services (Vogel, 2011). This combination enabled data collection in both, online and offline modes and real time data representation. Finally, during the third development stage we continued to address the interoperability issues, thus the last prototype of the visualization completely relied on an Internet based environment (real time and online). The final effort during this process was to conduct a user testing study (Vogel, Kurti, Milrad, & Kerren, 2011). The three development stages made our software system more robust as a product compared with the earlier implementation. A usability study was conducted for assessing the web-based visualization tool since it aggregated and presented the entire data collected using mobile devices. Assessment and testing of the web-based visualization tool was an important issue, in order to identify usability aspects that resulted in a number of concrete suggestions for the further enhancement and improvement of. These suggestions were later used and translated into requirements for further development.
The system architecture and implementation

During the efforts mentioned in the previous sections, the technical developments have evolved and changed rapidly, such as in terms of the design aspects, technology choices and implementation, as well as software & hardware components. Despite the rapid changes of such technologies these developments have not been reflected in the changes of the architecture of our software system (Vogel, Kurti, Milrad, & Mikkonen, 2012). The components identified in the initial architecture have been proven resilient to these dynamic changes and requirements. The results described in this paper are an effort to try to tackle some of the challenges described earlier and are an evolution of the efforts we conducted in one of our previous work (see Vogel, Spikol, Kurti & Milrad, 2010). During our earlier explorations and developments, we have proposed and implemented a system architecture that consists of five different blocks aiming to provide logical divisions between the different resources of our system. Figure 5 below illustrates the component view of the system architecture and its potential for expandability with other technologies and external systems.

In the architecture presented in Figure 5, resources are organized into different building blocks that integrate sensors, mobile data collection units, from the server side the data aggregation components used as data and content storage, and visual representation components that utilize diverse web APIs using external services block of this architecture (Vogel, 2012).

Figure 5. System architecture including main resources and components

The design and implementation of our mobile data collection tool followed with the integration of an open source Java based project into our software system (Anokwa, Hartung, Brunette, Borriello, & Lerer, 2009). This project/solution supported the use of a particular open standard called XForm. XForm is a standard based on a W3C recommendation that is used to build web forms for the easy exchange of data across platforms and devices using XML as the data format. In our case, the design of the forms for data collection used in our mobile applications was developed following the requirements identified from stakeholders, as introduced above. The solution we decided to adopt is based on the Open Data Kit (ODK) which supports various types of data and content inputs, including text, audio, pictures, video, visual codes and GPS and makes it possible to annotate the collected sensor data and content with location metadata (Anokwa, Hartung, Brunette, Borriello, & Lerer, 2009). The use of XForms facilitated data interoperability across a diverse range of devices and applications that compose our system. We have therefore developed several mobile forms that rely on the use of open standards, which provided us with flexibility, fast development and easy adaptation and integration of technological resources for different scenarios (user trials). Figure 6 shows the screen shot of LETS GO data collection tool.

In terms of software development, our major efforts were allocated for the implementation of the web-based visualization tool. The latest version of this tool enables the visualization of different types of geo-tagged content and sensor data collected using the mobile application described above. The web visualization tool utilizes APIs that provide multiple visual representations of the data set available in our repository. These representations allow users to actively interact with graphs, maps, images, and data tables. An initial version of this tool was implemented
completely in AJAX. Spite a user friendly interface and positive feedback from the users, we experienced some performance problems related to loading and processing huge amounts of data using AJAX (Vogel, 2011).

These latest drawbacks inspired the latest version of our visualization tool that has been entirely developed using Google Web Toolkit (GWT). Our latest version of web based visualization tool called GreenLab (see Figure 7) addressed a lot of the requirements generated during our testing efforts by using iterative cycles with users. This tool has become more stable than the previous AJAX version and it has a lot of features for mapping the data automatically, filtering the data based on different criteria, etc. The data visualization process in Green Lab is divided into two stages; first Green Lab selects the type of data collected during the activity with the mobile devices; and second, it presents and visualizes the collected data. In the first stage, Green Lab loads each data type and presents them as clickable buttons. Each type can contain several forms (XForms), which will be loaded after the user has selected a specific activity. In the second stage, Green Lab presents the data retrieved from each form. The filtering of data in Green Lab is located in a panel and the filtering mechanism triggers all active visualization to update, presenting only a certain part of the data set. Each checkbox as such listens for user clicks, triggering an event to update the views. The filtering panel view contains three kinds of options. The first filtering view is based on Organizations (namely participating schools) that follows with the Groups that belong to that organization. Selecting an organization will first filter the data on selected option and also present all groups for that organization, which also allows filtering specific groups. The Attributes filtering view is constituted from each attributes that can be filtered accordingly, by also selecting multiple attributes. Moreover, a single attribute can be filtered also by their values. The Dates filtering view can be used to choose From-To dates to set the time period the user is interested to investigate.

Green Lab contains three different visualization views for presenting the data, which are all resizable. The main visualization view starts up by presenting the data as a table, but has the possibility to switch to bar-, columns-, line-,
or an area-chart by navigating to the icons in the header. The second view contains a Map view, which locates and visualizes all the geo-tagged data collected by the mobile application. The last view contains only a Scatter Plot view, which allows filtering of two kinds of data attributes, by comparing them.

The design and implementation stages carried out during the past four years facilitated the identification of the main features in terms of sustainability of the LETS GO system. The three main salient features that we have identified during our design and implementation efforts can be enumerated as following: (1) Interoperability of the software and hardware components (2) Extensibility of the visual representation forms, and (3) Sustainability of the software solution. A more detailed view of these lines of action based on what we learned during the last year developing the LETS GO system are presented in the following sections.

Lessons learned

Proprietary software solutions are deployed extensively through multiple platforms such as the web, mobile devices and desktop applications. The use of diverse standards brings new challenges when it comes to flexibility, interoperability, customizability and extensibility of different components that are part of software systems. Continuous evolving web and mobile technologies combined with the changes of the environment result on dynamic and complex requirements that become extremely challenging. As indicated earlier, this paper aims to tackle some of these problems by providing deeper development insights into the issues of interoperability, extensibility and sustainability related to the LETS GO software system and its evolution during the last four years. These insights were gained during iterative user-centred development cycles of a software system designed and implemented for fostering collaborative science learning activities.

Interoperability of the software and hardware solutions

The notion of interoperability constitutes one of the most important principles in system integration (Zeng & Quin, 2008) and refers to "the compatibility of two or more systems such that they can exchange information and data and can use the exchanged information and data without any special manipulation" (Taylor & Joudrey, 2003). During the development efforts of the LETS GO software system, we have in practice been able to tackle two out of four interoperability categories as introduced by Sheth (1998), namely:

- Syntactic interoperability: differences in data formatting.
- System interoperability: heterogeneous systems and applications.

Despite considerable research efforts, achieving interoperability of various sensor readings and mobile devices and various web services has remained an open issue. In connection to syntactic interoperability our focus was related toward making use of open standards for data exchange such as XML, XForms and JSON. While from a system interoperability perspective, the focus was on making use of open software tools with cloud-based services for matching our requirements.

The features of the cloud environment and services made our system more flexible. Initially, traditional desktop-based integrated development environments were employed and the development then gradually moved towards a mashup-pattern that combined different service-oriented approaches. One identified issue was that the rapid speed and evolution of software and web technologies affected the development process and the application itself. From heavily using Internet based services, such as cloud environments and due to the problems encountered from such services, we started to deploy all our developments into our local repositories and environments. By migrating the LETS GO system to our local environment we mitigated the risks and uncertainties of the cloud development environments. Furthermore, this created new opportunities to closely address the interoperability issues of the software components comprising the LETS GO system. During the last year of development we specifically addressed interoperability issues in the “Mobile Data Collection” component and “Data Aggregation” component.

The interoperability issues in the “Mobile Data Collection” component dealt with both hardware and software issues. Since the current mobile data collection tool was tailored only to Android smartphones and having in mind the emergence of HTML5 and CSS3 as well as multiple mobile cross-platform frameworks (such as PhoneGap, Titanium etc.), we have started expanding the mobile collection tool toward iOS and Windows Mobile platforms.
The purpose of this effort will be to widen the base of the eligible devices to be used as mobile data collection tool (so we do not pose any limitations for the use of the mobile application in schools) as well as making them fully interoperable with the rest of the LETS GO system.

Interoperability issues in the “Data Aggregation” component have been addressed from the perspective of data export capabilities. The idea for such development was to make the LETS GO system open and interoperable with similar tools developed in other research projects. The Data Export component we have developed can be described as a middleware that prepares the surveys data stored on the ODK Aggregate server. The main application is a Java servlet that processes calls from clients and replies either a list of available “SurveyTypes,” links/URLs to all the stored forms and their submissions, or the actual data of the submissions. These calls can be processed in the form of a Web API, where the data is responded as JSON. This enables that all the data aggregated in the ODK aggregate becomes available for export using this servlet and in a JSON format. In the current version of the DataExportServlet all the data is read and exported as the clients upload it and store in the database.

Beside these efforts we have also been working on the development of the form rules as guidelines for design of the XForms for mobile data collection in a form of naming conventions. These naming conventions developed enable mapping of the collected data dynamically to the visualization tool by the form designed based on our guidelines. All these developments enabled our LETS GO system to be fully interoperable with different mobile devices as well as new visualization tools and services.

**Extensibility of the software and system architecture**

The massive use of mobile and web technologies for data collection purposes produces vast amounts of data. This is another challenging task that requires attention while trying to make sense of all the data generated by users. Therefore, as the amount of available data continues to grow, conceptualizing and developing new interactive tools for visualization becomes an important task to tackle these challenges, for, e.g., seeking new ways of presenting and sorting appropriate and relevant data, or managing and analyzing information (Ackerman & Guiz, 2011). Different visual representations can provide different insights to users by enabling them to observe data in context, to analyze these data and to draw different conclusions by using different analytical approaches (Eiselle, & Weiskopf, 2009; Sedig, Liang, & Morey, 2009). The extension of web-based visualization approaches, along with new forms of interactive collaborative technologies, is constantly growing (Sedig, Liang, & Morey, 2009). Lately, TEL researchers have been taking advantage of different interactive visualization techniques and tools (Linn, & Eylon, 2011). Research in this area indicates that visualizations have the potential to improve learning outcomes, especially related to inquiry science learning (Johnson, Levine, Smith, & Stone, 2010; Edelson, Gordin, & Pea, 1999; Linn, & Eylon, 2011; Pea, 2002). Moreover, interactive visualizations support and increase students’ engagement in scientific inquiry (Linn, & Eylon, 2011; Pea, 2002). In the scope of our work, “learning through collaborative visualization” refers to developments of “scientific knowledge that is mediated by scientific visualization tools in a collaborative learning context” (Pea, 2002). The latest version of the LETS GO system allows for integrating new interaction features provide by multitouch enabled devices and gesture based interaction in a way that we can expand the interaction modes in which learners work with the visualizations.

Recent developments of our LETS GO system include the implementations of two prototypes using gesture based interaction supported by the use of the Microsoft Kinect (Vogel, Pettersson, O., Kurti, & Huck, 2012) and touch enabled interactions facilitated by the use of the Samsung SUR-40 tabletop computing system (Müller, 2012). Both these prototypes are fully functional and make use of the data already stored at the LETS GO repository. The initial benefit seems to be the fact that these two new interactions paradigms promote collaboration among users while reflecting upon collected data. Figure 8 below illustrates the Natural User Interface (NUI) for the Green Lab application.

NUI *Green Lab* is a visually driven explorative interactive visualization tool. The tool focuses on a graspable presentation of the geo-tagged environmental data, collected during outdoor activities using mobile devices, in form of digital maps, charts, and images. The application provides a multi-user interface facilitating the synchronous collocated collaboration of at least two users. The interaction makes use of multi-touch interactions on the SUR-40 tabletop computing system and in-air gestures facilitated by the Microsoft Kinect depth sensor as direct input methods. Furthermore, the interface consists of freely movable digital items allowing the users to set up dedicated
workspaces and explore datasets on their own. Taking all this into account, the main goal was to provide users, such as students and teachers, a prototype supporting and extending collaborative science learning activities. Therefore, an initial usability study was performed upon these two extended developments (multi-touch and in-air gesture). The initial analysis revealed that the study participants achieved overall better results in the multi-touch scenario compared to the in-air gesture scenario. This led to the conclusion that the in-air scenario is not suitable for complex productive workflows, while the multi-touch interaction is. A distinct advantage in this case could be identified when it comes to the visualization of big amounts of data where multiple users could actively be engaged. All the participants approved the possibilities of the collaborative application and liked the visually driven data visualization and exploration as an offset to traditional workstations with single-user input. This overall finding highlights the need for an integration of new interaction technologies and scenarios in collaborative interactive data visualization, and especially in scenarios related to environmental science learning.

The latest activity we recently carried out with regard to “extensibility” was connected to National Geographic Society’s (NGS) GIS tool, which has been designed to support geographic investigations and encourage collaboration between young citizens and researchers. Our software system was successfully integrated with NGS’ GIS platform called FieldScope. FieldScope has been designed to support geographic explorations and to promote citizen science practices in real-world issues. One of the main drawbacks of NGS FieldScope was the lack of uploading data onsite where the data was actually collected. Thus, the main idea was to extend NGS FieldScope by using our mobile data collection tool. This illustrates the notion of extensibility of our software system in the sense of how sensor data and observations collected using our mobile application combined with the Export function from the Data Aggregation component were used to visualize these data sets in other tool such as NGS FieldScope. The activities we conducted validate the flexibility for data exchange and integration that our software system offers. Our software system has been conceived and based upon the notion of an open and extensible architecture (Vogel, 2012). Figure 9 below depicts the screenshot of NGS’ FieldScope that visualizes water quality data collected using the LETS GO system.
Sustainability of our solution

During the last year of development, our efforts were focused into making the current system a sustainable one, so it can be widely used even after the end of the project. Having in mind the problems we experience with cloud environments (as introduced previously), especially on changes on Google App Engine regarding authentication and limitation of the services, we decided to migrate the LETS GO system (i.e., aggregation server) into our own local environment. The entire environment is based on open source software and open standards. Furthermore, by having full control over this environment we foresee a long maintenance of this software solution and its application across different domains that require mobile data collection and visualization activities. The next step will be making our current solution even more accessible, open and usable for a long period of time.

The user testing study described in earlier sections provided us with additional requirements (Vogel, Kurti, Milrad & Kerren, 2011) that were implemented during the two additional evolutionary prototyping efforts (4th and 5th development iterations, introduced in Table 1). These two additional development efforts in total make five development iterations that made our software system extensible and sustainable while new requirements continuously emerged in these activities. These entire processes made it possible to verify that user requirements were adequately addressed while satisfying their needs. Figure 10 below provides details about our continued evolutionary prototyping efforts (as a continuation from Figure 4 introduced above) across a timeline related to requirements and prototype testing, mapped with the extensibility and sustainability aspects that were considered during these two last iterations. The fourth development stage addressed the extensibility challenges as described above. The fifth development stage made us think to make our system more sustainable towards providing an open platform comprised of a rich set of tools that offer flexible mobile and web based applications that can be deployed by users to support data collection, visualization and collaboration.

The LETS GO system has evolved over a four years period from a prototyping system to become a sustainable one with the possibilities to rapidly be adapted with new features and extensions by taking into consideration the rapid evolution of software and web technologies. In addition, we want to emphasize that the modular design and capabilities of such sustainable system have been conceived with the intention to reduce total platform replacements, where the replacement of a certain component or service as well as the extension of the system with new functionalities becomes increasingly feasible into our solution.

Conclusions and future work

The development lifecycle presented in this paper enabled us to gain valuable insights related to different aspects of mobile and web engineering while developing a system for supporting inquiry based learning activities. During the four years of development efforts, three software prototypes were implemented utilizing service-oriented approaches
that include mobile, web and interactive visualization modules. The main challenges we identified during these efforts were related to integration, interoperability, extensibility and sustainability of our software system while fostering collaborative science learning activities in the field of TEL. These efforts have been tested with more than 400 users in connection to several trials that took place during this period.

The LETS GO educational activities and tools enabled students to learn in a variety of way that encompass indoor and outdoor activities across locations and time with the supports of sensor technologies, mobile devices and web-based tools. The experiences and knowledge gained during these years enabled us to develop the LETS GO system to a sustainable and robust platform for mobile data collection, visualization and collaboration. The user trials allowed testing the software applications throughout five development iterations on authentic settings, while new requirements continuously emerged in these activities. Reflecting upon our latest development efforts and the results presented in this paper the main findings of our research are discussed in the lines below.

Collaborative technologies, which were used in the iterations of this project, facilitated the adoption of a learner/user-centred approach. The learner/user-centred approach has been suggested by Bonk and Cunningham (1998), where they emphasized “the need to anchor learning into real-world or authentic contexts that make learning meaningful and purposeful”. Sensor kits, mobile devices, web services and interactive technologies nowadays provide us with a vast amount of opportunities of embedding learning activities into real world settings. In these environments the real challenge is the need of matching the dynamic requirements that are generated during learning activities. Hence the main contributions that this paper addresses are the development insights while integrating the technological resources and support for successful implementation of the educational activities related to environmental science learning in authentic settings.

Based on the insights gained from our research efforts we consider that by utilizing an extensive prototyping approach, the discussion of ideas, designs, requirements and implementation possibilities with users/learners the development becomes more easily manageable and understandable. For testing the technical feasibility and understanding whether the technology and implementation behaved as expected, agile development approaches based on prototyping (by combining throwaway and evolutionary approaches) were utilized. They offered an easy and communicative way to test it on real time activities and in authentic settings. Furthermore, this approach helps to find a balance between the design and implementation stages by considering the rapid evolution of technologies.

The integration of diverse heterogeneous device environments where learning activities take place must be based on solutions that promote data exchange, integration and reuse. In our research, we have identified that using open standards technologies for data exchange, promotes systems interoperability and extensibility with new features. Clear cases of such approaches have been the extensibility with interactive technologies and services such as NUI elements and NGS Fieldscope. The initial benefit of this approach seems to be the fact that these new interactions paradigms promote collaboration among users while reflecting upon collected data during outdoors activities.

Moreover, the rapid technological changes affect the flow of learning processes and educational organizations. For enabling rapid changes to be smoothly reflected in everyday activities in this area, there must be well-defined processes to ensure the continual refinement of the applications developed. Facilitating the communication between research projects/researchers and developers on the one hand and research projects/researchers and educators on the other hand, are key factors for the success of these interventions and their sustainability. This approach would enable implemented technologies and applications be closely integrated into everyday educational practices, thus maximizing the benefits in terms of the long-term goals, costs, time, and to satisfy learners/educational institutions with their system. A systematic view on those aspects and their implication for developing sustainable software solutions to support mobile learning could lead to a number of potential benefits:

- Standard based systems
- Constant interaction with users/learners
- Incremental development
- Reduced time and costs
- Expandability
- Flexible change of technologies
- Higher usability
- Easy maintenance and sustainability
In summary, all these identified research insights and benefits were gained during iterative user-centred development cycles of a software system for fostering collaborative science learning activities. Moreover, they provided solid foundations in terms of the possibilities of tackling the requirements for supporting inquiry learning in a flexible manner. From a system perspective, these requirements are best fulfilled by using service-oriented approaches that facilitate interoperability through utilizing open source and open standards and by following the evolutionary approach of prototyping. These findings are directly related to software engineering processes aiming to address the requirements posed by mobile learning scenarios and applications. The issues of interoperability and extensibility of the software solution are directly connected with the possibilities of dynamic reconfiguration of learning spaces to respond to learners’ contextual needs. A sustainable design of technological support to meet these needs it requires to be closely developed and deployed in close iterations with different stakeholders (including also teachers and students). This approach may help teachers and learners to overcome some of the complexity of the learning activities and furthermore it may promote the seamless integration of physical and digital learning resources.

References


Informal Participation in Science in the UK: Identification, Location and Mobility with iSpot

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ABSTRACT
Informal participation in science is being recognized as an important way of developing science learning both for children and adults. Mobile learning has particular properties that have potential in informal science settings, particularly outside traditional educational settings. Mobile technologies provide new opportunities for learners to engage with science on the move. This paper reviews the impact of participation in informal science settings on some members of the public using the experiences of the iSpot project as a case study. iSpot aims to create and inspire a new generation of nature lovers by getting people to explore, study, enjoy, and protect their local environment. It facilitates an inquiry learning approach to identification of wildlife with support provided by a community developing round the resource. The iSpot project described here provides evidence of the ways in which informal participation in science can be enhanced by the use of technology. We draw on the findings of two case studies within the project - iSpot Mobile and iSpot Local. These demonstrate particular ways in which location-based activity and mobile learning can be developed and have an impact on the informal learning of science.

Keywords
Informal learning, Participation, Science learning, Mobile learning

Introduction
This paper discusses informal science learning in mobile contexts, and the theoretical framing and development processes used in the creation of iSpot (http://www.ispot.org.uk). It analyses two projects related to iSpot – iSpot Local, and iSpot Mobile– which have developed particular approaches to the support of informal participation in science.

Mobile learning
Informal participation in science is being recognized as an important way of developing science learning both for children and adults (see e.g., Bell et al., 2009). Informal learning (see Trinder et al., 2008) has become an important area of interest for education researchers in recent years. Livingstone (2001) has documented the informal learning opportunities used by adults and the issues which arise in studying such settings. Mobile learning has particular properties that have potential for productive activity in informal science settings, particularly outside traditional educational settings. Sharples et al. (2009) define mobile learning as “the processes (personal and public) of coming to know through exploration and conversation across multiple contexts, amongst people and interactive technologies” (p. 5). Sharples provides some examples of this process including MyArtspace where school pupils use mobile phones to support learning on fieldtrips to museums. In particular, mobile technologies provide new opportunities for learners to engage with science learning. Dierking et al. (2003) have a view of learning as a cumulative process involving connections and reinforcement among a variety of learning experiences and describe informal science education as “science learning which is strongly socioculturally mediated and occurs across a wide range of physical contexts” (p. 109).

Here we discuss the impact of participation in informal science settings where mobility is an asset. The National Science Foundation describe informal learning as follows:
“Informal learning happens throughout people's lives in a highly personalized manner based on their particular needs, interests, and past experiences. This type of multi-faceted learning is voluntary, self-directed, and often mediated within a social context…; it provides an experiential base and motivation for further activity and subsequent learning.” (NSF, 2006, Section I, Introduction.)
Increasingly it is recognised that mobile technology can play a part in Citizen Science activities (discussed further below). See e.g., Robson (2012) describing the use of mobile phones in CreekWatch. It is important to emphasise with Sharples et al. (2009) that in mobile learning what is mobile is the learner. This is important for the topic of this paper: mobile learning of science in informal settings. In the iSpot case studies which follow, the learner is always mobile, sometimes accessing a website from a field location, sometimes using a mobile device but always engaged in location-based learning. Mobile learning in science settings has been studied both in formal and informal settings. There are a range of relevant studies in formal learning (e.g., Littleton, Scanlon, & Sharples, 2012; Chen, Kao, Yu, & Sheu, 2004) but fewer in informal settings. Early examples of studies which demonstrate the potential of mobile learning in informal science settings include that of Clough (2009). She describes developing mobile support for nature trails, and researching the use of mobile technology with GPS in the geocaching community. It is a challenge for learning scientists to develop and study learning in such completely informal settings.

Approach to development, theoretical framing of the design and methodological challenges

In this section we set out the development of the design of the iSpot project. A core group (Jonathan Silvertown, Martin Harvey, Richard Greenwood and Doug Clow) led the creation of iSpot, the iSpot website, and generated its initial design by informal discussion, based on the expertise they brought to the project, which included field biology, citizen science, online learning, and software development. Some iSpot team members were driven by theories of participatory design. An initial motivation was the exploration of applications of geographically referenced teaching and learning. Next we compare the features and intentions of the work with theoretical perspectives from research on learning.

iSpot supports a community of practice (Lave & Wenger,1991) where members learn from legitimate peripheral participation (Wenger, 1998) and develop their expertise through a process close to apprenticeship. A central theoretical design principle for work on communities of practice is the support of different modes of participation. Preece and Shneiderman (2009) set out a 'Reader to Leader' framework, categorising successive levels of social participation in online communities as reading, contributing, collaborating and leading. Other work suggests that a developmental model is not a good fit with observed activity in online learning sites: rather, different users participate in different ways at different times (as described in the 'Fairy Rings' model see Clow and Makriyannis, 2011).

One way to consider a contribution on the iSpot website is as a shared social object (see e.g., Knorr-Cetina, 2001) which can structure this participation, and scaffold participation in the community of practice. iSpot also reflects the constructivist notion of authentic learning activities (Jonassen, 1999) together with what Scardamalia and Bereiter (2006) describe as knowledge building: The learning activity is not only akin to scientific activity, it initiates learners into the knowledge-creating culture and enables them to actively contribute to scientific knowledge.

The development of a system such as iSpot needs to combine, in a cyclic approach, research, pedagogical design, and technology development. Accounts of socio-cognitive software design (Sharples, Taylor & Vavoula, 2007; McAndrew, Taylor and Clow, 2010) are influential in developing such processes, as are principles of Agile software development (http://agilemanifesto.org). Substantial engagement and envisioning activities with stakeholders were conducted, followed by deployment of the system to gather feedback from users.

There are a number of definitions of design-based research: our approach was in line with Barab and Squires’s description: “Design-based research [...] was introduced with the expectation that researchers would systemically adjust various aspects of the designed context so that each adjustment served as a type of experimentation that allowed the researchers to test and generate theory in naturalistic contexts” (Barab & Squire, 2004, p. 3). In some aspects of our project, particularly the development of the mobile app this included iterative cycles of designing (both pedagogy and technology), running an inquiry, and then evaluation and analysis that fed into the next cycle. Thus some of the key findings of the research become embedded within the system: not just in the design of the software, but in how it is used by the growing and developing community of practice.

So the approach taken in the design of iSpot was the co-design of technology and pedagogy i.e. to design the educational activities and technology together, drawing on a participatory design approach (see e.g., Penuel, Roschelle & Schetman, 2007).
There are methodological and practical challenges associated with developing an understanding of how learning takes place in the communities which use iSpot. The learning episodes which involve a user can be relatively short and informal. An important perspective on learning that comes from the public understanding of science movement is to think more broadly about the impact of engagement. Relatively simple models of learning, such as the deficit model used at first in work on the public understanding of science, were replaced by an investigation of the potential outcomes, including increased awareness and impact on attitudes, as well as engagement and participation. Groups enabled by technology will form round particular interests and issues suggesting a need to assess how expertise can develop in these groups. There is a complexity to examining such learning settings as iSpot. We need to look more broadly at them, in terms of new data and analysis methods (Scanlon, 2012, July).

**Citizen science**

In considering the learning which takes place through participatory science enabled by the use of mobile technology in field settings, it is necessary to look for some different ways of examining those learning settings and the use of mobile technology. Dron and Anderson (2007) describe how online communities enable different types of participation in the form of groups, networks and collectives.

iSpot may be described in Dron and Anderson’s terms as a network. It also can be seen as an example of citizen science. Wiggins and Crowston (2011) provide a typology of citizen science projects where members of the public work in combination with researchers. Hand (2010) and Newman et al. (2010) caution that additional verification may be necessary on projects which involve citizen scientists. Rotman et al. (2012) surveyed volunteers on ecological science projects to find out their motivations for participation, and many cited their desire to increase their scientific knowledge.

**iSpot**

This section describes iSpot, the project at the heart of this paper. This paper uses the iSpot project to examine the ways in which informal participation in science can be enhanced by the use of technology, and in particular ways in which location based activity and mobile learning are developed in the project. iSpot allows an inquiry learning approach to the identification of wildlife with support provided as part of a community of practice. It is important to note however that in what follows we are drawing examples from approaches taken in the particular case studies, rather than describing the whole cycle of development in the iSpot project or all the particular design decisions taken to develop its website.

iSpot (McAndrew et al., 2010; Woods & Scanlon, 2012) aims to create and inspire a new generation of nature lovers by getting people to explore, study, enjoy, and protect their local environment. The iSpot web site (home page shown in Figure 1), launched in June 2009, allows users to post observations of animals and plants on the site, and the iSpot community helps to identify them reliably. As a web-based system was used, this allows users to access and learn 24/7 and at anyplace with Internet access. These observations constitute the ‘shared social object’. Support is provided for identification partly by online resources but more fundamentally by the community of practice active on the site. The site connects together informal novice learners with experts in a wide range of natural history fields, including over 100 who are representatives of natural history organisations. Learning the name of an organism you have observed is the first step in learning about it. Furthermore, the process of recording observations of species - including the name of the species, the location and the time of the observation - is the fundamental unit of activity in biodiversity monitoring and research. Indeed, selected observations from iSpot users are now used as part of formal biodiversity monitoring. Thus iSpot enables learners to engage in Scardamalia and Bereiter (2006)'s knowledge building: they contribute to new knowledge, as a community activity.

A key feature of iSpot is its sophisticated but easy-to-use reputation system, which provides an indication of each user's expertise on the site (see Clow and Makriyannis, 2011). Unusually among online reputation systems, as well as providing an indication of “social” reputation on the site, the iSpot reputation system includes elements designed to provide sound indicators of the expertise – or learning – displayed through activity on the site. The reputation system structures and makes manifest expertise, facilitating learners' development within the community of practice.
iSpot findings on participation and learning

The impact of iSpot can be seen through its wide reach. Currently it has over 31,000 registered users who have added more than 200,000 observations with over 340,000 images, identifying more than 6,900 different species. The project has identified two species previously unrecorded in the UK: a bee-fly (Systoechus ctenopterus) and euonymus leaf notcher moth (Pryeria sinica). Further empirical analysis of learning activity on iSpot is underway, but some initial findings are presented here.

Qualitative analysis shows clear examples of users who start as complete novices, but come to fairly sophisticated understanding of identification. There is also quantitative evidence of users learning. For instance, analysis of a sample of 407 users as they progressed through submitting and identifying their first fifty observations within iSpot is strongly suggestive of learning. As shown in Figure 2, users showed improvement in their ability to identify other people’s observations over the period that they submitted observations: As users progress from their first to their 50th observation posted on iSpot, they have a bigger percentage of correct identifications that is they are more likely to identify what they have seen for themselves.

![Figure 1. iSpot home page](image)

![Figure 2. How people improve in identifications from repeated use of iSpot](image)
The crowdsourced identification model within iSpot, rewarding improvement in ability to identify observations, provides some evidence that people are learning and improving their understanding of nature through iSpot. However, a person may gain reputation through identifying very common species and without expanding their knowledge of other species.

In order to get a better understanding of how and whether people learn from using iSpot we require empirical evidence of improvement in people’s ability to identify a greater variety of observations as their reputation improves. We designed the iSpot intelligent quiz to test this knowledge. The quiz was launched in July 2013, since then around 350 people per week have taken one or more quizzes, so an average of around 50 people per day. The quiz is tailored to the level and subject area that people request when they start a new quiz on iSpot. The reputation level that iSpot provides is a good indicator of the level that people should take but there is no restriction on the level so, for example, a level five expert could take a level 1 quiz and vice versa. The data from the weekly logs shows however the people are averaging about 7 out of ten for quizzes across the skills levels which suggests that people are naturally finding a level which challenges them.

The quiz has a number of different types of question that test a range of knowledge within a specific domain, some questions are multiple choice and others are about entering the correct name or type of observation. The data collected so far indicates that people who use iSpot are gaining knowledge about nature.

Face-to-face outreach work has reached over 55,000 beneficiaries, over 10,000 from hard-to-reach groups, whilst over 800 participants have used iSpot at local “bioblitz” events, including schools, local government and voluntary sector organisations.

This account of iSpot provides the framing for the description of two specific projects linked to iSpot that particularly explore mobile and ubiquitous learning: iSpot Local and iSpot mobile.

**iSpot mobile**

The first case study linked to iSpot is iSpot Mobile. The iSpot website was already available to be viewed on mobile phones. However, since people are outdoors making observations, there was both a need and an opportunity to use mobile phones with digital cameras to make observations and interact with the iSpot community.
The iSpot mobile design approach

A lightweight contextual design approach to establishing the requirements for the mobile app was taken based on the user-centred design process developed by Beyer et al. (1998), exploring the types of users, the scientific context of nature study, the environment which they would be exploring and the learning outcomes to be achieved. We defined the main purpose of developing the mobile app as allowing users to create and upload observations (a combination of photo, identification, and location) to iSpot using their mobile device and to become part of the iSpot community using tools for sharing information. The secondary purpose was to enable iSpot website functionality on a mobile device in a native format and using the enhanced capabilities of a multi-touch mobile phone. For example the ability to pinch to zoom on images to see greater detail and the ability to use the devices to interact with the iSpot community whilst on the move and to enhance their experience through utilising the geo-location services available within mobile devices.

A core group consisting of Jonathan Silvertown, Martin Harvey, Will Woods and Richard Greenwood produced the initial design. A light-touch user-centred design approach was used for app development, beginning with a storyboarding process using experiences from users of the current iSpot website. Specifically, data was collected from a small selected group of experienced iSpot website ‘volunteer’ users whose practice was monitored through interviews and forum discussion, taken alongside usage data from the website, and feedback from the core group to establish common patterns of use. These were converted into stories to build a coherent functional specification. For example, one user said “I am running an inquiry based learning project and I want to [use the iSpot mobile app to] develop scenarios around ecosystems that I’m observing, for example birds in my garden, population of bugs in my flower bed, fauna in my pond ...”

The user-centred design approach that the team adopted involved gathering feedback about how people engaged with early prototypes of the environment to inform later iterations. Twenty people volunteered. A small number of volunteers from the existing iSpot community were also invited to participate, including iSpot “mentors” (associates who work with iSpot to assist others in identifying observations). A series of usability and accessibility testing cycles were conducted during the course of the app development. The feedback was gathered and interpreted by the project team to help improve the functionality and design of later iterations.

First iteration

The first iteration of the app started in October 2011 and took a total of ten weeks including development, bug fixing and testing. An initial issue was that Android devices have all manner of shapes and sizes of screen and this made the display of the images a challenge. Figure 4 shows a screenshot of the observation list.

Testing took place over a two-week period which included an evaluation conducted by a usability expert. The results indicated that the app was missing some critical functionality and had a number of bugs.

![Figure 4. Screenshot of original iSpot app design](image-url)
The application was also provided to a group of ten experienced mobile users. For example, one experienced iSpot user suggested a process of checking and validating an observation using the mobile app, producing the following scenario: “What iSpot offers is an authoritative resource for helping people learn identification. The new app could be like having an expert out in the field with you which is, I'm sure you'll agree, the best way to learn identification; in the field not through photographs.” To test these scenarios, users were asked to go out and take observations in naturalistic settings and then gain identifications from the iSpot community and then to provide feedback on this experience.

From the feedback it was clear that people were generally enthusiastic about the functionality of the app but they were less positive about the interface design. For example, here is a quote from notes taken during an interview with one of the testers:

“She thought she had to put something in the scientific name or the common name and did not realise that she could leave these blank (she knew it was a ladybird but there was not the option to say just ladybird so she selected one of the named ladybirds, a 10 spot one, even though she knew it was wrong just to get to the next screen and submit the observation).”

The iSpot service is distinctive from competitors as it references species dictionaries and because observations are identified by the iSpot community, often within a very short time of being observed and uploaded: half of all un-named observations are identified within an hour of appearing on the site. The app therefore provides these unique services to mobile users, allowing them to have observations identified and potentially to identify and agree with the identification of other people’s observations.

The evaluation process established that the service created for iSpot Mobile largely mimicked the iSpot website navigation and the design felt quite sterile. The team concluded that the app should therefore be completely redesigned around a navigation and layout more suitable for a mobile app, increasing the interactivity and social elements.

**Second iteration**

In January 2012, a second iteration of application specification, design and development took place. A mobile interface designer worked alongside the developer to implement a set of improvements to the interface.

This design iteration involved providing a big button menu screen as the ‘home’ screen to get into the main app functionality (Figure 5). The designer created a stylised logo and incorporated design features of the iSpot website to improve the app and make it feel more nature related by using grass and wildlife within the layout.

*Figure 5. Second iteration of iSpot app*
The redesigned tool the users directly to the observations. We made the observation thumbnail images larger to increase usability and aesthetic appeal (see Figure 6). To avoid removing valuable screen ‘real estate’ on what is a small screen we explored using a dynamic menu which users could click on or swipe to view and which provided all the functions within the application, allowing extensibility using horizontal swipe to access menu choices.

Further testing was conducted with another group of ten mobile proficient users. This interface received positive feedback from users, including the design, with comments such as:
- “Pull down icon menu intuitive once you try it for the first time”
- “Tried taking photo of pot plant and identifying it. Intuitive interface. Easy to add details. Recognised my location. Though somewhat cramped with keyboard. Pleased to see my first observation appear on iSpot.”
- “Overall I have found the app to be extremely stable, easy to navigate and fairly intuitive.”

However, there were still concerns that the navigation was not providing rich interaction and direct engagement, and that this interface design was not scalable, i.e., as functions were added how would they be incorporated into the fixed four button menu?

As a consequence of the positive feedback from both user testing and technical testing the team felt in a position to move towards releasing the beta version of the app to the public. The Android iSpot application “stable beta” was released to the public via the Google Android app store (Google Play) on 8th June 2012.

**Third iteration**

The third iteration of development began in August 2012. This iteration incorporated improvements to the application through the feedback gained from the testing processes, through user feedback from the beta release, and through use of enhanced reference material from Google on designing for the Android Platform (http://developer.android.com/design/index.html). The beta app on the Google Play store received positive feedback from the public.

The third iteration included enhancements to the geo-location services to provide “around here” information about observations within a specific locale, i.e., within a 1 kilometre radius of the current location using the GPS capability of the device. Users can also scroll to move the map location and receive information about observations within a 1 kilometre radius of any location. There are enhancements to the social and community aspects of the application, in particular allowing users to identify other people’s observations as well as comment on them. Finally, there are improvements to the discovery and filtering services, to filter on species type, to allow users to quickly find out information related to a particular observation, and to create their own individual journeys of self-discovery.
The full release, as a consequence of the testing and evaluation, provides a richer and more interactive experience with an improved user interface, including a contextual “active menu” and larger images, as shown in the sample screenshots below (Figure 7).

![Sample screens from current iSpot app development showing (1) “active menu” and text overlays on images (2) The slide out navigation panel (3) The post comment and post ID capability](image)

**Figure 7.** Sample screens from current iSpot app development showing (1) “active menu” and text overlays on images (2) The slide out navigation panel (3) The post comment and post ID capability

### iSpot mobile testing and evaluation

A further round of comprehensive testing was conducted prior to release using the state-of-the-art mobile eye tracking and mobile data capture facilities available within the Open University Jennie Lee Research Labs (http://jennielee.open.ac.uk). The app was judged to be more robust, fully featured and a better user experience. For example comments included:

“[The] ‘Around here’ map showing locations of observations in my immediate vicinity seems clear …and easy to use”

After the testing and feedback, the version 1.0 product was released to the Google app store (Google Play) in December 2012. It is achieving over 1000 installations per month and currently has a user rating of 3.8 out of 5 (27 September 2013).

As learners become more mobile, the mobile apps may become the default way of engaging with iSpot and establishing participatory science learning journeys. The app may prove particularly suitable for individuals or groups engaging in local community bioblitzes. The iSpot team expect to use the app to support local group learning activities of this type in the future.

### iSpot Local

The iSpot Local project extended the iSpot approach to investigate the potential of using hyper-local events to frame the learning activity, moving it from a largely virtualised activity (on the iSpot website) to a grounded, community, mobile setting – including beyond the reach of electronic networks. This built on and extended the existing community of practice and knowledge building approach.

#### Bioblitzes

The key mediating event in iSpot Local was the bioblitz, a survey of the wildlife at a particular site at a particular point in time - say an afternoon, or a day. The general public, supported by a team of experts, try to identify and
record as many different organisms as they can within the time. This can generate real scientific data (knowledge building) as well as engaging the public in the scientific process - and the site itself - through active participation and learning within a community of practice. However, in traditional bioblitzes, it can be difficult to manage the data generated by the public, and identifying the species observed is problematic.

iSpot Local addressed these challenges by coupling the wider perspective and observational recording abilities of iSpot with hyper-local engagement with community stakeholders and effective practical management of the bioblitz events. The basic activity of iSpot Local is set out in Figure 8, a cartoon developed to explain the bioblitz to participants.

Six bioblitzes were organised across the South West of England, at a range of sites from schools to more public sites. The IT facilities available on site ranged from a high-speed wifi network and room full of dedicated computers (at a school) to a nature reserve with no power, no network, and negligible mobile phone voice signal. The team used a hybrid, flexible approach to technology to maximise the benefits given the nature of the site, typically using a set of laptops in a marquee to log photographs and observations, which were uploaded to iSpot later if connectivity was limited on site.

An important feature of iSpot Local was the way in which mobile access - mediated, supported and contextualised - enabled the hyper-local (the individual bioblitz) to connect to the worldwide (the international community network of experts and enthusiastic amateurs on iSpot).

![Cartoon produced to help explain the iSpot Local approach](image)

**Figure 8.** Cartoon produced to help explain the iSpot Local approach

### Development approach

Engagement with a wide range of stakeholders was critical to the success of the project. The funded project partners were the UK Open University, Ambios Ltd (a small not-for-profit company promoting environmental understanding) and Learning South West (a membership organisation coordinating learning and skills and youth work, with members including local authorities, colleges, private training providers and voluntary sector organisations). In line with the design approach, the project partners engaged extensively with many other stakeholder organisations including adult educators, family learning specialists, local government, volunteers, technical specialists and natural history experts.

The project developed and validated a three-phase model for ensuring effective participation including pre-bioblitz work, the bioblitz itself, and post-bioblitz activities. Thus the participation in the on-site activities was scaffolded and embedded through framing and linking activities, enabling the learner's participation in the community of practice.
In addition, as part of the iterative approach to development, some technical development was carried out to create a module to enable observations from a bioblitz to be embedded within a community website, part of which is shown in Figure 9 below.

![Figure 9. iSpot Local map showing observations at one of the bioblitz sites](image)

**iSpot local evaluation**

Evaluation started at the beginning of the project, with the production of an initial Evaluation, Dissemination and Mainstreaming Action Plan. As described above, the design-based research approach meant that much of the outcomes are embedded within the practice developed as the project continued.

The bioblitz sites were generally open for participants to come and go as they pleased, and the participants were very diverse, from primary school-age children through to retired-age adults in their 80s, and with previous experience of nature ranging from negligible to expert naturalists.

To engage with this diversity, a range of evaluation methods were employed to supplement analysis of the online activity, including observation, registration cards and evaluation cards during the bioblitz, and follow-up discussions with selected participants and stakeholders (e.g., school teachers).

Participation levels recorded through Registration Cards were high at the events, with significant data uploaded to iSpot. There was also a high level of activity by the wider iSpot community, with tentative identifications arising from an iSpot Local bioblitz rapidly translated into confirmed identifications on the website, and high numbers of others indicating agreement and posting further comments.

In total, 820 people participated directly in the six iSpot Local bioblitzes, making more than 1,800 observations in the course of the bioblitzes. On iSpot, these observations received over 2,000 identifications (some observations had more than one identification), from the bioblitz participants and the wider iSpot community. These identifications in turn received over 3,000 agreements. Most participants (74%) were children under 18 and the rest were adults. The gender ratio was roughly equal (53% female, 47% male). As a result of this engagement and participation, the iSpot reputation system was able to confirm over 1,250 observations as having a “Likely ID”–confirmed by sufficient expertise. This is clear evidence of the participants taking part in genuine “knowledge building”: despite the diversity of their initial expertise, they were able to jointly contribute to new knowledge.

The feedback from the participants shows further evidence of the participants' engagement and learning–for example, the feedback from the evaluation cards included a parent reporting that the best bit was “Watching my children get so involved, questioning and learning about the world around us that we don’t always stop to appreciate.” Another participant reported that they gained “A better appreciation of just how much wildlife lives alongside us in the school field. Brilliant experts, really approachable.”
Engagement with iSpot Local motivated many participants to engage further with learning about nature—for instance “Examining and cataloguing and drawing the wild flowers in the lane to Granny's house’ and ‘Have looked at iSpot site and held our own mini bioblitz in the garden.” The diversity of the participants was reflected in the diversity of outcomes from the activities: at one site, the volunteers engaged in conservation work planned to run repeat events annually to track the effects of their work; at another (a school), follow-up learning events targeted to the children’s interests and the curriculum were developed.

The use of bioblitz events coupled with the iSpot website, in the context of a wider learning community, shows the potential for the iSpot website to support a vision of mobile, ubiquitous and lifelong learning at many levels, harnessing the power and range of a global, broad network of expertise with local concerns and knowledge.

The individual learner, located in a particular environment, was connected to multiple potential sources of learning, ranging from informal personal contact with experts through to technology-mediated access to explicit learning resources and relevant formal education opportunities. This rich environment structured their apprenticeship within a community of practice, and enabled them to engage in knowledge building.

Conclusions and lessons learned

The paper has drawn on an evaluation of the iSpot Local and iSpot Mobile projects to consider evidence on the impact of participation, and on which features can be identified as important in the design of such community projects. In particular, explicit attention was paid to how learners can be supported to be members of a community of practice, with participation structured around a shared social object, engaging in knowledge building as active contributors to knowledge, and the iterative, integrated approach to development have all proven valuable.

The overall experience of the iSpot project with its analysis of the improvement in identification as users become more experienced provides some evidence of knowledge development. However it is also possible that the users are becoming more proficient with the system so there is room for further investigation of how learning taking place with the system.

We know from the analytics of people’s progress through iSpot that they appear to be improving their identification knowledge as they become more experienced users of iSpot. The new quiz service within iSpot, also available on mobile, will provide further evidence to assess whether learning is taking place.

iSpot Local and iSpot Mobile are two elements within a comprehensive roadmap for iSpot development, with a full range of objectives to be achieved within the project through to the end of 2014. These include the internationalisation of the service, extensions to support integration with other systems and services (Facebook, mobile, species dictionaries), improvements to the service robustness, personalisation and the ability to support local and regional content to create an adaptive user-centred service and services to further test the learning that is taking place through analytical tools and intelligent quiz to track how users are increasing in their ability to identify and understand nature.

The iSpot Local project and the iSpot Mobile app are examples of mobile learning: the learners access iSpot in a range of contexts, settings and locations as appropriate to their individual situation. To a degree they are also an instantiation of the vision of context-aware ubiquitous learning (Hwang et al, 2008): the location of an observation is a crucial piece of information on iSpot, and it is possible to use location-aware sensors to capture this data automatically from the learner’s context.

Each case study illustrated a different facet of informal participation in science and contribution to knowledge in this area. The iSpot Mobile case study demonstrated the impact of a design based research approach to the development of such systems. The formative feedback also provided us with information on the processes by which the mobile app would facilitate learning. The iSpot Local case study showed how online communities of practice can be extended and connected to physical locations, providing more contextual opportunities for knowledge building, and co-creating new scientific data.
This experience and analysis demonstrates some of the potential for mobile and ubiquitous technologies to support learning in informal contexts but certain issues remain. These new developments include an iSpot site created for Southern Africa, managed by the South African National Biodiversity Institute so is showing evidence of how the initiative can be translated into new settings. Also, iSpot has linked up with Treezilla an ambitious Citizen Science project to map all of Britain’s trees and record vital data about tree disease and the environmental benefits that trees provide, developing a mobile app for use as part of the Open Science Laboratory initiative. The sustainability plan involves moving the infrastructure to managed cloud-hosting over the next twelve month period and for moving support for the application and services to the central IT department over the next two years, to be completed by July 2015. This underwriting of such a research system demonstrates the understanding of the importance of iSpot to the Open University and to the growing community that it supports. The iSpot team led by Jonathan Silvertown works in partnership with nature organisations (currently more than 100), the iSpot community, and other stakeholders, to enhance iSpot and to help further assure its longer-term future.

Acknowledgements

The authors are grateful to all those involved in iSpot, including Jonathan Silvertown, the originator and overall project leader, the rest of the iSpot team, the many groups and organisations supporting iSpot, and all participants in iSpot. The analysis of learning in iSpot and Figure 2 summarizing data were provided by Jonathan Silvertown and Martin Harvey. iSpot was funded by the UK National Lottery through the Big Lottery Fund for England between 2007 and 2012, as part of the Open Air Laboratories project (www.opalexplornature.com) and the British Ecological Society and the Wolfson and Garson Weston foundations. The iSpot Local project was funded by JISC through the eContent Programme.

References


Implementing Mobile Learning Curricula in Schools: A Programme of Research from Innovation to Scaling

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ABSTRACT

Many countries, regions and education districts in the world have experimented with models of one-device-per-student as an enabler of new or effective pedagogies supported by mobile technologies. Researchers have also designed innovations or interventions for possible adoption by schools or for informal learning. Of critical interest to the community is the question of how the more successful of these top-down or bottom-up models or innovations can proliferate to more usage, adoption and adaptation across levels of the education system. This paper describes a research programme that demonstrates how to make successful research innovations count in practice and that delineates what types of educational R&D involving scaling need to take place to make the critical link to impacting practice. We do this in the context of one such curricular innovation in a Singapore school that moves through the various phases to where the innovation is becoming an integral part of routine classroom practices.

Keywords
Mobilized curriculum, Translation and scaling up, Seamless learning model, Design-based research, Science education

Introduction

The literature on educational technology research is packed with examples of pilot studies and proofs-of-concepts. It is rarer, in fact, in the literature, to see a project move through the various phases to where the innovation actually has become an integral part of routine classroom practices. In our collaboration work with a primary school in Singapore, we have developed a viable innovation model (the Seamless Learning Model or SLM in short) by working with a class of primary school students over a period of two school years. The innovation involves the transformation of the existing science curriculum into an inquiry-based one which leverages the affordances of mobile technologies. Because SLM demonstrated increased student achievement, the school has decided to scale-up the roll-out of the transformed curriculum to more classes and more subjects in the coming years, thus providing the opportunity to study an innovation as it scales up.

In this article, we trace the journey of this research programme that started with the co-design of a 1:1 (one-mobile-device-per-student) mobilized curricular innovation for a primary school in Singapore, leading to the establishment of efficacy findings by researchers, the decision to scale-up by the school, and the plans for scaling-up. In doing so, we elucidate a multi-term research agenda on an 1:1 mobilized curriculum that studies scaling beyond the initial proof-of-concept to broad and deep usage in the context of a research-based innovation in a school in Singapore. Such an agenda articulates the research questions and posits the scaling research framework and approaches involved. We hope this can provide an existential example of how researchers can do research that addresses the multi-term, multi-pronged, multi-level and systemic aspects of school-based innovations, and that ultimately benefits schools and yet at the same time, derive and refine scientifically and empirically theoretical frameworks, design principles, resources and strategies for learning.

Our research approach: Design-based research and our roles as meso-level mediators

With the goal of working towards scalable and sustainable classroom practices, we took a design-based research (DBR) approach to address complex problems in real classroom contexts in collaboration with practitioners, and to integrate design principles with technological affordances to create solutions to real needs of teaching and learning. The goal of design research is to conduct rigorous and reflective inquiry to test and refine innovative learning environments as well as to refine new learning-design principles (Brown, 1992; Collins, 1992). DBR is iterative as researchers strive to engage in design, work with teachers to enact the design in classroom settings, do research on
the contextualized learning processes, develop or refine theories of learning, engage in iterative re-design, and thereby continue the cycle of design and implementation. It is characterized as being interventionist, iterative, process-oriented, utility-oriented and theory-oriented (van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). It is distributed across teachers and is ongoing, as opposed to a completed trajectory that we as researchers can foresee and oversee. DBR can result in greater understanding of a learning ecology by designing its elements and by anticipating how these elements function together to support learning (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003).

Cognizant of the multiple level constraints that act on teachers adopting new curricular innovations in the classroom, we recognize the complex interplay of multiple dimensions of education reforms. Thus, we approach our programme of research from a systemic change perspective that recognizes the micro, meso, and macro levels of educational systems (Looi, 2011; Looi, So, Toh, & Chen, 2011). The policy imperatives governing Singapore’s educational landscape constitute the macro-level factors, and the contextualized classroom-based work and interactions as micro-level factors. By meso levels, we adopted the view of Jones, Dirchinck-Holmfeld, and Lindstrom (2006) where they define: “meso is an element of a relational perspective in which the levels are not abstract universal properties but descriptive of the relationships between separable elements of a social setting” (p. 37). Meso-level agencies can be perceived as the “recontextualizers” or “constructors of pedagogic discourse who de-locate and re-locate discourse, moving it from its original site to a pedagogic site” (Jephcote & Davies, 2004, p. 549).

<table>
<thead>
<tr>
<th>Macro-level actors:</th>
<th>Meso-level actors: Researchers as re-contextualizers who moved discourse from original to pedagogic site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policymakers or other actors who set the climate or policies for educational reforms in schools and in learning</td>
<td><strong>Meso-level environment:</strong> The socio-cultural factors that make up the school’s learning ecology such as the classroom setting situating between individual activities, small groups and larger communities.</td>
</tr>
<tr>
<td><strong>Macro-level environment:</strong> As seen in national plans or Masterplans where a conducive macro-environment for innovative practices is enabled by governance practices through:</td>
<td><strong>Meso-level emphases</strong> Interpreting and operationalizing macro-level emphasis by:</td>
</tr>
<tr>
<td>- Setting up the infrastructures</td>
<td>- Effecting the desired epistemological and socio-cultural changes via design research</td>
</tr>
<tr>
<td>- Creating readiness</td>
<td>- Mapping to effective classroom orchestration and implementation that seeks to achieve the desired micro-level interactions and outcomes, via design research</td>
</tr>
<tr>
<td>- Phasing changes</td>
<td>- Considering systemic forces and mediating inter-related tensions to lead to sustainability and scalability</td>
</tr>
<tr>
<td>- Institutionalizing and undergoing creative renewals</td>
<td>- Providing resources</td>
</tr>
<tr>
<td>- Providing resources</td>
<td><strong>Micro-level actors:</strong> Individuals such as students and teachers</td>
</tr>
<tr>
<td><strong>Macro-level emphases:</strong> Setting broad educational outcomes</td>
<td><strong>Micro-level environment:</strong> Interactions or discourse within small group and classroom settings</td>
</tr>
<tr>
<td>- Scanning trends and directions, and reviewing research at meso-levels and micro-levels that inform pedagogical and technological practices</td>
<td><strong>Micro-level emphases</strong> Informing macro and meso-level emphases by:</td>
</tr>
</tbody>
</table>

| Figure 1. A systemic framework for enabling innovative practices via the alignment of macro, meso and micro levels (adapted from Looi et al., 2011, p. 11) |

The socio-cultural factors of the school’s learning ecology constitute the meso-level environment. As researchers from the university, we serve as meso-level actors who work in that environment to recontextualize pedagogic discourse. This re-contextualization process is a “meso-level” mechanism. The orchestration of efforts from all
actors will contribute explanatory power to the sustainability of an intervention. By approaching this pedagogy-driven reform at the macro, meso and micro levels, we seek the alignment of systemic forces at work to provide a buttress for sustainability. Thus we, as researchers as the meso-level actors, help the school practitioners understand and interpret policy imperatives and actualize them into classroom teaching and learning practices in ways that are informed by research and theories. Figure 1 shows the roles of actors in these three levels in enabling and sustaining innovation.

The curricular innovation informed by the seamless learning notion

Through a DBR approach and a lens of researchers serving as meso-level mediators to work with the teachers, we first conducted several research cycles in the three-year research project entitled “Leveraging Mobile Technology for Sustainable Seamless Learning in Singapore School.” The work helped us to develop a viable innovation model (the Seamless Learning Model or SLM in short) by working with a class of primary school students over a period of two school years. The innovation involved the transformation of the existing science curriculum into an inquiry-based one which leverages the affordances of mobile technologies. The project was framed in the broader context of constructing “seamless learning” environments to bridge different learning contexts (such as between formal and informal learning settings, individual and social settings, and learning in physical and digital realms), mediated by mobile devices in 1:1, 24x7 basis (Chan et al., 2006; Wong & Looi, 2011). The basic rationale is that it is not feasible to equip students with all the skills and knowledge they need for lifelong learning solely through formal learning (or any other single learning space); henceforth, student learning should move beyond the acquisition of content knowledge to develop the capacity to learn seamlessly (Chen, Seow, So, Toh, & Looi, 2010). Nevertheless, as such a learning approach is a tall order for students who are more accustomed to the present instructivist-dominated education system. In this regard, we envisaged the design and enactment of long-term seamless learning curriculum where teachers engaged learners in an ongoing enculturation process (Wong, 2013b) in nurturing their habit-of-mind in seamless learning.

We first describe the underlying intent and the guiding principles of this curricular innovation enabled by mobile technologies. These were what shaped the curricular innovation, and they had been iterated and improved progressively through a process of DBR by working with teachers over three years. The process was marked by in-situ iterative and collaborative cycles of co-design by researchers and the teacher, leading to enactment by the teacher in one experimental class with data collection. The researchers observed the classes, and provided feedback to the teacher to improve the design and subsequent enactments. The class was a mixed-ability class.

The design of the learning units in the mobilized curricula for science is designed based on these design principles (Zhang et al., 2010):

- Design student-centered learning activities (to promote engagement and self-directed learning)
- Make students’ thinking process visualizable (so that they can be shared and subject to further refinement)
- Incorporate different learning modalities (to personalize learning)
- Design for holistic and authentic learning (make science learning meaningful)
- Facilitate social knowledge building (to promote collaborative learning)
- Ensure that the teacher plays the role of facilitator (to move away from didactic teaching)
- Provide an environment to integrate all learning activities (students have a hub to launch or continue their learning activities)
- Assess formatively (through the learning activities, students can receive feedback for their own ideas from peers or the teacher)
- Extending classroom learning activities beyond school hours and premises (to support the notion of seamless learning).

In the co-design process, researchers worked with teachers to revise and mobilize two years’ worth of the national curriculum for Primary 3 and 4 Science by considering the opportunities afforded by ubiquitous access to mobile devices. Activities were designed which seeks to extend learning activities beyond the classroom. To support the continuous and long-term learning activities, 34 students from the experimental class were each assigned a smartphone with 24x7 access in order to mediate a variety of learning activities such as in-class small-group activities, field trips, data collection and geo-tagging in the neighbourhood, home-based experiments involving parents, online information search and peer discussions, and digital student artifact creation, among others.
The key epistemological design commitments of the curricular innovation are: learning as drawing connections between ideas, and learning as connecting science to everyday lives, across multiple learning spaces. The curricular commitment is seamless learning, and inquiry-based facilitation and learning. The technological commitments include: technology for construction, technology for communication, and technology for searching information anywhere anytime.

Concerning the curricular commitment, in science teaching, the Ministry of Education of Singapore has advocated the use of the BSCS 5E Instructional Model (Bybee, 2002). This 5Es model consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. Each phase has a specific function and contributes to the teacher’s coherent instruction and to the learners’ formulation of a better understanding of scientific knowledge, attitudes, and skills. The model is used to sequence the learning activities in a science lesson or over a series of science lessons.

The designed curriculum was developed with the use of software apps on the GoKnow™ MLE (Mobile Learning Environment) that runs on a Microsoft Windows Mobile operating system. The GoKnow MLE enables teachers to create differentiated lessons easily via its online learning management system, GoManage, and it enables students to easily personalize their learning experiences (Looi et al., 2009). MLE supports teachers in creating complete, coordinated, curriculum-based lessons that employ multiple media and applications (e.g., text, graphical, spreadsheet, animations, and the like). It is an environment in which students engage in the specified learning activities and create various artefacts. It includes software tools such as:

- KWL (what do I already Know? what do I Want to know? What have I Learned?) to allow students to learn in a self-regulated way,
- Stop Watch that supports timing of events,
- Sketchy™ as an animation/drawing tool, and
- Picomap™ that allows students to create, share, and explore concept maps.

Typically, the lesson is designed to provide opportunities for the student in the Explore, Explain and Elaborate phases of 5E to use the software tools to do their science inquiry. In the Engage phase, the teacher motivates the inquiry by doing some classroom science demonstration or posing some science questions. In the Evaluate phase, the teacher or student peers review the work done on the software tools to detect and correct students’ developing conceptions of the science concepts.

We designed a total of twelve MLE units in the two years of intervention. Note that we did not design the whole curriculum in one go before the intervention commenced. During and after each design-enactment cycle for a MLE unit, we reflected upon the lessons and apply such understanding to inform the design of the next MLE unit. In addition to offering a logical flow for learning the domain knowledge, we had progressively incorporated various types of inquiry/seamless learning activities, from simpler to more demanding ones. This was to facilitate the students’ gradual changes in their habits of mind moving towards learning seamlessly. For example, while the earlier activities involve the students expressing their understanding using the software tools or capturing artifacts outside of the classroom and relating them to the curriculum concepts, the latter activities involve some form of parental involvement in the students’ learning.

Through a process of considering the space of activities enabled by the affordances of the software tools and the smartphones, and the kinds of activities that would be beneficial for primary school science students, we develop a categorization of the 10 major types of smartphone-mediated activities as shown in Table 1. Table 2 summarizes the essential information, including what smartphone-mediated activities were incorporated, of the twelve MLE units.

<table>
<thead>
<tr>
<th>Table 1. Types of mobile-assisted activities incorporated in the MLE curriculum (Wong, 2013b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity ID</td>
</tr>
<tr>
<td>KWL</td>
</tr>
<tr>
<td>Anim</td>
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<tr>
<td>Ph</td>
</tr>
<tr>
<td>CM</td>
</tr>
<tr>
<td>Dsc</td>
</tr>
<tr>
<td>Trp</td>
</tr>
<tr>
<td>Exp</td>
</tr>
</tbody>
</table>
Activities with parental involvement

Videos & other tools

Web search and media playing
Internet Explorer, YouTube app

In-situ multimedia content creation & forum discussion
ColInq (with geo-tagged postings, each served as a discussion thread)

<table>
<thead>
<tr>
<th>Level &amp; time period</th>
<th>Topic</th>
<th>Anim</th>
<th>KWL</th>
<th>Ph</th>
<th>CM</th>
<th>Dsc</th>
<th>Trp</th>
<th>Exp</th>
<th>Par</th>
<th>Web</th>
<th>Col</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb 2009</td>
<td>Classification for living &amp; non-living things</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Feb &amp; Mar 2009</td>
<td>Classification of animals</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mar &amp; Apr 2009</td>
<td>Plant</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Mar &amp; Apr 2009</td>
<td>Plants &amp; their parts</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
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<tr>
<td>Mar &amp; Apr 2009</td>
<td>Fungi</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Apr &amp; May 2009</td>
<td>Materials</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Aug &amp; Sep 2009</td>
<td>Body systems</td>
<td>√</td>
<td></td>
<td>√</td>
<td>√</td>
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<td></td>
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<td></td>
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<tr>
<td>Jan &amp; Feb 2010</td>
<td>Cycles</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Feb &amp; Mar 2010</td>
<td>Matter</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Apr 2010</td>
<td>Light &amp; shadow</td>
<td>√</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Apr &amp; May 2010</td>
<td>Heat &amp; temperature</td>
<td>√</td>
<td>√</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Jul 2010</td>
<td>Magnet</td>
<td>√</td>
<td></td>
<td>√</td>
<td>√</td>
<td></td>
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</tbody>
</table>

Note. The first seven units constituted the Primary 3 mobilized curriculum; the last five belonged to the Primary 4 curriculum.

Demonstration of efficacy of innovation

The curricular innovation involves designing a coherent and sustainable classroom program. The unique research context is that we worked with a school with 9 classes in the cohort of Primary Grade 3 taking the science subject. The experimental class followed the same class schedule and assessment schemes as the rest of the classes. What evidence can we demonstrate in establishing the efficacy of the innovation? Our analysis of the science examination scores after the one year intervention (with the experimental class using the mobilized curriculum to replace the traditional curriculum) shows that amongst the 6 mixed-ability classes in Primary (Grade) 3 in the school, the experimental class performed better than other classes as measured by traditional assessments in the science subject (see, Looi, Zhang, et al., 2011). With mobilized lessons, students were found to learn science in personal, deep, and engaging ways as well as developed positive attitudes towards mobile learning. We feel that this result is a very worthwhile contribution to the field, as much research work on mobile learning focus only on units of at most a few weeks duration or they are add-on activities to some existing curriculum.

The use of the mobilized technologies provides many leverage points for the researchers and teachers to co-design a new curriculum that focus on inquiry learning. Once designed, the curriculum can be enacted by science teachers, and it is important for the teachers to understand the design principles behind a mobilized curriculum for inquiry learning and how to implement in the way to harness the best learning outcomes for students. We see a shift in the teacher’s attitudes and behaviors towards science teaching, from a style that sees her pre-occupied with just covering the curriculum to one that allows her to watch over and facilitate students’ work on the inquiry activities on their handhelds.
With the mobilized lessons, we observe students engaging in science learning in personal and engaged ways. They demonstrated their understanding of science phenomenon in multimodal ways and did self-directed learning by doing online search and exploration on questions related to the curriculum topics. They engaged in instructional activities that involve their parents, as in our mobilized lesson for the body systems. This lies in contrast to the more “traditional” way of learning, in which students learned science from the didactic instruction of the teacher or from the textbook.

Providing the basis: Explicating and theorizing the SLM model

The pilot has shown that Seamless Learning (SL) is a viable pedagogical model. SLM harnesses the portability and versatility of mobile devices to promote a pedagogical shift from didactic teacher-centered to participatory student-centered learning (Facer et al., 2004). With appropriate learning design, the mobile technology facilitated the transformation of classroom learning activities into a more student-centered, personalized, and social learning process for the students where they need to process and associate their experiences or the information received in the informal contexts with the knowledge that they have acquired or constructed in the classroom, reflect upon any discrepancy, and apply the knowledge to solve real-life.

As design-based researchers, we also seek to work towards theories for how to get students to learn as self-directed seamless learners (Looi et al., 2010; So, Kim, & Looi, 2008; Wong, 2013b). We explore how the theories and methodology of self-regulated learning (SRL), an active area in contemporary educational psychology, are inherently suited to address the issues originating from the defining characteristics of mobile learning: enabling student-centered, personal, and ubiquitous learning (Sha, Looi, Chen, & Zhang, 2012). These characteristics provide some of the conditions for learners to learn anywhere and anytime, and to be motivated and able to do so in a strategic way, namely, self-regulate their own learning. We propose an analytic SRL model of mobile learning as a conceptual framework for designing and analyzing mobile learning, in which the notion of self-regulation as agency is at the core (Figure 2). The rationale behind this model is built on our recognition of the gaps in the current conceptualization of the mechanism and processes of mobile learning, and the inherent relationship between mobile learning and SRL.

At the center of the model is the notion of self-regulation as agency, referring to the learner characteristics that function as internal driving forces initiating and sustaining a self-regulated mobile learning process. The key personal factors include domain knowledge, prior experiences, motivation, and metacognitive awareness, epistemological beliefs, and so on. Self-regulated mobile learning processes can be understood and analyzed by means of SRL theories and methodologies (e.g., self-report survey, trace analysis). Mobile learning processes that are regarded as manifestation/exercises of agency (fundamentally composed of motivation and metacognition) can be understood, analyzed, and assessed from the theories and methodologies of SRL. Second, mobile learning activities are supposed
to be mediated by mobile technologies and devices, which presumably function as social, cognitive, and metacognitive tools. The existing studies in mobile learning largely focus on the social and cognitive functions but ignore the metacognitive function.

**Methodological contributions: Studying students on the move**

SLM advocates continuous learning by the students inside and outside of the classroom. The curriculum incorporates components where they use their personal mobile devices to do planned activities at home or outside of the classroom, and where they also learn in emergent and unintended ways. The challenge for us researchers is how to study “seamless learning” as synergistic and continuous learning across multiple spaces and time scales which involves theoretical and methodological challenges (Toh, So, Seow, Chen, & Looi, 2013). With students constantly on the move and many of their interactions happening in informal settings, researchers face significant challenges for investigating and documenting emergent forms of learning and participation across multiple contexts. The challenges of collecting data for students on-the-move include making sense of the voluminous data collected, and navigating the complexity of ethical issues involved in the intrusive and non-intrusive data collection methods.

To fill the gap in mobile learning research, we innovated on a methodological approach for researching digital kids’ learning supported by mobile technologies. The specific focus on methodological issues is significant with recent trends in mobile learning research’s focus on learning beyond school settings. Building on earlier work on methodological issues (e.g., Hsi, 2007; Martin, 2004; Vavoula & Sharples, 2009), we adopt and adapt the method of cooperative inquiry to study the sense-making endeavors of digital students who are always on-the-move and learning across multiple settings. We do so by working with parents who would cooperate to collect data such as by using video-recording and taking photos of their children doing things on their mobile devices.

**Moving beyond the Proof-of-concept: From innovation to scaling**

Is the curricular innovation ready for scaling and how do we know to what extent scaling has taken place? One of the most cited literature on scaling is that of Coburn (2003) who defined scale as encompassing four interrelated dimensions:

- **Depth:** Depth refers to deep and consequential change in classroom practice, altering teachers’ beliefs, norms of social interaction, and pedagogical principles as enacted in the curriculum.
- **Sustainability:** Sustainability involves maintaining these consequential changes over substantial periods of time.
- **Spread:** Spread is based on the diffusion of the innovation to large numbers of classrooms and schools which will adopt and adapt the innovations.
- **Shift in reform ownership:** Shift requires districts, schools, and teachers to assume ownership of the innovation, deepening, sustaining, and spreading its impact.

Building on this work, Clarke and Dede (2009) added a fifth dimension, namely, evolution, in which the innovation, as revised by its adapters, is influential in reshaping the thinking of its designers and creating a community of practice that evolves the innovation.

Our 3-year design research study in the primary school has helped achieve some successes in dimensions of scale by Coburn (2003) in four ways:

- **Depth:** The intervention has created positive learning gains for the students of the 2 classes and positive changes in attitudes and knowledge of the 2 teachers (Looi, Zhang et al., 2011).
- **Sustainability:** Clearly changes have occurred in the school with evidences from research analysis (Looi, Zhang, et al., 2011; Zhang et al., 2010) during the two years of intervention, and from interviews with the stakeholders (school leaders and teachers).
- **Spread:** In 2009, we worked with 1 teacher and 1 P3 class. In 2010, we worked with 2 teachers and 2 P4 classes. The school is spreading the mobilized curriculum for science to all P3 classes in 2012, and to all P4 classes in 2012.
- **Shift in reform ownership:** The school has taken over ownership by driving the spread of the mobilized curriculum for science to all P3 classes in 2012.
When the curricular innovation using mobile devices has been developed and studied in the context of one class, and the empirical evaluation of the mobilized curriculum has shown its potential for learning effectiveness, the school leaders decided that it was a worthwhile innovation and, in consultation with the researchers, would like to scale up the innovation.

We envisage the following four levels of scaling in the life-cycle of educational research and development work that lead to practical and policy implications for how to scale up in a school context:

**Level 1:** Developing the intervention as an innovation through a pilot in one or two classrooms  
**Level 2:** Grade-level scale—spreading to more classes in a grade level and eventually to a whole grade level  
**Level 3:** School-level scale—spreading the innovation to a whole school  
**Level 4:** District or country-level scale—in which such work will have policy implications for the educational authorities.

We note that many research interventions do not survive the first level, or they merely go through many research funding cycles to iterate and re-design the intervention, and stop at that. Our interest is those research innovations which have been shown to have demonstrated learning efficacies, and there is purpose and commitment from all the relevant stakeholders to scale-up the intervention. We know it is rare for bottom-up research interventions to move from Level 1 to Level 2, let alone to the other levels. Thus it is critically important to study and learn from the few instances out there that actually move up the levels, and this is towards exemplifying and informing how research can really bridge the research-practice gap by through such scaling studies.

To make SLM an integral part of classroom practices, what would then be useful for the school and for the Ministry of Education is to “ruggedize” the innovation for sustainability to retain substantial efficacy in diverse or even relatively barren contexts. To ruggedize the innovation, robust-design strategies are needed that will enable the innovation to be used in multiple settings (Clarke & Dede, 2009). The school has moved onto the Level 2 and has plans to share the model with other schools.

So far, we have created a successful story of research-informed technology-enabled practices in the school, but we want to study further how to sustain such successful practices over time after an initial influx of resources and other forms of external support. For sustained changes, we would reemphasize the importance of meso-level mechanisms that support teacher capacity building and reinforce school leadership and culture. Barab & Luehmann (2003) discuss issues of sustainability and local adaptation as crucial for scale. They describe the teacher’s role in local adaptation as identifying local needs, critiquing the innovation in the light of those needs, visualizing possible scenarios of implementation, and finally making plans or decisions concerning the implementation. Teachers will be ultimately involved in the adoption, customization, and implementation process, and they are continually remaking and contextualizing the innovation in terms of their local context. Barab and Luehmann (2003) argues that instead of the equation

\[
\text{Designed Curriculum} = \text{Implemented Experience}
\]

it should be

\[
\text{Teachers Perceptions} + \text{Designed Curriculum} + \text{Classroom Culture} = \text{Implemented Experience}
\]

For example, stark differences would exist between the customization and implementation of an innovation by a subject-matter focused teacher who is very concerned about students’ understanding of the content compared to a logistically focused teacher who is most concerned that the activities run smoothly and in the appropriated time frame. Our current phase of research studies how different teachers would locally adapt the innovation and what the resulting implemented experiences for the students and for the teacher would be. The critical research questions are:

1. How to adapt and to “ruggedize” the innovation for sustainability to retain substantial efficacy in diverse contexts of more classes in the grade level and more teachers, in which some of the conditions for success are absent or attenuated? This includes designing a more device-independent curriculum intervention for mobile learning. By clarifying the design principles and the design affordances, it is hoped that the new curriculum development model is more generic and less dependent on the devices the students use.
2. What is the impact on depth, sustainability, spread, shift of ownership and evolution when a school takes over ownership and scales up an innovation developed from one class to more classes and eventually to a whole grade level?
3. What are the strategies for curriculum development and professional development models needed to support the spread of a mobilized curriculum to one whole level?

4. What are the strategies for organizational, technological and institutional changes needed for such a sustainable and scalable translation of research into practice?

A key issue in scaling is how to explicate the curriculum for the typical teacher. While during a pilot, one can leave both the content and the instructional strategies “looser” and “less-defined,” that strategy will not work when all teachers read, use and interpret the same curriculum. The curriculum needs to be specified (Cohen & Ball, 1999). The goal is to make the content and the instructional strategies explicit – make the curriculum transparent for the teacher to enact initially and to adapt subsequently.

Another key issue relates to ongoing professional development. Teachers need to be provided with continuous support as they transition to a new curriculum, providing the performance support (Cohen & Ball, 1999). In contrast to a pilot, where the teachers are typically highly motivated and are top-notch teachers, as an innovation goes to scale, all teachers must be brought up to speed. Some of those teachers will be motivated and some less so; some teachers will be highly competent and some less so. Thus, professional development that is ongoing, continuous must be put in place to help all the teachers, especially the weaker ones, understand how to rollout the innovation.

The teachers need more collaborative work sessions so they can help each other with suggestions on instructional strategies and with tweaks to the curriculum. Those additional collaborative work sessions are critically important. If teachers feel isolated, they will not enact the innovation. They need to form their own learning community for mutual support and rely less on the research team. Moreover, the fundamental issue is to shift the teachers’ epistemological and educational beliefs from being a transmissionist and behaviorist to being a socio-constructivist – without the shift, all the curricular mobilization efforts will become a mere formality.

Aligned with the issue of teachers adopting and adapting a new pedagogy, there is a need to make the formative evaluation techniques explicit and to show teachers how to use the formative assessments in order to tailor their instructional practices to the specific needs of the individual students. In order to go to scale, all teachers need to use the same formative assessment techniques and thus these techniques must be made explicit and teachers must be given support as they learn how to administer and use those formative assessments.

The curricular innovation is enabled by mobile technologies. A more sustainable approach is to adapt the curriculum for a more generic mobile technology. This makes the curriculum and the formative assessments work with a broader range of mobile technologies and applications. While initially the innovation used smartphones, the goal is to create materials – curriculum, instructional strategies, and formative assessments that are mobile technology agnostic. Mobile technologies are changing very quickly; thus, we do not want our learning resources to be tied to a specific mobile technology. Moving towards the blending of mobile and cloud computing technologies (Wong, 2012) is a direction in our agenda for scaling up. The new direction will not only offer a feasible solution to the above-stated challenge of changing technologies, but also has the potential to open up new opportunities for developing more advanced affordances to mediate a wider range of seamless learning activities.

What have we learned about scaling so far?

At the school, we have moved from serving 80 students (2 teachers) to serving 320 students (6 teachers). That almost order-of-magnitude jump in who is supported requires R&D if that transition is to be effective. What we learned in the pilot was critically important, e.g., that SLM can be an effective pedagogical model in supporting students as they engage in inquiry-based learning. However, in going to scale, the issue is no longer one of efficacy but one of infrastructure – how do we take an innovation that was hand-crafted and make it more rugged, more robust, more stand-alone, more transparent.

By the end of academic year 2012, all teachers of P3 have enacted the curriculum. What have we scaled up to enable this spread to all teachers and all classes in P3? The scale-up comprises these multiple dimensions:

1. Mobilized curricula (to lead students to self-directed learning and to bridging informal learning spaces)
2. Teacher facilitation skills
3. Teacher readiness
4. Student readiness including hardware and software training
5. Technology infrastructure, e.g. WiFi and 3G Connectivity; availability of mobile devices in 1:1, 24x7 basis

On assimilating the curriculum into the classroom culture (Squire, MaKinster, Barnett, Luehmann, & Barab, 2003), we summarize the challenges the teachers faced in doing a new curricular innovation that builds new skills and competencies beyond what is usually assessed in the standardized assessments used in the school. In the researchers’ interviews with the teachers, the teachers raised these concerns:

- They are not sure if they are conducting the designed curriculum lessons in the right way. Some teachers expressed doubts on the students’ ability for doing self-directed learning.
- Some teachers expressed that they needed help in developing and practicing questioning skills in the classroom.

What support was provided to the teachers to help them to address these challenges? The response to the first concern was for the researchers to provide support to the teachers by giving personalized feedback after each lesson enactment, and by helping the teachers to adapt the lessons for different ability students. The response to the second concern was for teacher sharing facilitated by the researchers in the weekly curricular design meetings to discuss questioning skills via modelling by a teacher or researcher, and by lesson study discussions on a recorded classroom sessions. While researchers provided these initial scaffolding, the plan was to build up the capacity of this group of primary 3 science teachers so that they can sustain the innovation in the coming years with fading from the researchers in the subsequent year.

In levelling up the capacity of the teachers, some new activities were planned. Arrangements were made for teachers to observe their peers conducting the lesson activities. There were some discussions for each teacher to co-teach with another teacher, but this was later not followed up on because of time constraints and time tabling issues (for example, when the teachers are teaching concurrently thus making it difficult to visit other classes for co-teaching). The researchers decided to edit short clips of videos which they found out to exhibit good teaching and learning scenarios to be shared with other teachers.

Scaling to Chinese and English language learning

In previous sections, we reported the outputs of our past research – the explication of the SLM, the curriculum development principles, the research methodology to study learners on the move, the PD model, our experience and understanding in fostering the technological and systemic conditions for the establishment of a sustainable 1:1 seamless learning environment, etc. Apart from the scaling up of the science curriculum, these research findings and deliverables are also serving as the basis for scaling the SLM to other school subjects. To date, two language subjects, namely, Chinese and English, have embarked on their respective journeys of transforming their curriculum into seamless learning environments, again with the eventual aims of cross-school scaling up.

“MyCLOUD” (My Chinese Language ubiquitOUts learning Days, 语飞行云) (Wong, Chai, Chin, Hsieh, & Liu, 2012) is a levelling up effort of the completed study of “Move, Idioms!” (Wong, 2013a; Wong, Chin, Tan, & Liu, 2010). The DBR study aims to develop a holistic and scalable mobile- and cloud-assisted Chinese Language (CL) seamless learning environment that is informed by language learning/acquisition theories for P3-P5 students. The project involves a 2½-year school-based intervention (August 2011-November 2013). The intention is to enculturate students in carrying out CL vocabulary learning and communicative writing activities that encompass formal and informal learning settings. Under this approach, students are assigned mobile devices on 1:1, 24x7 basis in order to stimulate and support their language learning both within and beyond the classrooms. In addition, a cloud-based, device-independent MyCLOUD learning platform leveraging mobile and cloud computing technologies has been developed for the purpose. Another aim is to design new classroom practices that will be integrated into the existing formal curriculum as well as foster students’ competency to engender deep CL learning. The learning design principles developed by the researchers specifically foreground the bridging of language input (classroom, textbook-induced learning, and sharing of students’ linguistic artifacts) and output (students’ daily use of the target language through creations of linguistic artifacts such as photo taking / sentence making and social networking), and the bridging of learning contextualization and learning generalizations/reflections. On top of the more generic 10 features/dimensions of seamless learning as proposed by Wong and Looi (2011), the additional language learning-specific SLM dimensions rooted in various language learning theories may become the basis of the our future exposition of a Seamless Language Learning model. In addition, the research team is working towards spreading the curricular innovation to four more schools by 2014.
Aligned with the goal of implementing seamless learning and cultivating self-directed learners, smartphones were adopted in a trial design and implementation of the Primary 3 English language curriculum at Nan Chiau Primary School. This “WE Learn Project” is a scaling up of the seamless learning initiative in Primary 3 Science. By transforming the classroom from the traditional teacher-centered model to a learner-centered one, the project hopes to enhance the learning outcomes of students. In “mobilizing” the English curriculum and making it inquiry oriented, the teachers and curriculum developers drew on the two pedagogical strategies of P4C and Marzano’s P4C (Philosophy for Children), (Lipman, 1980) draws on the Socratic method of learning pioneered initially in Plato’s dialogues and focuses on learning how to ask a question and how to respond when asked a question. Marzano’s 6-steps to Better Vocabulary Instruction, (Marzano & Pickering, 2005) help children understand words by building relationships and links amongst the words, by using words in their proper contexts.

In science, in CL and the English language learning, while the particular styles of pedagogy have their differences, the pedagogies are, at their roots, inquiry-oriented, and learn-by-doing pedagogies that reinforce each other (Norris et al, submitted). In all these three subjects, the affordances of the mobile technology enable the students to use multiple modalities and multiple media, and to carry and use the smartphones anywhere and anytime as a learning hub.

At this point of writing (in November 2012), there are now approximately 350 P3 (3rd grade) students using mobile computing devices daily for science. Out of these 350, 120 students are also using the devices for English and Chinese language (MyCLOUD) learning. The school has plans to scale to approximately 700 students in P3 and P4 in science, to 350 students on P3 English, and 350 students in Chinese language learning.

**Conclusion**

Within the educational research community, many research projects focused on designing or establishing the efficacy of innovations that work well within specific contexts. They typically face the conundrum of narrowing the research-practice gap when it comes to changing or transforming practices in schools and other contexts for learning, and to scaling up to meet the needs of a broader audience. Such research projects are also not organized to address the challenge of long-term systemic improvement as research-practice partnerships often go in tandem with short-term funding of grants and program initiatives at foundations and government agencies. This paper describes a multi-year research programme for doing scaling and implementation research. The agenda is contextualized in the example of a mobile learning curricular innovation in a Singapore school as it goes to scale.

In this curricular innovation on mobile learning, we established that SLM can raise student achievement in the context of one class and one teacher. We have developed models for:
1. Transforming a curriculum to harness the affordances of mobile technologies
2. Technology infrastructure and support for a mobilized curriculum
3. Teachers’ professional development through working with 1 teacher for a grade level 3 (P3) class in 2009 and 2 teachers for two grade level 4 (P4) classes in 2010.

Because SLM demonstrated increased student achievement, the school decided to scale-up the roll-out of the transformed curriculum to all the eight P3 classes, by doing the planning in 2011 and doing the scaling in 2012. The next step in the research and implementation trajectory brings us to scaling research which seeks to make research count in practice. The goal is to study the adoption and the adaptation of the curricular innovation as it goes to scale to more classes, more levels and more subjects, and to documenting the benefits of balancing fidelity of implementation with adaptation to dynamic local contexts. The programme of research enables us to articulate the SLM curriculum, the supporting resources, the teacher learning and professional development models with analysis of their impact, efficacies as well as weaknesses. The scaling research will establish a model of scaling that recognizes the range and diversity of teachers’ local needs as well as the necessary adjustments they need to make in order for the innovation to be useable and effective, and how the school can support them to know how to adapt the innovation and yet retain the essence of its efficacy.

We hope that our narration of the ongoing research journey from innovation to practice and to scale can inspire other research initiatives that will address the multi-term, multi-pronged, multi-level and systemic aspects of school-based
innovations, and that yet at the same time, advance theory, frameworks, design principles, resources and strategies for effective and sustainable mobile learning.

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References


Ubiquitous Learning Project Using Life-logging Technology in Japan

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ABSTRACT

A Ubiquitous Learning Log (ULL) is defined as a digital record of what a learner has learned in daily life using ubiquitous computing technologies. In this paper, a project which developed a system called SCROLL (System for Capturing and Reusing Of Learning Log) is presented. The aim of developing SCROLL is to help learners record, organize, recall and evaluate ULLs. Using SCROLL, learners can not only receive personalized quizzes and answers to the questions, but also navigate and be aware of their past ULLs supported by augmented reality views. In particular, this paper introduces an approach that helps learners record their learning experiences in daily life from life-log photos with the help of SenseCam. To evaluate the effectiveness of this system, a case study of an undergraduate English course is presented to show how it can be used to facilitate seamless learning.

Keywords

Mobile learning, Ubiquitous learning, Learning log, Life logging

Introduction

CSUL (Computer Supported Ubiquitous Learning) or context-aware ubiquitous learning (u-Learning) is defined as a technology-enhanced learning environment supported by ubiquitous computing technologies such as mobile devices, RFID tags, and wireless sensor networks (Ogata & Yano, 2004; Wu, Hwang, & Chai, 2013). It is characterized by its augmented learning environment which presents information on personal mobile devices through the Internet based on the detection of physical objects in surrounding environment using sensing technologies (Hwang, Tsai, Chu, Kinshuk, & Chen, 2012).

The fundamental issues of CSUL are:
1. How to record and share learning experiences that happen anytime and in any place.
2. How to retrieve and reuse them for future learning.

To tackle these issues, LORAMS (Linking of RFID and Movie System) (Ogata, Matsuka, El-Bishouty, & Yano, 2009) was proposed. There are two types of learners in this system. One type consists of providers who record their experiences on video. The other type are learners who, when encountering some problems in their learning, may find the videos uploaded by the first groups of learners useful. The system automatically links between physical objects and the corresponding objects in a video and allows sharing among users. By scanning RFID tags, LORAMS shows users the video segments that include the scanned objects. Although this system is useful in certain environments, it is not currently easy to apply in practice. Therefore, we have begun a more practical research project called “ubiquitous learning log” (ULL) in Japan in order to store intentionally what learners have learned as ubiquitous learning log objects (ULLOs) and consequently reuse them. The project was conducted from October 2009 to March 2013 with the financial support by PRESTO of the Japan Science and Technology Agency (JST).

We define a ubiquitous learning log (ULL) as a digital record of what a learner has learned in daily life using ubiquitous technologies, and propose a model called LORE to show the learning processes from the perspective of the learner’s activity (Ogata et al., 2012). In this paper, we propose a system called SCROLL (System for Capturing and Reusing Of Learning Log) that helps learners log their learning experiences with photos, audios, videos, locations, QR-codes, RFID tags and sensor data, and share their ULLOs with others. Also, a learner can receive personalized quizzes and answers to their questions. This system is implemented both on the web and on the Android smartphone platform. With the help of built-in GPS and cameras in smartphones, learners can navigate and be aware of past ULLOs via the augmented reality view.

Originally, the term “learning log” was used for personalized learning resources for children. The logs were usually visually written notes of learning journals, which could become an integral part of the teaching and learning program.
and which had a major impact on their drive to develop more independent learners. Research findings indicated that journals were likely to increase meta-cognition and reflective thinking skills through students becoming more aware of their own thought processes (Hung et al., 2014; Hwang, Wu, Zhuang, & Huang, 2013; Stockwell, 2007; Susan & White, 1994; Wood Daudelin, 1996). Our approach focuses on how to enrich learning logs and promote retention and meta-cognition by using mobile, ubiquitous and context-aware technologies.

Life-logs

Life-logs are a notion that can be traced back at least 60 years (Bush, 1945). The idea is to capture everything that ever happens to us, to record every event we experience and to save every bit of information we ever touch. For example, SenseCam (Hodges et al., 2006) is a sensor-augmented wearable still camera which is proposed to capture a log of the wearer’s day by recording a series of images and capturing a log of sensor data. This is a great tool for recording life logs, as it is a small digital camera that is combined with a number of sensors to help capture a series of images of the wearer’s whole daily life at the proper time, and can be worn around the neck (Figure 1). Originally this device was designed as a memory aid.

MyLifeBits (Gemmell, Bell, & Lueder, 2006) stores scanned material (e.g., articles, books) as well as digital data (e.g., emails, web pages, phone calls, and digital photos taken by SenseCam). The Ubiquitous Memory system (Kawamura, Fukuhara, Takeda, Kono, & Kidode, 2007) is a life-log system using a video and RFID tags. Another application, Evernote (www.evernote.com), is a tool to save ideas using mobile devices such as Android and IPhone. The common idea of these projects is to use life-log data as a memory aid. SCROLL, however, aims to utilize life-log data for the learning process.

SCROLL

Design

In this paper, a ubiquitous learning log (ULL) is defined as a record of what a learner has learned in daily life using ubiquitous technologies. ULL is considered as a set of ULOs (Ubiquitous Learning Log Objects). The learning can also be considered as the extraction of meaningful knowledge from past ULLs that serves as a guide for future behavior (Wood Daudelin, 1996). Figure 2 shows the learning processes from the perspective of the learner’s activity model called LORE (Log-Organize-Recall-Evaluate). These four steps are explained as follows:

1. Log what the learner has learned: When learners face problems in daily life, they may learn some knowledge by themselves, or ask others for help. The system records what is learned during this process as a ULO. We designed two modes to record learning contents – active and passive. Here is a typical scenario of the active mode – when a foreign student in Japan walks into a supermarket, there are many foods that he/she does not know how to say in Japanese. The student can take a photo of this food by Smartphone and ask someone how to say it in Japanese, then log the learning content as a ULO including the photo, the name of the food in both Japanese and the learner’s mother language, location, time, etc. However, in the passive mode, a device such as a life-log camera can take photos of food and record the contextual information such as location and time automatically and wait for the learner to review the recorded contents before logging them as ULOs.

2. Organize ULL: When a learner tries to add a ULO, the system compares it with other ULOs, categorizes it and shows similar ULOs if they exist. There are many ways of categorizing ULOs. For example, a foreign student
in Japan learned a new word “tofu” in a supermarket and logged this process as a ULLO. This ULLO can be categorized as “Japanese,” “Food,” “Supermarket,” etc. As such, it is difficult for the system to categorize it. Therefore, in the designed system, users can add their ULLOs into multiple categories and add several tags to each one. After that, they can review the learned contents by category/tag. Similar objects can be found by matching titles, content of photos, locations and categories, and then the knowledge structure can be regulated and organized.

3. Recall ULL: Learners may forget what they have previously learned. Rehearsal and practice in the same or another context in idle moments can help to recall past ULLOs and to shift them from short-term to long-term memory. Therefore, the system provides some quizzes and reminds the learners of their past ULLOs.

4. Evaluate: It is important to recognize what and how learners have learned by analyzing their past ULLs, so that they can improve what and how to learn in the future. Therefore, the system refines and adapts the organization of the ULLOs based on the learners’ evaluation and reflection.

All of the above learning processes are supported by SCROLL.

We designed SCROLL to implement several types of learning, including self-directed and personalized learning, reflective learning, collaborative learning, situated learning, experiential learning, and seamless learning.

Self-directed and personalized learning

The first kind of learning is self-directed and personalized learning. We designed SCROLL based on the following two objectives that enable self-direction and personalization:

- The system can be aware of a learner’s current context. Currently, the context includes location and time. For the location information, the system can detect whether learners are near the place where they uploaded a learning log and whether there are location-based learning logs recorded by other learners nearby. If either requirement is met and if the availability of the device is high, the system will present a quiz based on the knowledge gained in that location or notify the user of the surrounding learning logs added by others.

- The system can record the context data when learners use the system as their context history and then detect their learning habits by analyzing their context history. If the system detects learning habits, and the circumstance meets these habits, it will issue a recommendation message to encourage the user to review what he/she has learned.

Reflective learning

An important goal of the SCROLL system is to help learners recall what they have learned after they have archived their learning logs. When a learner captures a learning log, in addition to its location-based property mentioned...
above, a number of things are designed as retrieval cues for the learner. For instance, according to the picture superiority effect (Defeyter, Russo, & McPartlin, 2009; Shepard, 1967), learning logs with pictures are much more likely to be remembered than those without. In addition, according to the basic research on human learning and memory, practicing retrieval of information (by testing the information) has powerful effects on learning and long-term retention. Moreover, compared with repeated reading, repeated testing enhances learning even more.

For the above two reasons, taking advantage of photos, locations and so on, the quiz function is proposed. Three types of quizzes can be generated automatically by the system: yes/no, text multiple-choice and image multiple-choice.

Usually, learners can examine themselves by taking quizzes (Hwang, Tsai, & Yang, 2008), but two more ways that are instigated by the system are provided. One is that when a learner moves to the place where he/she captured the knowledge, the system can present quizzes about the learned knowledge. The other is that if learners have learning habits, the system will prompt them to review what they have learned using quizzes. These two methods are discussed in detail later in the paper.

**Collaborative learning**

We designed SCROLL to also encompass collaborative learning. Since learning logs are logs registered arbitrarily by each learner, collaborative learning in SCROLL adopts an asynchronous model. Any learner in this system is able to share ULLOs, and the system will show their shared ULLOs to others. Besides, they can also ask others questions about their shared ULLOs. In reflective learning, shared ULLOs can also be used to generate quizzes in order to help learners learn more objects.

**Situated learning and experiential learning**

According to Lave & Wenger (1991), situated learning is learning that takes place in the same context in which it is applied. Itin (1999) defined experiential learning as “learning from experience.” We introduce a concept called "task" in SCROLL to implement situated learning and experiential learning. Learning in the same context enhances the learning effect, and past experiences help learners learn effectively. Tasks refer to the activities through which they can acquire knowledge. Tasks are conducted in the circumstances where learning can happen such as in a school, hospital, post office and so on. For instance, if the system recommends the Japanese word “トマト (tomato)” to a learner in a supermarket, learners can talk with the staff in the supermarket using the word “トマト (tomato),” such as asking its price, location, related recipes and so on. It has been proved that by talking with a native Japanese speaker using the recommended word, learners can master the word well (Jonassen & Grabowski, 1993). The activity of asking about the information is a kind of “task.” Learners who save learning logs are responsible for providing what kind of knowledge can be gained by carrying out the task, and one learning log can be used in several tasks. Moreover, the system provides some predefined tasks in different contexts in order to reduce the learners’ burden when they save their learning logs. In addition, the tasks can be created by the learner and designated by the administrator of the system.

The system assigns an appropriate task for a learner according to the difficulty level of the task and the learner’s ability. For example, asking the price of the product is easy for learners, while asking about vegetable recipes is quite difficult for most learners. When learners receive the recommended learning log and the task, they are also asked to provide feedback for the system. For example, they are asked to take photos of the target object if the learning task is to find where the object is. Moreover, if the learning task is to learn about the place of the object, they need to collect and fill in the environmental information on the system. Only by providing feedback can the users prove that they have really gained the knowledge. Moreover, if the learners meet new problems when carrying out the tasks, they can record them in photos, videos, audios or texts and upload them to the system in order to ask for help. Such accumulated data is also meaningful for other learners.
Seamless learning

Recent progress in mobile and wireless technologies offers us a new learning environment, namely “seamless learning” (Wong & Looi, 2011). It allows learners to learn anytime, anywhere, and provides them with multiple ways of learning throughout the day. By seamless learning, we mean learning which occurs with seamless transitions between in-class and out-of-class learning (Hung et al., 2013). The American College Personnel Association (1994) has indicated the importance of linking students' in-class and out-of-class experiences via providing seamless learning environments to achieve academic success.

Based upon the above ideas, we designed the following Seamless Mobile-Assisted Language Learning Support System (hereafter called the SMALL System) (Uosaki et al., 2012) as a sub-project. The main objective of SMALL is to link learners’ out-of-class learning to their in-class learning. Once a learner uploads a newly learned word to SCROLL, our main system, SMALL, runs a search through the previously updated textbook data. If the new word is found in the textbook data, it jumps to the textbook page where this word is used. Another example is that when a user reads an uploaded textbook and clicks a word, then it jumps to the SCROLL system page to show how other learners have learned this word in different contexts in their out-of-class learning. In this way, users’ out-of-class and in-class learning can be intertwined. We learn words from contexts. In order to master words, it is important to come across them used in various situations.

System interface

We implemented SCROLL both on web and smartphone platforms. It consists of the following components:

ULL recorder

This component facilitates the way learners upload their ULLOs to the server whenever and wherever they learn. As shown in Figure 3 (1), in order to add a ULLO, a learner can take a photo, ask questions about it and attach different kinds of meta-data to it, such as its meanings in different languages.

![Figure 3. SCROLL interface on an Android mobile phone](image)
ULL finder

If a learner registers a new ULLO, the system checks whether the same object has already been stored by comparing the name fields of each object using a thesaurus dictionary. Also, a learner can search ULLOs by name, location, text tag and time. Using this function, learners can understand what, where and when they learned before. Figure 3(2) and Figure 4 (left) show the list of the learner’s ULLO, which helps him/her to recall all of the past ULLs. Besides, it allows the learner to be aware of others’ learning objects and to re-log them if deemed useful. This means that a learner can make a copy of another learner’s learning object into his/her own log. Therefore, learners can obtain a considerable amount of knowledge from others even though they have not experienced that knowledge themselves. By sharing ULLOs with other learners and relogging the other learners’ ULLOs, the acquisition of knowledge is enhanced.

ULL reminder

As shown in Figure 3(3) and Figure 4(right), the system generates simple multiple-choice quizzes based on the metadata of the stored ULLOs. For example, the idea of “quiz with image” is to ask a learner to choose an image that describes the word given by the system. The system immediately checks whether the answer is correct or not. These quizzes are generated according to the user’s profile, location, time and the results of past quizzes and helps learners to recall what they have learned (Li et al., in press). The quiz function is designed not only to help learners to reinforce what they have learned, but also to recommend what other learners have learned and to remind them of what they learned in the past according to their current location and their preferred time. In order to achieve these targets, they can take quizzes whenever they want. In addition, they can send their location information to the server continuously. Therefore, the server side can automatically assign quizzes for them based on their location and time information. It notifies them by showing an alert message and vibrating the mobile phone. Whenever they move around an area where they have encountered some objects, the system will send them quizzes regarding those objects. Furthermore, they can set a time schedule to receive the reminder quizzes.

ULL navigator

The ULL navigator provides mobile augmented reality that allows the learner to navigate through the ULLOs. Like Wikitude (“Wikitude,” n.d.) and Sekai-Camera (“Sekai Camera Web,” n.d.), it provides a learner with a live direct view of the physical real-world environment augmented by a real time contextual awareness of the surrounding objects.
When learners are moving around with their mobile phones, the system sends alerts to the phone as soon as they enter the region of ULLOs according to the GPS data. This view is augmented, associated with a visual compass, and overlapped by the nearest objects in the four cardinal directions. Also, it provides the learners with a list of all surrounding objects. When the learner selects one or more of these objects, the Google map will be retrieved and marked with the learner’s current location and the selected objects. Moreover, the system shows a path (route) for the learner to reach the locations of the objects. This assists the learner in acquiring new knowledge by discovering existing ULLOs and recalling the learner’s own ULLOs.

An important component of the system is the ULL recorder. The current ULL recorder requires learners to capture learning contents (e.g., photos) manually. They might find this troublesome and it might disturb their learning activities. Thus, we have tried to find a better way to log learners’ learning content automatically and unconsciously. We found that SenseCam is able to do this. However, the second problem is: Among the very large amount of captured photos by SenseCam, what are the learning contents? After using SenseCam, we found that there are many kinds of context data such as temperature and brightness that can be used to help learners recall the captured objects. Besides, these data can also be used to help us improve our ULL reminders. This is an extra benefit of the passive capture of data.

**PACALL**

**Design**

Until now all the work that we have done has been using the active rather than the passive logging mode. This means that learners must record their learning experiences consciously. Compared to the passive mode, in the active mode we are more likely to miss learning chances since we are not necessarily able to record what we have learned, or sometimes we just forget to record it. Therefore, we introduced passive capture in our project with SenseCam and named the proposed system PACALL (PAssive CApture for Learning Logs). In the real world, there are so many things that we have learned but we usually miss the chance to review them; that is, we do not know what we know. Similarly, it is certain that we are not able to learn what we have not noticed. Therefore, we considered this in the learning process.

Since this research is based on our previous work (Ogata et al., 2010) in which we used the active mode to register ULLOs, we need to make it clear how the passive mode differs from the active mode. We compare the features of both in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Passive</th>
<th>Active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of photos taken</td>
<td>Many (~3000/day)</td>
<td>Few (&lt;1/day)</td>
</tr>
<tr>
<td>Data quality</td>
<td>Poor (by SenseCam, image only)</td>
<td>Good (by Camera /Smartphone/Tablet PC, image with GPS, Video etc.)</td>
</tr>
<tr>
<td>Recording time distribution</td>
<td>Continuous</td>
<td>Intermittent</td>
</tr>
<tr>
<td>Content completeness</td>
<td>High (user's whole daily life)</td>
<td>Low (only specific scenes)</td>
</tr>
<tr>
<td>Consciousness</td>
<td>Unconscious</td>
<td>Conscious, Intentional</td>
</tr>
<tr>
<td>Reflection</td>
<td>Strong</td>
<td>Weak</td>
</tr>
<tr>
<td>Workload</td>
<td>Low (captured automatically)</td>
<td>Quite high (capture manually &amp; upload manually)</td>
</tr>
<tr>
<td></td>
<td>High (review &amp; upload a large number of photos)</td>
<td></td>
</tr>
</tbody>
</table>

In the first three rows of Table 1, the two modes are compared in terms of photos. When we use SenseCam, it takes photos automatically and continuously, while in the active mode, smartphone photos can only be taken at the time we intend to. As a result, more photos are taken in the passive mode than in the active mode. However, because of the storage problem and some other technology limitations, photos taken by SenseCam are lower in quality; they are however of sufficient quality to be used as ULLOs.

In the next two rows of Table 1, the comparison is made in terms of learning contents. When we use a camera or smartphone, many learning contents are logged in our spare time such as at lunchtime. However when we use
SenseCam, because the recording is processed continuously, we can get photos whenever and wherever we are. As such, the photo contents cover our complete lives. The content type in the active mode, however, is richer than that in the passive mode because in this research the learning content captured by SenseCam consists only of photos.

In the last two rows, the comparison is related to the learners. In the passive mode photos are taken unconsciously, while in the active mode the learner must take photos consciously. When learners use SenseCam, they must review the whole learning process, and reflect on what they have seen and what they have learned and what they missed learning. This process will help them to remember the contents.

According to this comparison, we can see that the passive mode has many advantages over the active mode for language learning by photos. The quality of the photos is low, but it is still acceptable for our purpose. However the biggest disadvantage is the workload. SenseCam takes photos continuously. Consequently a huge number of photos are produced, and the more photos, the heavier the workload. If this workload is reduced, learners can learn language in the passive mode more easily. This is the key issue of using the passive mode in language learning. In this research, we focus on reducing the workload when reviewing the photos, and propose a system that can filter the photos to help learners review and upload ULLOs easily.

Figure 5. How the passive mode supports learning

Figure 5 explains this process and shows how to support learning in the passive mode. We classify all the objects surrounding us into four groups – “(I) I know what I know,” “(II) I know what I don’t know,” “(III) I don’t know what I know,” and “(IV) I don’t know what I don’t know”. For example, for non-English speakers, when a learner walks outside and sees a fire hydrant, if he notices it and knows how to say it in English that is status (I). If he does not know how to say it in English, that is status (II). Since he has noticed it, and does not know how to say it, he can learn it from a dictionary or by asking someone else. Then the status will change from (II) to (I), which only happens consciously in active mode.

Another situation is the case when he did not notice it. If he has not noticed the fire hydrant how can he learn it? The answer is that he can’t without some form of assistance. Therefore, we would like to encourage learners to use passive mode to support their learning. There are also two kinds of “don’t know” situation. In one case, the learner already knows how to say it in English (status III). In this case, captured life-log photos can help him notice this fire hydrant and let him review it. In status IV, captured life-log photos let him know there is an object that he does not know, and then he can have a chance to learn this object (B to C). This is a good way to help learners become aware of what they do not know if they do not notice it.

This system is a sub-system of the Ubiquitous Learning Log, named PACALL. It stands for PAssive CApture for Learning Log. We set the whole capturing process in passive mode. After that, PACALL analyzes all of the captured photos and finds several important ones to help learners determine which are worth recording.
Figure 6 is the flow of PACALL when analyzing captured photos. It consists of 5 steps: Loading raw data, Filtering bad photos, Finding good photos, Photo recommendation, and Learning analytics. These steps are introduced in detail in the following.

**Loading raw data**

There are three types of raw data in PACALL: life-log photos, sensor data, and GPS data. Life-log photos are currently captured by SenseCam. In the future, we plan to apply this system to photos taken by smartphones or compact digital cameras which are far more commonly used. That will be more convenient and useful. Suppose a learner took a trip and took many photos. Then she can use this system to find photos which contain useful learning contents.

The sensor data are recorded by SenseCam, and the GPS data are created by the portable GPS unit.

**Filtering bad photos**

In this research, a bad photo is defined as a photo that is hardly recognizable or that is a duplicate of other photos. We define three types of bad photos:
- Dark: a dark photo taken with insufficient light.
- Duplicate: the photos are duplicated.
- Defocused: the photos are blurry and cannot be recognized well.

We use image processing to identify these bad photos. Currently, we are using OpenCV to detect dark photos, and LIRE (a plugin for Lucene) to detect duplicated photos.

**Finding good photos**

A good photo is defined as one that contains clear objects. We use OpenCV to find good photos mainly by feature detection.

After filtering bad photos and identifying the good photos, the rest are of mediocre quality. Those photos might contain learning contents, although they are not so clear. The top priority is given to good photos and then mediocre ones come next when shown to learners to choose.
Photo recommendation

Once photo sorting is finished, the next stage is learning assistance. Our challenge is to detect useful information from photos by machine, and recommend photos that contain information. We define four types of recommended photos:

Character photo: a photo that contains characters. These characters are possibly used as learning contents. Here we are using text detection to find these photos.

Face photo: a photo containing a face. Actually, these photos are usually not appropriate for learning content because of privacy issues. However, faces are also information from photos.

Taggable photo: a photo that can be tagged by text. Tags are an important piece of information and can be used as a title of the photo.

ULLO-like photo: If there is a similar photo that was already registered to the SCROLL as a ULLO, it can possibly be used as a ULLO as well.

System interface

In the previous section, we introduced our design of the flow of analyzing photos. In this section, we explain its functionalities (i.e., PACALL Uploader, PACALL Browser and PACALL Recaller) in detail.

PACALL Uploader helps learners upload all the photos after capturing. We have made it easy to upload all the captured photos to the server. Because of the limitation of web technology, this process was not easy in the past. However with HTML5, it became possible. When learners want to upload a whole folder, they can select a photo folder and upload all the photos to the server. Also, the file of sensor data and GPS data will be uploaded.

After uploading the raw data (photos, sensor data and GPS data), the system will analyze all the data and show the results.

![Interface of PACALL Browser](image)

Figure 7. Interface of PACALL Browser

When all the photos are uploaded to the server, the learner can reflect on them with help from PACALL. The PACALL Browser has an interface for browsing all the photos, and it tags photos and provides some information to
help the learner find important photos (Figure 7). Currently, we provide three main functions in the browser – PACALL Filter, PACALL Searcher and PACALL Recognizer.

PACALL Filter classifies all the photos into categories such as Manual, Normal, Duplicate, Dark, Face and Recommendation. Here “Manual” means that a photo is taken manually by pressing the manual button of SenseCam. It usually happens when a learner finds something valuable to record. “Duplicate” and “Dark” mean bad photos. “Face” means the photos that contain faces, and “Recommendation” includes Manual, Faces and other good photos that contain information or similar photos that have been uploaded to SCROLL before. Such photos have tags under them such as 3d or 4d meaning that they were uploaded to the system three or four days ago.

When a learner clicks one photo in PACALL Browser, the PACALL Recaller will be opened. The photo and similar photos and sensor data will be shown on this page to help the learner recall the captured content. There is also an “Upload” button on this page. If the learner decides to upload this photo to SCROLL as a ULLO, he/she can click this button, and the photo will be uploaded to the SCROLL system directly and the page will jump to the learning log registration page (Figure 8). Figure 8 shows the interface of ULLO registration in the SCROLL system. On this page, a learner can see the location of the selected photo and other similar photos captured by SenseCam. If there are some similar photos that are already uploaded in SCROLL, they will also be shown on this page. Once “Upload Now” is clicked, the system will ask the user to answer a survey that lets the system know whether he/she knows it and whether he/she noticed this object when it was captured. The data can be used to evaluate our system and help the user analyze his/her learning situation. When an object is uploaded to the system, the SCROLL system will use the “organize,” “recall” and “evaluate” model to help users remember uploaded objects. For example, if a learner uploaded a photo and set the title as 消火栓 in Japanese, but does not know how to say it in Chinese, he/she can send a question along with the uploaded ULLO. SCROLL will send this question to all Chinese users. After receiving answers from them, the user can learn a new Chinese word. In the quiz module of SCROLL, a learner can answer quiz questions that are created automatically from uploaded ULLOs. By answering these questions, the learner’s knowledge will be enhanced.

![Figure 8. PACALL Recaller](image)

**Evaluation**

We have conducted an evaluation experiment for PACALL. This section introduces the method and result of this experiment.
Method

Since this is an initial evaluation experiment, the study group consisted of 4 Japanese university students taking an undergraduate English course. In this experiment, they were asked to upload photos of learned objects along with titles both in Japanese and English. They used three methods of recording the photos. The entire evaluation experiment lasted for 3 weeks and consisted of 3 phases:

Phase 1: SenseCam

During this phase, students were asked to wear SenseCam every day for one week. Every evening, they needed to review all the life-log pictures and choose proper pictures to upload to SCROLL. They were requested to record the time spent.

Phase 2: Tablet PC

In our previous work (Ogata et al., 2012), we compared the learning effectiveness of Tablet PCs and a traditional learning method such as taking notes. It was found that using SCROLL on a Tablet PC was more effective than the traditional learning method. In this experiment, we compare SenseCam with the Tablet PC in terms of log methods, as logging with a Tablet PC is considered as active, while logging with SenseCam is considered as passive. During this phase, all the students were asked to record and upload the learning log objects every day using a Tablet PC for one week. We used a Samsung Galaxy Tab in this experiment. The operating system of this Tablet PC is Android, and we developed an Android client that can upload the photos to the system conveniently.

Phase 3: SenseCam+PACALL

During this phase, the PACALL system was introduced into the experiment. This phase was almost the same as Phase 1. All the students should wear SenseCam every day for one week. Every evening, they used the PACALL system to classify the life-log pictures and upload the pictures. They were requested to record their time spent. Besides, they were asked to count the number of classifications after all the pictures were uploaded.

Result

Learning chances - Differences in number of ULLOs uploaded per day

We examined the number of uploaded ULLOs among these three learning methods. Figure 9 shows the average number of uploaded ULLOs for each of the four participants.

![Figure 9. The average number of uploaded ULLOs](image)

In this chart, the horizontal axis shows the four subjects, and the vertical axis shows the average number of ULLOs uploaded by each subject. It shows that they uploaded more photos in the SenseCam and SenseCam + PACALL.
modes than in the Tablet PC mode. As a result, the passive mode with SenseCam offered them more learning chances than the active mode. Moreover, it is found that PACALL increased the number of uploaded pictures in most cases (except S2). After this experiment, we examined why the number of uploaded pictures did not increase for S2, and then we interviewed him. We learned that at that time he was not so serious about the experiment and just managed to upload 3 pictures a day as a norm. However the result of Figure 11 shows that it took him nearly half the time to review and upload photos in SenseCam + PACALL mode compared with the time spent in SenseCam mode, so it is expected that if he had been more involved and spent more time, the number of uploaded ULLOs would have increased. In normal circumstances in the subjects’ daily lives, the pictures captured by SenseCam were similar whether using PACALL or not, and the numbers of uploaded objects were almost the same. However, from the feedback, it was found that PACALL reduced the workload of reviewing life-log pictures. The learners could choose pictures and upload them more quickly. So the number of uploaded pictures using SenseCam + PACALL is larger than that using SenseCam only.

**Learning quality - Can learners remember uploaded ULLOs that are taken unconsciously in passive mode?**

What is the difference in the learning effect of the active and passive modes? This is the second question that we attempted to answer. Therefore, we gave all the students a test after each phase to see whether they had remembered the uploaded objects. We devised a test consisting of the uploaded pictures and asked them to write down the title of the pictures, then judged their memory, grading them from 0 to 5, where 5 means they remembered clearly and 0 means no recall at all. Figure 10 shows the results.

![Figure 10. Memory level of active and passive modes](image)

In Figure 10, we can see that the memory level of active mode is a little higher than that of passive mode. In active mode, the learner takes pictures consciously. Naturally the impression of the photos is deeper than that of those taken in passive mode. Besides, the number of uploaded photos in passive mode was larger than that of active mode which might be reflected in their memory level. Therefore this result is understandable. Even though their memory level was lower, when we consider the fact that they registered more photos as their learning logs, we interpret that our system gave them more chances to learn in passive mode. Therefore we believe that the system contributes to their learning.

**Workload issue - How much value does the PACALL add to passive learning mode?**

We examined how PACALL contributed to reducing the time spent on the whole procedure. We asked students to report the spent time, and Figure 11 shows the result.

This chart clearly shows that the developed system reduced the time spent reviewing the life-log pictures by nearly a half. Of course, the workload in passive mode is higher than that in active mode, but very few learning contents are missed. In the future, we will focus on how to reduce the workload and help learners to reflect on and find good photos more easily.
We received some suggestions and feedback from the students which helped us to understand the usage of PACALL and to improve our system. Some typical feedback is listed as follows.

I think PACALL is easy to use. When I use the SenseCam without PACALL, I must find good photos in the folder from the browser. However when using PACALL, I just select them and click “upload.” The time is shown with the photo in PACALL, which is also helpful for selecting photos. Besides, inappropriate photos are already excluded by this system. It also helps.

It is better to use the Android Tablet PC in conjunction with the PACALL system.

In the passive mode, the learning contents are recorded even when I do not want to learn anything. On the other hand, in the active mode, photos can only be taken when I want to learn something.

I feel very embarrassed when using SenseCam.

The accuracy is not good enough for analyzing blurred photos.

The above comments show that this system is easy to use and the users seem moderately satisfied with the system. In the passive mode the learning contents could be recorded even if learners do not want to learn. In other words, the life-log pictures create more chances to learn vocabulary. However, the learners may feel embarrassed when wearing the SenseCam in public. Moreover, there is a privacy issue which is yet to be resolved. As for the problem of embarrassment, in the future, we believe that the SenseCam will get smaller and look better, and hopefully, learners will not feel so embarrassed wearing it. Besides, the algorithm for classification needs to be improved in the future.

**Conclusion**

This paper describes a ubiquitous learning log project in Japan called SCROLL. This project was partly supported by PRESTO of the Japan Science and Technology Agency (JST) from 2010 to 2013. It aimed to capture learning experiences in daily life and reuse them for learning and education. Especially, this paper focuses on capturing ubiquitous learning logs using life-log photos, which are automatically taken by SenseCam. We developed a system named PACALL to help learners find learning contents from life-log photos. Also, we took a further step in analyzing life-log photos for the main system. Therefore, PACALL is not only a learning content provider but also a learning content analyzer. Besides, the provided data of PACALL can also be used by the quiz module of SCROLL to determine the proper time for presenting learners with quizzes. We found that there are many useful pieces of information that can be mined from the life-log photos. In the future, we will improve the algorithm of image processing in this system and conduct an evaluation experiment.
Since SCROLL is intended to be used in general domains and for life-long learning, we will apply it to many application domains including foreign language, math, physics, and science education, and conduct a long-term evaluation with a larger sample of subjects. Another area of our future work is learning analytics. We plan to analyze the accumulated data in the learning logs to find learners’ learning patterns and learning habits in order to supply more appropriate learning materials in more appropriate places and at more appropriate times to improve the learning effects of the system.

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References


Context-Aware Mobile Role Playing Game for Learning – A Case of Canada and Taiwan

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ABSTRACT

The research presented in this paper is part of a 5-year renewable national research program in Canada, namely the NSERC/iCORE/Xerox/Markin research chair program that aims to explore possibilities of adaptive mobile learning and to provide learners with a learning environment which facilitates personalized learning at any time and any place. One of the sub-projects of this 5-year national research program is to design and develop context-aware mobile learning services. The research team of the sub-project applied narrative theory to design a location based Context-Aware Mobile Role Playing Game (CAM-RPG) in order to give students feeling of living in the game world and role playing, exploring the game world, completing the quests, and learning things. A pilot study was then conducted to see how the two game features – context-awareness and story generation – influence students' attitude towards the use of the mobile educational game. The research findings suggest that the story generated in CAM-RPG positively influences users' attitude towards game use and increases users' perceived game usefulness. With the research findings, other components and outcomes of sub-projects, such as natural language processing, location-awareness, multiple input forms, social networking, and student modeling, can then be put together as one piece to provide students effective and efficient mobile learning experiences.

Keywords

Context-awareness, Location-based, Narrative theory, Educational game, Mobile game, Role-playing game, Technology acceptance model

Introduction

The exponential growth of wireless technology in recent years, increasing availability of high bandwidth network infrastructures (e.g., the SuperNet in Alberta), advances in mobile technologies and the popularity of handheld devices have opened up new accessibility opportunities for education. This has given rise to a five-year research program, funded by Canadian federal government and Alberta Provincial government in collaboration with various industry partners. The program aims to explore and develop different applications and content delivery systems, extending our understanding of mobile learning to provide rich learning experiences in order to not only improve the existing educational environment but also to widen access to education for the disadvantaged, particularly those living in remote and rural communities, who generally do not have access to learning opportunities and the disabled, who need specialized devices and applications for learning.

The learning environment that is being developed under this research program consists of different servers and databases, and provides several services for students. The location-awareness service is aimed to help mobile students forming face-to-face-learning groups. Moreover, innovative social networking functions are integrated in the learning environment. An adaptive mechanism is also developed that is responsible for providing learners with learning materials that fit their individual learning styles. The context-awareness service identifies the personalized context-aware knowledge structure in an ubiquitous/pervasive learning environment and is aimed to direct individual learners to learn and move in the real world using automatically generated guidance messages. Furthermore, learners are supported by an intelligent and multimodal asynchronous questions & answers (Q&A) knowledge sharing platform.

The program has three stages. The first stage consists of Canadian research team designing and developing the game and Taiwanese team designing and conducting the pilot study to verify the usability of the game. The second stage involves Canadian team improving the game according to the feedback received in the first stage and conducting a pilot study in Canada for both the iterative development process and cultural difference investigation. The last stage of the program involves application of the well-designed final product in a formal class and a comparative experiment involving both Canadian and Taiwanese students. The program is currently at the end of first stage.
In 2010, the research team of context-aware sub-project developed a Context-Aware Mobile Educational Game (CAMEG) (Lu, Chang, Kinshuk, Huang, & Chen, 2010a, 2010b). The game generates a series of learning activities (i.e., a learning activity chain) to enable students to interact with specific real objects (e.g., projector, restroom, pine tree, etc.) and virtual objects (payroll system, business policy, E-Commerce course, etc.) in authentic environments. The series of learning activities is automatically generated for individual students according to their learning history and surrounding context (i.e., learning objects associated with the chosen role that the student wants to play, the chosen learning theme, student's location, etc.).

However, majority of the existing educational games, including mobile games, have not looked at such individual feelings. Focus has primarily been on how to teach specific discipline or curriculum in formal educational and on-the-job training settings (i.e., workplace, school campus, museum and historical site). These games become boring when students are simply asked to conduct certain activities one-by-one repeatedly. Few researchers have talked about how to design the contents of mobile educational games in order to make them attractive for the students. This paper focuses on this aspect with aim to improve effectiveness of the mobile educational games.

The rest of the paper is organized as follows. The next two sections introduce the research background by reviewing relevant literature on educational games. The research model and hypotheses used in this research are then described. This is followed by the description of the pilot design and the collected data. Statistical analysis methods are then used to find the answer to the research question. Finally, the implications of the findings are discussed and conclusions are drawn.

**Background and motivation**

In the last decade, many researchers have seen mobile learning (m-learning) as a further evolution of e-learning (Georgiev, Georgieva, & Smrikarov, 2004). Unlike computer-based learning (learning at a specific place with desktop computers), m-learning delivers education and training materials to a variety of lightweight devices such as personal digital assistants (PDAs), tablet PCs, smartphones, and mobile phones, which users can comfortably carry and use for learning anywhere, at anytime (Keegan, 2005). Beyond the learning devices, some researchers also think that the context of pedagogy differs between e-learning and m-learning. Especially for environmental sciences, m-learning brings potential benefits for learners' self-learning by realizing real-time and location-based learning materials (Jones, Scanlon, & Clough, 2013; Vogel, Spikol, Kurti, & Milrad, 2010).

Brown and colleagues argue that students can learn specific knowledge more efficiently by interacting with a situated environment (Brown, Collins, & Duguid, 1989). Learners can observe or touch the learning objects and can interact with the m-learning system immediately. Hwang, Yang, Tsai, and Yang (2009) also point out that context-aware learning is an innovative approach for detecting student situations and providing students personalized services and adaptive support. Wu and colleagues argue that context-aware ubiquitous learning enables students to interact with learning objects in the real world with the supports from the digital world (Wu, Hwang, & Tsai, 2013). It is important for a mobile learning system to be context-aware; hence, the research team decided to create an interesting context-aware mobile game for students learning domain knowledge.

Garris, Ahlers and Driskell (2002) applied an instructional model in games that uses game-feature-relevant instructional contents as inputs and makes the game-play a cycle. In this model, the repeatable judgment-behavior-feedback activity is a game cycle. These repeated activities can increase the student's motivation and enjoyment of playing the game, enable students to play the game continuously, and increase students' confidence in the gameplay (Garris, Ahlers, & Driskell, 2002).

Researchers have also identified the importance of story in the games (Connors, 2013; Simon, 2012; Sanders, 2011). Connors (2013) argues that story is fundamental for players remembering their gaming experiences and a game might be less impactful without the story. Simon (2012) argues that players may perceive two games to be exactly same if the games have no story, which would have negative effect on learners’ motivation to come back to play the games. Sanders (2011) argues that story can make players aware of the goal of the game and can keep them exploring the game.
In order to make the Context-Aware Mobile Role Playing Games (CAMEG) interesting for the users and to motivate them to play, narrative elements were taken into consideration in this research. Narrative theory covers the elements that a story needs (Conle, 2003); therefore, it was decided to design the story generation engine based on narrative theory. The narrative elements such as storyline, character, and interaction have been analyzed in the literature and used in the game-based learning system design (Ying, Wu, Chang, & Heh, 2009). Researchers have also integrated various narrative elements and designed different approaches for generating story (Akimoto & Ogata, 2011; Akimoto & Ogata, 2012). The research team therefore applied narrative theory to enhance CAMEG in order to give students feeling of living in the game world and role playing, exploring the game world, completing the quests, and learning things. At the end, the enhanced mobile educational game with stories - Context-Aware Mobile Role-Playing Game (CAMRPG) was developed in 2011 (Lu, Chang, Kinshuk, Huang, & Chen, 2011c).

The research team has subsequently been tackling the following research question: do the two game features – context-awareness and story generation – really influence students' attitudes towards using such educational mobile role-playing games? A pilot study has been conducted, where a questionnaire (and associated statistical analysis) was employed to gather students' attitudes toward the game.

**Story decorated context-aware mobile role-playing game**

To develop a lightweight, flexible, and scalable mobile educational game based on the research components designed by various sub-projects of the research chair program, a multi-agent architecture (MAA) has been used (Lu, et al., 2010b, 2011a). A multi-agent system is a software environment containing many agents who are responsible for their own tasks while collaborating with other agents whose responsibilities belong to the pre- and post-requisite tasks. Multi-agent architecture is particularly useful for developing mobile applications because it can divide a complex task into several smaller tasks and can assign these tasks to different agents. Moreover, these agents can work either within same device (e.g., a mobile phone) or on different machines/platforms as a distributed system (Balaji and Srinivasan, 2010).

Figure 1 shows the multi-agent architecture of the mobile educational game developed in this research. More details for the responsibilities of each agent and the collaboration among agents can be found in Lu, et al. (2011a).

Figure 2 shows the screenshots of the game-play of CAMRPG. During the game-play, the Player Agent is the only agent that interacts with the user and enables data exchange between the user and other agents.
As shown in Figure 2, in the game, roles and corresponding pre-defined themes are designed for students to have opportunity to choose what learning direction and discipline they really need. For instance, a student who takes Introduction to Management Information System course may want to know more about what enterprise support system is and what benefits a business can gain from it. In such circumstances, the student can choose a particular role and theme s/he wants to play, for instance, a chief information officer (i.e., step 2).

The game then generates learning activities for the individual students according to the chosen role and theme. Before the students are asked to do the learning activities, the game makes stories up automatically and uses the stories to populate the generated learning activities for the individual students (i.e., step 3). After the students finish reading the story, the game shows them the learning activities (i.e., step 4). The students can use the built-in camera to collect the required learning object(s) by taking pictures of the objects’ QR codes (i.e., step 5). Once the game has verified the correctness of the collected learning objects, it delivers each student a piece of text-based learning material about the corresponding learning object (i.e., step 6). In addition to text-based learning contents, the learning contents can also be HTML-based, binary-based image, URL of webpage, media stream and Flash animation.

At the end, the game checks if the students have completed all generated learning activities for the chosen role and theme. If there are other activities left, the game takes the individual students back to step 3 to read another story and asks them to finish another learning activity (as flow B on Figure 2 shows). If no activity is left, the game takes the students back to theme selection screen (as flow A on Figure 2 shows). The students can then either choose another theme or can even take another role.

**Research model and hypotheses**

The research team decided to explore the connection between student's perceived usefulness of the game and the two features (i.e., context-awareness and story generation) step by step, with the following research question "do the two game features – context-awareness and story generation – really influence students' attitudes towards using educational mobile role-playing games?"
A number of models have been proposed in the literature for analyzing user perceptions and acceptance towards technological systems. A well-established and tested model in the literature is the Technology Acceptance Model (TAM), proposed by Fred D. Davis in 1986. This model has become one of the most common instruments used to explain the users' behavioral intention of using an innovative technology. Original TAM has four constructs: the perceived ease of use, the perceived usefulness, the attitude toward using the innovative technology, and the behavioral intention of using the innovative technology.

Some researchers have also examined the acceptance factors for educational games or entertainment games by adding their own variables to the original model to explore the influences of different external variables, for instance, gender, gaming experience, learning opportunities and the unified theory of acceptance and use of technology (UTAUT) (Bourgonjon, Valcke, Soetaert, & Schellens, 2010; Ibrahim, 2011). In the pilot study of this research, two external variables (i.e., the two game features, namely context-awareness and story generation) are proposed for inclusion in the original TAM.

The proposed research model is adopted from the research done by Ibrahim (2011) and Bourgonjon et al. (2010). Different from previous models, this research has four moderators, namely gender, gaming experience, smartphone experience, and context-awareness feature as variables. The reason for taking smartphone experience into consideration is analyze whether or not the students who do not have experience in using smartphone encounter difficulty in using the game and perceive low ease of use than the students who have experience in using smartphone. Figures 3 and 4 show the macro view (i.e., all considered theories) and micro view (i.e., the detailed constructs) of the proposed research model respectively.
The hypotheses needed to be verified in the research model are listed in Table 1.

<table>
<thead>
<tr>
<th>Macro view</th>
<th>Micro view</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>H1: Attitude has a positive effect on behavioral intention.</td>
</tr>
<tr>
<td>H2</td>
<td>H2a: Perceived ease-of-use has a positive effect on attitude toward using CAMRPG.</td>
</tr>
<tr>
<td></td>
<td>H2b: Perceived usefulness has a positive effect on attitude toward using CAMRPG.</td>
</tr>
<tr>
<td></td>
<td>H2c: Perceived ease-of-use has a positive effect on perceived usefulness.</td>
</tr>
<tr>
<td>H3</td>
<td>H3a: Context-awareness feature has a positive effect on attitude toward using CAMRPG.</td>
</tr>
<tr>
<td></td>
<td>H3b: Story generation feature has a positive effect on attitude toward using CAMRPG.</td>
</tr>
<tr>
<td>H4</td>
<td>H4a: Context-awareness feature has a positive effect on perceived usefulness.</td>
</tr>
<tr>
<td></td>
<td>H4b: Story generation feature has a positive effect on perceived usefulness.</td>
</tr>
</tbody>
</table>

**Pilot design and data collection**

The purpose of the pilot study was to analyze whether a mobile learning system with the two features improves learners’ willingness of using it. Initially, the researchers introduced the game and conducted a demonstration in a Management Information System (MIS) class at a national university in Taiwan. The researchers explicitly told the students that there was no compensation, reward, or recognition for anyone who participated in the study. It was also made clear that there were no consequences for not taking part in the study.

The experiment environment of the pilot study consisted of three laboratories located within one building of the university. Since all participants were taking undergraduate level MIS course at that moment (June, 2011), the MIS course contents and concepts were incorporated into the game and a virtual science park was built in that building. The park consisted of many famous IT businesses and companies that virtually resided in the park, and participants interacted with those organizations in the virtual park while playing the game.

The participants were asked to complete a demographic questionnaire before playing the game. All participants had 20 minutes to play the game in the authentic learning environment using the smartphones prepared by the researchers.

As the participants started to play the game, they received story-enhanced learning activities and looked for the required learning objects in the real world. The learning objects were associated with MIS topics/concepts and were presented in different formats, such as video clips, presentation slides, case studies, and real systems. In the gameplay, participants acted as information technology (IT) experts and received quests from their boss (i.e., a non-player-controlled character). The quests asked them to visit the science park (i.e., the authentic learning environment) and collect some important information for their company. While they were playing, they would learn about these learning objects actively through presentations and demonstrations instead of sitting passively in a classroom and receiving lectures from the course instructor.

After the game-play, they were asked to fill out the technology acceptance model questionnaire. The questionnaire had thirty one five-point Likert-scale items (ranging from 5 for "strongly agree" to 1 for "strongly disagree") to address four main constructs of Technology Acceptance Model (i.e., perceived ease of use, perceived usefulness, attitude toward using, and behavioral intention of using), and two examined constructs (i.e., context-awareness and story generation).

**Reliability analysis**

The questionnaire was adopted from previous research results, and its validity and reliability have been proven by Lu, Chang, Kinshuk, Huang, and Chen (2011b). The data collected in this research was analyzed before using it to examine/verify the hypotheses. Some participants did not show up at the scheduled time, hence, the corresponding
responses of the questionnaire were removed. In addition, responses of two more participants were removed because they had extreme values for all questions and had conflicting answers for the flip-flop items. The final valid sample therefore included 62 students, consisting of 34 male and 28 female students.

Table 2 lists the results of reliability analysis. The Cronbach's alpha for the overall questionnaire is 0.826, indicating that the questionnaire (and its items) can be seen as reliable because its internal consistency is good enough (i.e., exceeds 0.75) (Hair, Anderson, Tatham, & Black, 1998).

The results showed that all constructs, except the behavior construct, had good measure of reliability. The three items of the behavior construct were reviewed and it was concluded that these items might not explain the construct well in this research because of the different subjective situations this research has. The three items had no correlation with the other constructs either. Therefore, the behavior construct was removed.

<table>
<thead>
<tr>
<th>Table 2. Reliability analysis results of the technology acceptance model questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct</td>
</tr>
<tr>
<td>Perceived ease of use (PEoU)</td>
</tr>
<tr>
<td>Perceived usefulness (PU)</td>
</tr>
<tr>
<td>Context-awareness feature (CA)</td>
</tr>
<tr>
<td>Story generation feature (SL)</td>
</tr>
<tr>
<td>Attitude toward using CAMRPG (ATT)</td>
</tr>
<tr>
<td>Intention of using CAMRPG (IT)</td>
</tr>
</tbody>
</table>

**Note.** Bold and underline = Cronbach's alpha value is lower than 0.75.

Validity analysis

Next, the internal commonality of items for each factor in the research model was examined using principal component analysis. Three items – PEoU3, PEoU4, and CA02 – were found to have factor loading less than 0.6 and therefore not good enough for presenting the construct. It was decided to remove these three items. The removal of PEoU3 and PEoU4 also improved the Cronbach's alpha value of "Perceived easy of use" construct by bringing it to 0.774, and the removal of CA02 improved the Cronbach's alpha value of "Context-awareness feature" construct to be 0.807. The remaining items could then be used to represent the factors respectively. Lower factor loading may have occurred due to unclear questions or misunderstanding. They need to be revised to fit the presented constructs in future studies and experiments. Table 3 lists results of all constructs in principle component analysis.

<table>
<thead>
<tr>
<th>Table 3. Validity analysis results of the technology acceptance model questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
</tr>
<tr>
<td>Factor 1: Perceived ease of use (PEoU) α = 0.743</td>
</tr>
<tr>
<td>I2: It is easy to learn how to play</td>
</tr>
<tr>
<td>I31: The system flow is clear and simple to me</td>
</tr>
<tr>
<td>I32: The terms and functions in the game are easy to understand</td>
</tr>
<tr>
<td>I5: User interface are easy to use</td>
</tr>
<tr>
<td>I35: I can get familiar with the learning objects quickly</td>
</tr>
</tbody>
</table>

| Factor 2: Perceived usefulness (PU) α = 0.793                                             |
| I26: It provides me enough information for what I want to know               | .762       |
| I29: I can get needed information quickly within the game                   | .758       |
| I24: The learning activities can save my time in learning                   | .741       |
| I26: This game makes me want to explore the game's world                    | .733       |
| I25: This game provides me enough information for learning                  | .703       |

| Factor 3: Context-awareness feature (CA) α = 0.752                                    |
| I15: The learning objects are associated to my chosen theme                  | .844       |
| I14: If a quest required multiple learning objects, all of them can be found in the authentic learning environments | .761       |

Note: Bold and underline = Cronbach's alpha value is lower than 0.75.
Factor 4: Story generation feature (SL) α = 0.832
I12: The objects can be found in the learning environments .755
I16: The quest difficulty is from simple to complex .717
I17: It doesn't generate exactly same quest for me .701

Factor 5: Attitude toward using CAMRPG (ATT) α = 0.807
I7: I would like to use the game much more if I can team up with other players in the game .875
I9: The stories give me some ideas of what I should do .826
I10: The integration of storyline and quests is perfect .813
I8: The storyline makes the game more interesting .775

Factor 6: Intention of using CAMRPG (IT) α = 0.679
I23: I hope the course's instructor to apply "CAM-RPG" into the course .710

Descriptive statistics
The demographic questionnaire collected participant's gender information, experiences of playing games, time spent in playing games, and experiences with smartphones. Table 4 lists basic information for the final sample of 62 participants.

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Smartphone(s) using experience</th>
<th>Playing video games</th>
<th>Playing handheld video games</th>
<th>Playing computer games</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>34</td>
<td>10 (29.4%)</td>
<td>30 (88.2%)</td>
<td>29(85.2%)</td>
<td>34(100%)</td>
</tr>
<tr>
<td>Female</td>
<td>28</td>
<td>9 (32.1%)</td>
<td>21 (75%)</td>
<td>22(78.5%)</td>
<td>27(96.4%)</td>
</tr>
<tr>
<td>Total</td>
<td>62</td>
<td>19(30.6%)</td>
<td>51(82.2%)</td>
<td>51(82.2%)</td>
<td>61(98.3%)</td>
</tr>
</tbody>
</table>

Note. Overall α = 0.826, total variance explained is 67.54%

At the end, a valid and reliable technology acceptance model questionnaire for measuring participants' attitude towards mobile educational game with six constructs and twenty eight items was determined and confirmed. Quantitative statistical method was then used to get the answers for the research questions.

Data analysis and results
In order to answer the proposed research question, descriptive statistics was initially used to summarize the collected data and compare the constructs' mean and standard deviation values for different groups (e.g., gender smartphone use and player types). Independent t-test was then used to explore whether or not different groups of participants have different attitudes toward CAMRPG.

Descriptive statistics
The demographic questionnaire collected participant's gender information, experiences of playing games, time spent in playing games, and experiences with smartphones. Table 4 lists basic information for the final sample of 62 participants.
Table 4 shows that most participants had rich experiences of playing games, especially computer games. Video and computer games are both found to be major entertainment activities for them. In addition, only 30.6% of participants had experiences of using smartphones.

Quantitative analysis

Independent t-test was used to explore whether there were significant differences in technology acceptance between different groups of participants (e.g., gender, time spent playing computer games, and experiences of using smartphones). The statistical data analysis in Table 5 shows two meaningful results: (1) female participants have more positive feedback than male participants for all constructs; and, (2) there is no obvious difference between male and female participants in their responses for six constructs. The results are in line with the findings of previous researchers (Gwee, Chee, & Tan, 2010; Law, 2010; Papastergiou, 2009).

<table>
<thead>
<tr>
<th>Construct</th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>t value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived ease of use</td>
<td>Female</td>
<td>28</td>
<td>4.3429</td>
<td>.40682</td>
<td>1.579</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>34</td>
<td>4.0765</td>
<td>.81205</td>
<td></td>
</tr>
<tr>
<td>Perceived usefulness</td>
<td>Female</td>
<td>28</td>
<td>4.3000</td>
<td>.37515</td>
<td>1.987</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>34</td>
<td>3.9882</td>
<td>.75629</td>
<td></td>
</tr>
<tr>
<td>Context-awareness feature</td>
<td>Female</td>
<td>28</td>
<td>4.0000</td>
<td>.29313</td>
<td>0.106</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>34</td>
<td>3.9882</td>
<td>.56126</td>
<td></td>
</tr>
<tr>
<td>Story generation feature</td>
<td>Female</td>
<td>28</td>
<td>4.0982</td>
<td>.51523</td>
<td>1.065</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>34</td>
<td>3.9412</td>
<td>.62480</td>
<td></td>
</tr>
<tr>
<td>Attitude toward using CAMRPG</td>
<td>Female</td>
<td>28</td>
<td>4.2589</td>
<td>.36945</td>
<td>1.519</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>34</td>
<td>4.0368</td>
<td>.74907</td>
<td></td>
</tr>
<tr>
<td>Intention of using CAMRPG</td>
<td>Female</td>
<td>28</td>
<td>3.9857</td>
<td>.60106</td>
<td>1.422</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>34</td>
<td>3.7471</td>
<td>.70032</td>
<td></td>
</tr>
</tbody>
</table>

From Table 5, it can be seen that although the mean values of both groups are quite high (positive) for all constructs, male participants have relatively higher standard deviation. This circumstance shows that male participants may have extreme high or low responses for these constructs. It is notable that the statistical analysis for experience of using smartphones shows no obvious difference between smartphone users and traditional mobile phone users.

Multiple regression

To explore the cause-effect relationships in the research model, a simple linear regression (i.e., use of attitude towards using CAMRPG to determine the intention of using CAMRPG) and several multiple linear regressions (e.g., use of perceived ease of use, perceived usefulness, context-awareness feature, and story generation feature to determine attitude towards using CAMRPG; and, use of perceived ease of use, context-awareness feature, and story generation to determine perceived usefulness) have been used. Such multiple regression analysis is typically used to examine and predicate the linear relationship between one dependent construct and one or more independent construct(s).

First, the independent factors were analyzed before entering the regression model in order to know whether there is a collinear problem in the statistics. A collinear problem is a statistical situation in which two or more predictors (independent constructs) in a multiple regressions are highly correlated. This situation causes an abnormally high R-square (i.e., explanatory power) in the regression model because the variances, standard error, and parameter estimates of predictors are probably inflated. It may also cause insignificant or incorrect coefficients (e.g., positive to negative) between predictors and affected variables.

The existence of linear dependence in the independent constructs can be determined by observing the collinearity statistic fields in Table 6. A collinearity statistic indicates that the construct may have a serious overlap (i.e., a collinearity problem, which means there is high correlation between the independent constructs) if the variance
inflation factor (VIF) is over 10 and tolerance tends to zero (Hair, Anderson, Tatham, & Black, 1998). The results show that there is no serious collinearity issue between the independent constructs in Table 6, in which tolerance > 0.1, VIF < 10, and no two variables' variances > 0.8 at the same line.

Table 6. Coefficients of perceived ease of use, perceived usefulness, context-awareness and story generation feature

<table>
<thead>
<tr>
<th></th>
<th>Unstandardized coefficients</th>
<th>Standardized coefficient</th>
<th>t</th>
<th>Significance</th>
<th>Collinearity statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>ß</td>
<td></td>
<td>Tolerance</td>
</tr>
<tr>
<td>(constant)</td>
<td>.441</td>
<td>.423</td>
<td>1.044</td>
<td>.301</td>
<td>.260</td>
</tr>
<tr>
<td>Perceived ease of use</td>
<td>.296</td>
<td>.137</td>
<td>.323</td>
<td>2.162</td>
<td>.035*</td>
</tr>
<tr>
<td>Perceived usefulness</td>
<td>.338</td>
<td>.146</td>
<td>.346</td>
<td>2.311</td>
<td>.024*</td>
</tr>
<tr>
<td>Context-awareness feature</td>
<td>.015</td>
<td>.156</td>
<td>.012</td>
<td>.099</td>
<td>.921</td>
</tr>
<tr>
<td>Story generation feature</td>
<td>.248</td>
<td>.111</td>
<td>.234</td>
<td>2.235</td>
<td>.029*</td>
</tr>
</tbody>
</table>

Note. Dependent variable: Attitude toward using CAMRPG *: p < 0.05

Table 7. Collinearity diagnostics

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Eigenvalue</th>
<th>Condition index</th>
<th>Variance proportions (constant)</th>
<th>PEoU</th>
<th>PU</th>
<th>CA</th>
<th>SL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.968</td>
<td>1.000</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>2</td>
<td>.015</td>
<td>18.274</td>
<td>.41</td>
<td>.12</td>
<td>.07</td>
<td>.01</td>
<td>.01</td>
</tr>
<tr>
<td>3</td>
<td>.009</td>
<td>23.118</td>
<td>.21</td>
<td>.06</td>
<td>.00</td>
<td>.00</td>
<td>.84</td>
</tr>
<tr>
<td>4</td>
<td>.005</td>
<td>32.640</td>
<td>.30</td>
<td>.03</td>
<td>.32</td>
<td>.71</td>
<td>.01</td>
</tr>
<tr>
<td>5</td>
<td>.003</td>
<td>38.685</td>
<td>.09</td>
<td>.79</td>
<td>.61</td>
<td>.28</td>
<td>.13</td>
</tr>
</tbody>
</table>

Note. Dependent variable: Attitude toward using CAMRPG. PEoU = Perceived ease of use; PU = Perceived usefulness; CA = Context-awareness feature; SL = Story generation feature.

Table 8 lists the coefficients of four independent constructs towards the dependent construct – attitude towards using CAMRPG. Three constructs (i.e., perceived ease of use, perceived usefulness, and story generation feature) present significant coefficient measures (ß = 0.323, 0.346, and 0.234, p < 0.05).

Path analysis for the multiple regressions model

Figure 5 shows the path diagram of the research model. The result of path analysis shows that the attitude towards using CAMRPG (ATT) has strong effects on the intention of using CAMRPG as 0.455 (p < 0.001) of path coefficient. The effects of perceived ease of use (PEoU), perceived usefulness (PU), context-awareness feature (CA) and story generation feature (SL) explain 74% of the attitude towards using CAMRPG, while perceived ease of use (PEoU), perceived usefulness, and story generation feature have significant effects (ß = 0.331, 0.437, and 0.234, p < 0.05) on the attitude towards using CAMRPG, but context-awareness feature does not (ß = 0.012). For the cause-and-effect relationship between the independent variables, the effects of perceived ease of use, context-awareness feature, and story generation feature explain 75% of perceived usefulness, while perceived ease of use (ß = 0.678, p < 0.001) and story generation feature (ß = 0.206, p < 0.05) have significant effects on perceived usefulness, but context-awareness feature does not (ß = 0.066).
Findings and discussions

Data analysis revealed several findings that can help in understanding users' attitudes towards and acceptance of the proposed mobile educational game as well as exploring the answer of the research question: do the two game features—context-awareness and story generation—really influence students' attitudes towards using educational mobile role-playing games?

These findings are categorized into three categories: common findings (i.e., those that have been proven in other research), important findings (i.e., those that are supported by this research), and unexpected findings (i.e., those that did not support our assumptions in this research).

Common findings

Findings suggested that the original technology acceptance model presents good results in cause-and-effect relationship of all factors (e.g., PEoU, PU, ATT, and IT). In particular, for the path coefficients found between perceived ease of use and perceived usefulness, the results indicate that ease of use is an important factor in context-aware mobile educational game design as well as other technology acceptance issues. Users appreciate a simple and easy-to-use interface, and a user-friendly interface directly impacts perceived usefulness. In addition, attitude towards using CAMRPG and intention of using CAMRPG also present strong significant coefficients in our research model. These findings have been proven in many studies that have focused on the acceptance towards information systems.

Important findings

First of all, the descriptive statistical data (i.e., Table 6) shows that the responses from both males and females were positive in terms of appreciation of the proposed CAMRPG. In addition, responses of female participants to all factors were relatively higher than those of male participants in the pilot.

The result did not show any significant differences between participants who have experience using smartphones and those who only have experience using traditional mobile phones. The reason may be that the participants in this pilot were undergraduate students and they were all familiar with mobile phones and games. Therefore, experience of
using smartphones did not affect acceptance of innovative technology. On the other hand, from the perspective of national research program, this result suggested that there is no need to worry about whether or not a user has used a smartphone while deploying such context-aware mobile role-playing game for learning.

Unexpected findings

From the path analysis results, it was found that most of the proposed factors qualified to explain the dependent variables, except the context-awareness feature factor. One reason perhaps is that the context-awareness feature is transparent to its users. For instance, a participant will receive from the game only those learning activities that involve learning objects in a library if the game detects that the participant is in library at that moment. So the participant would not feel what exactly the feature does for him or her. Another reason could be that the experiment environment in the pilot might not have represented the concept of context-awareness well enough to make participants aware of this game feature. For instance, the pilot was conducted using a virtual science park that was built in a university building used by the participants regularly for attending classes, which made it difficult for participants to have immersive feelings that they were in San Francisco or Helsinki. Finally, this pilot did not cover different buildings and did not continue over a longer time period. In such case, the participants could not experience scenarios like signing on to get quests at different places. These shortcomings might have caused the context-awareness feature factor to present relatively lower measures and an insufficient cause-and-effect relationship on the path coefficient.

Conclusions

This paper presented the outcome of the first stage of the context-aware sub-project, under the auspices of the 5-year national research chair program, namely the context-aware mobile role playing game, in which its kernel – learning activity generation engine and story generation engine – can automatically generate a series of story-based learning activities. This game can help users in learning by role-playing in authentic learning environments. The story makes up the learning activity chain resulting in more interesting and immersive learning process. Integrating story into a mobile educational game increases the perceived effectiveness and satisfaction toward the game, especially for the male students. On the other hand, the story reduces the perceived efficiency of using the system.

The findings indicate that participants in the pilot found the context-awareness feature of the game to be less important for the game-play and this factor did not affect their attitude towards using the game. The findings also identified the importance of authentic environment in mobile learning. The pilot study designed in this research clearly demonstrated that the context-awareness ability of the system was not even noticed by students, since they were asked to imagine a floor of a teaching building in school campus as a country in the world, hence there was a lack of an authentic environment. Such mismatch between the virtual and the real world has potential to reduce the perceived usefulness of the context-awareness functionality.

To make users aware of the advantages of a context-aware mobile educational game, subject selection (e.g., learning environment, selected learning topic, and learning materials) would be an important issue. The current game seems to work well for outdoor teaching/learning as well as learning based on treasure hunting paradigm at particular sites (e.g., museums, botanical gardens, and historical sites). It is also suitable for replacing orientation/training courses for freshmen and new students of the graduate programs. However, such game might not be suitable in environments in which learning objects have no strong connections to either the learning topic or the environment (e.g., trying to learn a business intelligent system from a desktop computer in a laboratory).

The pilot study encompassed only a short-term intervention whose effect may not be carried for long run. The research results also provided a clear picture of what learning topics may be more appropriate for applying context-aware mobile role-playing games, what authentic environment and learning objects are the best for deploying context-aware mobile learning systems, and what features are important to students who use mobile role-playing games.

The next stage research will focus on continuing the architecture design and proof of concept of the services developed under the national research program. This includes the incremental improvement of various modules
Based on proof of concept evaluations in Canada as well as continuing to integrate the developments within the overall system. As the research results show that the context-awareness feature is difficult to be noticed when the learning environment is a mix of mismatched virtual and real worlds, augmented reality may help in enhancing the perceived usefulness of context-awareness feature of the game. Also, in order to increase the effectiveness of the game, ordinary learning activities, such as field trips and remedial learning can be integrated into the game. Future plans of the context-aware sub-project include: (1) study and application of augmented reality concept within the interactive mobile learning systems in order to provide students the benefits of context-awareness; (2) develop Android version of CAMRPG and deploy it in rural areas for K-12 education and field trips; and, (3) integrate the outdoor remedial instructions and worksheet idea together to provide students an even more personalized ubiquitous learning experience according to their academic performances and the context surrounding them.

References


Potentials of Mobile Technology for K-12 Education: An Investigation of iPod touch Use for English Language Learners in the United States

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ABSTRACT
This case study investigated a m-learning initiative by a large school district in the United States to provide iPod touch devices 24/7 to teachers and students of English Language Learners. We described the initiative and presented the research findings of its implementation for two years at elementary and middle school levels. The results revealed the iPod touch was used to support language and content learning, provide differentiated instructional support, and extend learning time from classroom to home. However, several challenges were identified such as significant time demand on the teachers, technical issues, the need for professional training and dedicated support staff. Implications for teachers, instructional technologists, school administrators, and researchers were discussed.

Keywords
iPod touch, Mobile device, M-learning, English language learners, K-12 education

Introduction
Emerging mobile technology is having a transformative impact on how people live, learn, work, and play. According to 2012 Horizon Report for K-12 Edition (Johnson, Adams, & Cummins, 2012), “mobile devices & apps and tablet computing as technologies expected to enter mainstream use in the first horizon of one year or less.” Incorporating mobile devices in K-12 education has experienced increased interests and schools in the United States (US) are looking for new opportunities and possibilities introduced by the mobile technology. We describe an initiative by a large school district in the southwest region of US to provide iPod touches 24/7 to teachers and students of English Language Learners (ELL). We present research findings of its implementation for two years from 2010 to 2012 at elementary and middle school levels. ELL students are those who speak diverse languages such as Spanish, French, Portuguese, Chinese, and Japanese. With different levels of English proficiency (some have been in US schools for several years, while others are new to English language instruction), they represent distinct academic challenges in language acquisition. Especially in the region, Spanish-speaking students are a rapidly growing population. The goal of investigating iPod touch use over two implementation cycles is to gain an in-depth understanding of the potential benefits of such devices as a teaching and learning tool for the ELL population. The findings of this research have implications for teachers, instructional technologists, school administrators, and researchers as they explore and consider mobile technologies for K-12 education.

Relevant research
Mobile learning has garnered considerable interests from the educational community (Koole, 2009; Traxler, 2011) and literature on mobile learning has identified such affordances as flexibility, accessibility, interactivity, and motivation and engagement. Implementing flash card learning, for example, Kiger, Herro, and Prunty (2012) found third-graders improved their multiplication skills using iPod devices. Studies have shown Internet-enabled mobile devices can support cognitive learning (Peng & Chou, 2007); mathematics learning (Kalloo & Mohan, 2011); language and literacy learning (e.g., Coe & Oakhill, 2011; Kemp & Bushnell, 2011); and game-based learning (e.g., Liao, Chen, Cheng, Chen, & Cha, 2011).

For ELL students, ready access to information technology is considered a critical factor (Cummins, 2000). Mobile Internet-enabled devices can provide ELL students with access to learning resources for “comprehensible input” in language acquisition necessary for academic success (Cummins, 2000, p. 541). Using the mobile devices for audio with trade books provided by the school teacher-librarian in collaboration with teachers, Patten and Craig (2007) found iPod shuffle devices to support reading and writing with ELL students. By adding audio support to their text
reading and journal writing, the use of the iPod devices were also found to significantly increase student engagement and allow the students greater connection to the “U. S. popular culture” (Craig & Paraiso, 2007, p. 1840).

Despite the perceived affordances of m-learning, there is a paucity of research on using mobile devices with ELL students, especially how ELL teachers and students use such devices in classrooms for teaching and learning. This study investigates ELL teachers’ and students’ use of iPod touches in elementary and middle school classrooms as well as their perceptions of using it as a teaching and learning tool. Our research question is: In what ways can iPod touch devices serve as a teaching and learning tool for English Language Learners?

**Research project**

**Research background**

The mobile initiative, for which this research was conducted, took place in a large school district in the southwest region of US. The district has a 2011 enrollment of about 18,000 students in grades K-12 and covering an area of about 600 square miles. Of that population, about 4.5% are students with limited English proficiency. Spanish is the primary language spoken at home for about 90% of ELL students in the district, while the remaining ELL students speak a variety of other languages at home. Because of different levels of English proficiency, teaching ELL students is a unique academic challenge. In an attempt to address a substantial gap between the test scores of ELL students versus other students in the district, in September 2009 the school district purchased the latest mobile technology with Internet at the time - iPod touch - for every ELL student and teacher at the middle school level. By allowing ELL students, 24/7 utilization of the devices for accessing additional educational resources, the district is hoping to boost the ELL students’ English language proficiency. In this district, ELL students in grades K-5 are placed in bilingual instruction classrooms that consist of ELL students only. In sixth grade, ELL students transition away from bilingual classroom into mainstream regular education classroom where ELL students are mixed with non-ELL students with support from English as Second Language (ESL) teachers. In 2011-2012, this mobile initiative expanded from middle school level (grade 6-8) to 4-5 grades at elementary level for ELL teachers and students only.

In this paper, we report the research conducted in two cycles: Year One implementation from 2010-2011 and Year Two implementation from 2011-2012.

**Participants**

The participants in this research were two ELL middle school teachers and their students for the first cycle (during 2010-2011 school) and two ELL elementary school teachers and their students for the second cycle (during 2011-2012 school year). Two sixth-grade teachers were selected because they were among the first to implement the initiative. Two teachers, fourth and fifth grade, were selected because they were part of the initiative during the second cycle and were teaching only ELL students. Teachers’ demographics are provided Table 1. In addition to iPod touch, all these teachers had access to other technologies such as an interactive whiteboard, a desktop computer, a Mac laptop, and a document camera in their classrooms.

<table>
<thead>
<tr>
<th>Data collection period</th>
<th>Level</th>
<th>Teacher</th>
<th>Years of teaching</th>
<th>Grade levels taught</th>
<th>Total students taught/managed</th>
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<tr>
<td>Cycle one: 2010-2011</td>
<td>Middle school</td>
<td>Virginia</td>
<td>26</td>
<td>6-8</td>
<td>40</td>
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<tr>
<td></td>
<td></td>
<td>Claire</td>
<td>7</td>
<td>6-8</td>
<td>31</td>
</tr>
<tr>
<td>Cycle two: 2011-2012</td>
<td>Elementary school</td>
<td>Clara</td>
<td>14</td>
<td>4-5</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lydia</td>
<td>23</td>
<td>4-5</td>
<td>42</td>
</tr>
</tbody>
</table>

Table 1. Demographics of the teachers
Data sources and analysis

The primary data sources were (1) interviews with the teachers, (2) classroom observations, and (3) surveys with the students.

Interviews were conducted with each teacher at three different times: the beginning of their iPod touch implementation, the mid-school year and toward the end of the school year. The goal of these interviews was to understand the teachers’ and students’ experience and perceptions toward iPod touch use. Questions varied because of the different focus for each interview during the year. Sample questions are:

At Beginning-of-Year:
- How are you using the iPods?
- How are the students using the iPods?

During Mid-year:
- How are you using the iPod touch?
- Please describe how does the iPod touch help student learning? How does it constrain student learning? Provide examples.
- What, if any, challenges are there in developing iPod touch activities? Examples?
- How is iPod touch used outside of the school day?

At End-of-Year:
- How did you use the iPod touch in your teaching? What has worked and what has not?
- In your opinion, does the iPod touch make a difference in the students’ learning? Provide examples?
- In what way does iPod touch support your students’ learning? How does that compare to student learning without the iPods?
- Do you see any challenges in using the iPod? Explain.

All interviews were conducted face-to-face or through conferencing software, audio-recorded, and transcribed. Researchers also observed each teacher’s use of iPod touch in their classrooms. Field-notes were taken and details of the activities were written afterwards. The guidelines of Strauss and Corbin (1990) were followed in the data analysis: First, each interview was independently coded by one researcher to generate a list of initial codes, then another researcher reviewed and verified the codes. Necessary coding modification, realignment, and refinement were made during the process. This data analysis went through several iterative cycles until codes were categorized and themes emerged. Any disagreement was discussed until 100% inter-rater reliability was reached. Interview quotes were presented below as unedited. Observation notes were analyzed in a similar way and were used to supplement the interview data.

Three surveys were given to the students: at the beginning, middle, and end of the school year. The goal of the surveys was to seek students’ self-reported usage (as there was no tracking software available for iPods) and find out their perception toward having iPod touch as a learning tool. Sample survey questions are “How often do you use the following applications/features at school?” “How often do you use the following applications/features at home?” “How helpful or fun do you think the following applications or features are?” and demographic questions. Survey responses were analyzed descriptively and frequency data were tallied. Since not all students responded to all survey items, the results provided the percentages of those who responded to the questions. Throughout the data collection process, the research team met regularly to discuss what they observed in different classrooms, shared insights, and performed peer debriefing.

Findings

Year-one implementation

Virginia taught three classes per day to ELL students and two of these were dedicated to beginner ELL students while Claire taught four periods of ELL classes with three of these dedicated to beginners. In their second year of
iPod use in their classrooms, Virginia and Claire enthusiastically embraced the opportunity the iPod touch initiative presented and were the first group of teachers who implemented it in their classrooms.

Interviews with Virginia and Claire and classroom observations revealed both teachers had very positive perceptions toward using iPod touch and found ways to incorporate the device in their daily teaching activities as well as home assignments. Data analysis highlighted a few affordances of mobile technology in their case: Using iPod touch to (1) support language and content learning with Internet-based multimedia resources, (2) provide differentiated instructional support to accommodate students’ individual needs and create collaborative learning opportunities, and (3) extend learning time from classroom to home use and establish a better home-school connection.

Support language and content learning

The student iPod touches were preloaded and synced by the teachers with native apps along with an Internet browser as well as a variety of learning games, videos, audio books, multimedia, and textbooks. Virginia and Claire had students access a wide range of multimedia resources to support English language learning in classes as well as assigned homework.

During the classroom instruction, the students were able to access resources such as translation dictionaries that provided audio pronunciations along with images to support the vocabulary acquisition and audio textbooks. Claire described an English learning activity, “They go find a picture and the name of the picture, we use [the app] ComicLife for that, so they have a picture and vocabulary word and at the beginning they add a Spanish word to it.” Students used the devices for just-in-time translations as well as multimedia materials to support content learning in math, science, and social studies. For example, Virginia described, “I used a lot of the science videos and I try to keep it on the topic that the science teachers are teaching.” The iPod touch, as a small and portable computer with Internet access, was available to students 24/7 and provided them with a plethora of multimodal resources for English language and content learning.

Provide differentiated instructional support

In addressing various English language learning levels of these students, the teachers used varied apps and resources to allow students for access to appropriate levels of language and academic instruction. As an example, Claire spoke of how the iPod “allows more development, more customized learning” and said that with the iPod, “they have their private tutor” with non-judgmental support in their activities. Virginia also spoke of how the iPod use helped the students, “It’s private, it’s between them and, so they don’t feel stupid.”

The teachers assigned the activities and games appropriate for students’ specific language levels and were able to scaffold students more easily with iPod touch from basics in phonetics and sight words to more fluency and comprehension in advanced topic and subjects. Virginia described her differentiated instruction: “I give instructions: 7th grade, you go to this video, 8th grade you go to this video.” Collaborative learning was also afforded in allowing the students to share information gathered individually with other students in classroom discussion. Claire illustrated, “They feel free to say whatever they think and they don’t feel that pressure [to participate].” Besides supporting the students in shared learning activities, Virginia had her students access current events and collaborated in identifying key information and answered questions on the topic.

Extend learning time from classroom to home

The students were assigned homework activities using iPod touch for extended learning at home. Virginia elaborated on her literacy learning focus with iPods for “helping them read better and being oral speakers” with audio recordings. The ability to take the iPods home allowed the student further academic learning away from the classroom. Emily, a seventh grade student, summarized her iPod use for learning, “I practice more in the iPod.” With the multifarious learning games and apps, the teachers believed their students were more engaged in further practices than traditional homework materials and activities offered.
Claire considered the importance of allowing student access to the iPod away from school and said, “The iPod brings more a family into the issues of learning.” Some students’ parents were able to access the students’ grades at school as well as being able to monitor their children’s actual work on the iPod. Additionally, the teachers were able to assign the student homework that included the siblings and parents. For example, Claire had the students conduct a video interview of their parents talking of their educational experiences as children. Virginia included homework that had the students read to their siblings, “… take one of my baby books and read it to your little bothers and sisters.” Parents were able to access the Internet via iPod touch for their own use as well. Virginia identified an incident of finding “job application” and discovered that the student’s parent was seeking employment information via the device.

Middle school students’ usage and perception

The 6th, 7th and 8th graders were asked to report how often they used the available features on their iPod touch on a weekly average both at school and at home. The features available to the students can be grouped into three categories: Resource tools (e.g., calculator, calendar, accessing Internet, maps, listening to music and podcasts, and checking weather), media creation tools (voice recorder, notes, still and video cameras) and other applications (often in the form of games). Table 2 showed students’ responses for school and home use. Comparing mid-of-school usage to end-of-school usage, the data showed that a considerable percentage of students used resource and media creation tools for two or more hours per week during the mid-school year; however, at the end-school year, almost all of the students reported using these applications 0-1 hour per week. The results indicated that the highest use of the iPod touch occurred during mid-school year when teachers and students were engaged in using the resource and media creation tools as part of weekly learning activities. The noticeable decrease of usage pattern toward the end of the school year could be explained in part by the fact that much of the school time during the end-school year was spent on preparing for various state mandated tests and end-of-year curriculum exams and testing itself. Comparing school and home usages, the data indicated approximately 63% of the students spent 2 or more hours using the Internet at home (with 25.9% spent more than five hours at home while 16.7% spent more than five hours at school). This is also true for listening to music with 40.7% spent 2-5 hours at home while 11.5% at school and 25.9% spent more than 5 hours at home while 15.4% at school. That is, students spent more time using the Internet (both school or non-school related) and listening to music (non-school related) at home than at school.

We asked the students to name three features they used most often and found most helpful Accessing Internet, listening to music, and using the calculator were the three features the students used most often both during mid-school year and at the end-school year for resource tools. Voice recorder, video camera, and notes were used most often for media creation tools. Students found Internet and calculator most helpful for the resources tools and voice recorder and notes for media creation tools.

<table>
<thead>
<tr>
<th>Resource tools</th>
<th>Duration in hours</th>
<th>At school</th>
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<th></th>
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<th>Mid-year %</th>
<th>End-year %</th>
<th>Mid-year %</th>
<th>End-year %</th>
<th>Mid-year %</th>
<th>End-year %</th>
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<td></td>
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</table>
Challenges revealed

Several challenges were observed during this first cycle: Significant amount of time required of the teacher to learn to use iPod touch, finding appropriate apps, developing lessons that would integrate the mobile devices, managing the devices by charging, synching, downloading, and updating, and dealing with technical problems. These tasks presented challenges for the teachers who already had a demanding workload with teaching ELL students. In addition, the teachers had to attend necessary technology training required by the school district.

Another challenge was encountering technology issues such as loss of Wi-Fi capacity for use of multiple devices at once at school as well as teachers helping individual students with login problems. The devices were also potentially prone to breakage or loss as the students took them home and other settings away from the classroom. For example, during the school year, several devices were broken or lost. A few thefts occurred throughout the year and one theft of 15 iPod touches towards the end-school year with only one recovered. Other examples of damage included accidental mishandling and washing with clothes.
Similar data collection procedure was followed for both cycles. However, as researchers, we realized asking middle school students to self-report their weekly iPod usage can be a challenge as this age group often had a hard time remembering an activity within a week’s duration and had trouble understanding hours vs. minutes. Therefore, in surveying elementary students for the second cycle, we asked the students to report daily usage and made the response time duration from hours to minutes.

**Year-two implementation**

Clara and Lydia were partner teachers for 4th and 5th grade ELLs and both held a bilingual teaching certification. Clara taught math and science and Lydia taught English Language Arts and Social Studies. As a team, they collaborated on group activities, student discipline, and iPod integration. Clara also served as the manager of the devices, updating and syncing the devices for all 42 students. Compared to Virginia and Claire, Clara and Lydia, in their initial year of iPod integration, were less enthusiastic about this mobile initiative and they implemented the project because they were encouraged by the school district to participate in the initiative. The analysis highlighted a few affordances of mobile technology in their case: Using iPod touches to (1) support language and content learning with Internet-based multimedia resources and (2) provide differentiated instructional support to increase student engagement and collaboration in the classroom.

**Support language and content learning**

Clara and Lydia shared insights on their experience, explaining their efforts in incorporating iPod touches into their teaching. Similar to the middle school teachers, their experiences showed they used the tool for engaging students in language as well as content learning. They described how the iPod touch provided ELL students access to multiple resources that facilitated their learning. Clara detailed the process for multimedia use for vocabulary development: “They go online and find a picture that is associated with the word and download it or save it to their iPod and transfer it to their StoryKit. Then, they write the definition that goes with it. Then, they go into recording themselves reading their definition.” As another example, Lydia spoke of how she used the iPod for language and reading skills development, “We are using them in terms of recording their fluency or recording to listen to their reading.” Clara also stated, “All their science homework is uploaded into their iTouches” for easy sharing and grading, not possible with traditional instruction.

**Provide differentiated instructional support**

Clara described the differentiated learning opportunities made possible by being able to access the resources at students’ own levels as “none of my kids have ever been on the same level.” The students were engaged in using such resources as dictionaries and playing educational games at a level appropriate to their learning and therefore reinforcing skills such as reading and multiplication. Clara described her typical use in this way, “There is no more downtime in my classroom because any down time we had, even when I’m passing out papers, their iPads are always on their desk and they know that: ‘Okay, get it out and start working on your times tables’ or ‘get it out and work on divisibility.’” Moreover, the students enjoyed using the iPod touch for learning. Lydia spoke of a writing activity in which the students went on a field trip and created a story using StoryKit with images, “They loved it. They had enjoyed the field trip anyway and were able to go in to create their own story pretty much just with peer assistance.” Additionally, Internet access allowed students to pursue topics of their interest as Lydia described a student’s use, “He will look up his favorite baseball players, what their stats are, and he will have a new line of interests depending on what he he’s reading in his novels sometimes.” The students found the writing activities compelling when using images from the field experience. Clara added, “It’s fun for them. It’s not paper and pencil.”

**Elementary students’ usage and perception**

The 4th and 5th graders were asked to report how often they used the available features on their iPod touch on a daily average both at school and at home. The features available to the students were also grouped into three categories as
with the middle school students: Resource tools, media creation tools, and other applications. Table 3 shows elementary students’ responses for school and home use.

The overall usage patterns indicated an increase in use with the resource tools at school but a decrease in home use; an increase in use for the media creation applications at school, except for the camera, while the usage remained the same or decreased at home. In addition, home use of the video camera appeared to increase at the end-school year. For calculator, calendar, music and reminders, more than 50% of the students indicated not using them both at school and at home. These elementary students typically spent 30 minutes or less in using applications/features daily for approximately 2 to 2.5 hours each week. While relatively few apps/features were used for over an hour daily, of particular interest was that audio book use exceeded an hour.

For resources tools, when comparing the mid- and end- of year usage, it showed a decrease in calculators use both at school and at home. Conversely, the use of calendar, Internet, and maps increased at school and at home. Internet use at school increased by 32% at the 31-60 minute duration while Internet use at home remained the same at the mid-year and end-school. For the media creation tools, the data indicated the voice recorder, notes, and video camera showed a modest increase in usage at the 1-30 minute time frame at school, while at home the voice recorder use dropped and video camera use increased. These usage patterns corroborated with teachers’ interviews indicating the types of school activities the students were required to do. For the other applications category, the trend indicated that both school and home use increased at the 31-60 minute duration at school and home.

When the students were asked to indicate how helpful or fun the applications/features are, more than half of the students found all of the applications/features helpful with the exception of music. Reporting the percentages of the features that exceed 50% of student responses, all resource tools, except for music, were found helpful and all media creation tools were found helpful. The features with the highest percentage of the students finding it helpful was audio books of the resource tools (helpful with 92.3% at mid-year and 92.1% at end-year), and the voice recorder of the media creation tools (82.0% at mid-year and 81.6% at end-year). The high usage of audio books and voice recorder was consistent with the teachers’ description of assigned learning tasks with the iPod touch.

The responses of “how fun” features that exceed 50% of students’ responses showed: calculator was identified as Not fun (55% at end-year), Internet was indicated as Very fun (55% at mid-year and 63.1% at year-end) and other application category (predominantly as games) was indicated Very Fun (68.7% at mid-year). Responses of the other features were spread out and offered mixed results.

Table 3. How often students used iPod applications/features on average each day

<table>
<thead>
<tr>
<th>Resource tools</th>
<th>Duration in minutes</th>
<th>At school</th>
<th></th>
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<tr>
<td></td>
<td>Mid-year %</td>
<td>End-year %</td>
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<tr>
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<td>(n = 39)</td>
<td>(n = 38)</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>61-90</td>
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<td></td>
<td>0</td>
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<td>Internet</td>
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<p>|                | Mid-year %          | End-year %|       |       |       |       |
|                | (n = 39)            | (n = 38)  |       |       |       |       |
|                | 51.3                | 76.3     |       |       |       |       |
|                | 48.7                | 23.7     |       |       |       |       |
|                | 0                   | 0        |       |       |       |       |
|                | 69.2                | 57.9     |       |       |       |       |
|                | (n = 39)            | (n = 38)  |       |       |       |       |
|                | 30.7                | 42.1     |       |       |       |       |
|                | 0                   | 0        |       |       |       |       |
|                | 48.7                | 44.7     |       |       |       |       |
|                | (n = 39)            | (n = 38)  |       |       |       |       |
|                | 33.3                | 36.8     |       |       |       |       |
|                | 15.4                | 18.4     |       |       |       |       |
|                | 2.5                 | 0        |       |       |       |       |
|                | 55.3                | 26.3     |       |       |       |       |
|                | (n = 38)            | (n = 38)  |       |       |       |       |
|                | 36.8                | 65.8     |       |       |       |       |
|                | 5.2                 | 7.9      |       |       |       |       |</p>
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</table>
Challenges revealed

During the second year of implementation, the two elementary teachers communicated similar challenges as those by the two middle school teachers. For these two technology novices, they especially indicated significant amount of additional time required of them to carry out the project. In addition, these teachers pointed out they had to attend additional technology training during the holidays as well as in the classroom. Although the teachers indicated the benefits of the training, they also pointed out this was in addition to their regular workload. Apart from the technical issues, appropriate use of the devices was identified as an issue in the elementary setting. The teachers described individual students who misused the camera function as well as cases of attempts to bypass teacher-managed settings. Monitoring appropriate student use while supporting mobile device use in K-12 setting poses a specific challenge. Moreover, the teachers indicated a need for change in teaching approaches. While the purpose of this mobile initiative was to improve ELL students’ success on state assessments, the various affordances provided by mobile devices were found to encourage and support teachers to adopt more independent, learner-centered pedagogical approaches.

Discussion and implications

Discussion

The goal of this research is to investigate how iPod touch devices can serve as a teaching and learning tool for English Language Learners. Encompassing a two-year period with two implementation cycles, the findings revealed that iPod touch use can offer ELL students critical support for language and content learning (Banister, 2010; Craig et al., 2007; Kiger et al., 2012; Patten & Craig, 2007), as well as engaging students in enjoyable learning (Ullman, 2010). Three affordances of mobile technology are highlighted with the results: Using iPod touch to support language and content learning, provide differentiated instructional support, and extend learning time from classroom to home (Chan et al., 2006; Looi, Seow et al., 2010; Looi, Zhang et al., 2010). For these ELL students, several features are especially important: audio books, Internet access, and media creation tools. The iPod touch provides them with another learning platform in a just-in-time manner to facilitate their language acquisition and content learning. Teachers also have easier access to resources and tools to adapt and adjust their instruction to meet students’ needs (Lacina, 2008; Ullman, 2010). The noticeable changes in the teacher’s curriculum practices is to allow students to have more control over their learning. Because of the instant access to useful resources (e.g., translator, dictionary, voice recorder, and other applications) at anytime and anywhere, the students can use tools they previously did not have access to learn content materials. This is especially important for ELL students as they can practice language skills in different ways using multiple modes at school and at home. The teachers in this study noted a need to shift their pedagogy toward a more student-centered approach with affordances offered by mobile devices. Kukulsk-hulme and Traxler (2005) described the “discursive/didactic dichotomy” within m-learning as a complexity in teaching approaches in traditional environments (p. 27). Additionally, consistent with previous research suggesting that engaging games can provide enjoyable content learning (Huizenga et al., 2009), the results showed that the students often accessed the game apps both at school and home and considered such apps as fun. Educators should take advantage of the new opportunities and possibilities provided by mobile devices to “engage, motivate, support, and interest students” (Liao et al., 2011, p. 86) to positively influence learning.

Although there are clear benefits for using iPod touch in teaching and learning as this research indicated, the results also showed teachers will need significant added support for learning how to use and manage the devices. This is especially so for teachers who themselves are not enthusiastic technology users or technology novices. Using mobile technology requires teachers to allocate significant time and effort to learn to use the device as well as learn to integrate effectively in their teaching (Kukulkska-Hulme & Traxler, 2005; Traxler, 2011). The management of the devices for classroom wide use, in terms of charging, synching and dealing with multiple technical demands can also add a substantial load on the teachers (Franklin & Peng, 2008; Vogel, Kennedy, & Kwok, 2009).

Implications

Given the preliminary encouraging evidences of m-learning for ELL students and teachers, what we have learned from this research project for the past two years not only has implications for this district, but also should offer insights for teaching and learning practices for other schools that are considering similar initiatives.
For teachers

Teachers who plan to incorporate mobile devices should be prepared to invest considerable amount of time in learning the functionalities of the devices as well as in designing, planning, and developing effective learning activities. Preparing to use the device for instruction will require prior preparation during the summer, before the school year commences. Moreover, teachers should be flexible in their teaching practice, reconsidering curriculum as well as teaching and learning approaches in order to effectively leverage the full range of affordances that mobile devices can offer. ELL teachers should take advantage of the new possibilities to offer differentiated instruction in meeting the specific language and academic needs of ELL students. To accommodate students’ learning needs and encourage student-directed learning, teachers can consider management plans to monitor student learning and create activities that utilize a wide range of apps/features (e.g., audio recordings, video productions, digital stories) available on mobile devices.

For instructional technologies

School district’s instructional technology department played a key role in this implementation. Prior to and during the implementation, the instructional technologists should provide training for the teachers, focusing on the basic capabilities and operations as well as identifying appropriate apps and suggesting ideas on how to integrate the iPod touch into the overall curriculum. Additionally, instructional technologists must anticipate, identify and quickly resolve technical challenges as well as help teachers in making sure that devices are synced with the appropriate apps, media, software, and security settings. They need to make sure students and teachers know how to log in to their devices and access wireless Internet, while coordinating with the network infrastructure staff in ensuring for sufficient and reliable network resources availability. Technology staff also needs to remain available for troubleshooting technical problems so that these types of issues do not lead to frustration and disuse.

For school administrators and policy makers

The results of this research suggest that realizing the benefits of the iPod touch program requires initial and ongoing support from the school administration. Support should include dedicated instructional technology staff to provide training and on-going support as well as provide funding to purchase and maintain the iPod touches. It is suggested that policies and processes for fixing or replacing broken, lost, and stolen devices should be in place. Administrators should also consider how to get buy-in from teachers when rolling out a technology initiative such as this one and set and enforce guidelines for safe and appropriate use of the devices and their apps. Equipping entire classes with mobile devices can create a significant demand for wireless bandwidth and administrators need to make sure the infrastructure can meet the demand. Without the support to ensure a fully functional device most of the time, student and teacher frustration may lead to declining use and thus undermine or negate the affordances of these devices and their potential to enhance learning.

For researchers

Conducting classroom-based, mobile learning research is a challenge, especially in ELL classrooms. Given the nature of ELL instruction in US public schools, there are many classroom transitions in middle schools on any given day. ELL students can be in different content classes and capturing classroom iPod interactions consistently poses a challenge. Because there was no tracking software on iPods, usage has to rely on students’ self-reporting. Students’ responses often are short and less specific. Follow-up interviews could be considered to further examine students’ perception.

Conclusion

The experience of the two-year implementation of this mobile initiative and research findings suggest that mobile devices such as iPod touch can provide ELL students significant support for language and content learning and extend learning time from classroom to home. Audio books, Internet access, and media creation tools are found to be
especially important for these ELL students. While several affordances are revealed both at elementary and middle school ELL settings, substantial support in the form of professional training and administration support and encouragement is also highlighted.

References


The Impact of a Principle-based Pedagogical Design on Inquiry-based Learning in a Seamless Learning Environment in Hong Kong

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Department of Mathematics and Information Technology, The Hong Kong Institute of Education, Hong Kong // sckong@ied.edu.hk // ysong@ied.edu.hk

ABSTRACT
An inquiry-based learning pedagogy coupled with a seamless learning environment is a potential way to realise the educational goal of learner-centred learning in digital classrooms in the 21st century. An overarching research framework is proposed for preparing teachers to effectively develop pedagogical designs that are premised on theoretical principles and facilitate inquiry-based learning in a seamless learning environment. We carried out an initial study using the overarching framework. Three questions are addressed: how a principle-based pedagogical design was developed and implemented, the effect that the principle-based pedagogical design had on students’ domain knowledge gains and inquiry skills and how students advanced their domain knowledge and developed their inquiry skills. One teacher and 27 students from a local primary school were involved in the study. Both qualitative and quantitative data were collected and analysed over two weeks. Six inquiry-based learning lessons focusing on a scientific ‘rustproofing’ learning unit were conducted in a seamless learning environment, initiated in a digital classroom and extended to online discussions on a social network platform. The results reveal innovative ways of developing and implementing the pedagogical design in the rustproofing learning unit and demonstrate the pedagogical design’s positive effect on students’ domain knowledge gains and inquiry skills. In addition, how the students advanced their domain knowledge and inquiry skills were also explored and discussed.

Keywords
Inquiry-based learning, Primary school education, Principle-based pedagogical design, Seamless learning environment

Introduction
Educational reform calls for a paradigm shift to learner-centred domain knowledge learning. It is well recognised that the inquiry-based learning approach is a useful pedagogy for realising learner-centred learning (Marshall, Smart, & Horton, 2010). The inquiry-based learning process helps learners to develop inquiry skills, which are an important type of 21st century skill. The development of inquiry skills takes root during a child’s senior primary school years (Lakkala, Lallimo, & Hakkarainen, 2005). Digital classrooms are on the rise; students are connected and learn in a ‘one learner to one computer’ setting, and teachers are expected to be prepared to lead students to learner-centred learning in such classrooms as early as the primary school stage. The use of online learning platforms inside and outside digital classrooms supports resource access and peer interaction to develop students’ domain knowledge and inquiry skills (Kong & So, 2008; Lakkala et al., 2005). Incorporating the inquiry-based learning pedagogy into a seamless learning environment may thus be a potential method for realising learner-centred educational goals and driving teachers to apply and reflect on pedagogical designs. This study presents a design-based research framework for principle-based pedagogical design for inquiry-based learning in seamless learning environments. It details and reports the results of an initial study conducted using this framework in a Hong Kong primary school.

Research framework
With the goal of finding a meaningful and sustainable method of developing the teacher competence necessary to facilitate inquiry-based learning in a seamless learning environment, this research study seeks to address two issues. First, the method for developing teacher competence should be in line with the method for developing learner competence in inquiry-based learning. Second, the method for developing teacher competence should present evidence of the development of teacher competence and student learning improvement. This study adopts a principle-based approach to developing and implementing pedagogical designs for inquiry-based learning. This approach, which differs from the conventional approach that emphasises “best practices” with prescribed procedures, provides more flexible scaffolding under guiding principles. It attempts to build up teachers’ capacity to promote inquiry-based learning in a manner aligned with learners’ inquiry-based learning practice. This study also adopts a
A design-based research method is adopted to prepare teachers to effectively develop pedagogical designs that are premised on instructional principles. Learners learn in a seamless learning environment to develop the necessary skills to practice inquiry-based learning.

Inquiry-based learning includes three approaches: structured, guided and open inquiry, listed in ascending order of the learner’s autonomy over setting investigation problems and planning problem-solving procedures (Colburn, 2000). The literature suggests that the guided inquiry approach is especially suitable for young learners, as teachers only select core issues that are worthy of a learner’s inquiry (Hakkarainen, 2003; Marshall et al., 2010; Song & Looi, 2012). According to Wong and Looi (2011), seamless learning environments provide learners with opportunities to make use of diverse resources and tools in digital formats for learning and communication, which is initiated in digital classrooms and extended to online interactions. The technological support of a seamless learning environment allows learners to conveniently share and store multimedia resources, and to easily exchange and track discussion ideas with peers during the inquiry process. During class time, learners in digital classrooms are connected, and use digital technologies in a ‘one learner to one computer’ setting (Chan, 2010; Kong, 2011). Beyond the limited class time, learners typically use learning platforms to communicate with peers online, mostly to extend discussions or to engage in deeper discussions after class.

Pedagogical design refers to the organisation plan for learning activities and the actual implementation of the plan in a learning unit (Lakkala et al., 2005). Researchers have reported that principle-based pedagogical designs are more adaptable and conducive to transforming inquiry-based learning practices (Schwarz, 2009; Song & Looi, 2012; Zhang, Hong, Morley, Scardamalia, & Teo, 2011). The principle-based approach to pedagogical design defines the core principles of learning and teaching. According to Schwarz (2009), Zhang (2010) and Zhang et al. (2011), principle-based pedagogical designs focus on guiding principles and customizable practices. Teachers are afforded the flexibility to reflectively judge and adapt classroom decisions to accommodate different learning and teaching possibilities. Based on knowledge-building and social-constructivism theories (e.g., Scardamalia, 2002; Vygotsky, 1978), a set of theoretical principles premised on 12 knowledge-building principles and progressive inquiry principles (Lakkala, Muukkonen, Paavola, & Hakkarainen, 2008; Scardamalia, 2002; Song & Looi, 2012; Zhang et al., 2011) is considered suitable for pedagogical designs for inquiry-based learning.
Teachers need support from evidence-based research to make continuous pedagogical reflections. As such, the design-based research approach is suitable for gaining new insights. Design-based research attempts to combine theory-driven design with empirical analyses of practices in real settings. It creates a path to connect interventions to outcomes through an iterative mechanism of design, evaluation and refinement (Bell, 2004; Hoadley, 2004). Teachers are provided with iterative opportunities (as shown in Figure 1) to use principle-based pedagogical designs to enhance their competence in leading inquiry-based learning in a seamless learning environment. This study details and reports the results of an initial study on design-based research that explored the effect of using the principle-based approach to pedagogical designs for science inquiry in the seamless learning environment of a Hong Kong primary school.

The initial study was conducted using the overarching framework in a learning unit on ‘rustproofing’ conducted in the school’s Primary 4 class.

This study

Research context

The study took place in the initial cycle of design-based research on principle-based pedagogical designs for inquiry-based learning that aimed to develop teacher competence and learners’ science domain knowledge and inquiry skills in a seamless learning environment at the primary level in Hong Kong. According to recent territory-wide surveys on the development of technology-enhanced education in Hong Kong (Li & Kong, 2011), local primary school teachers are typically capable of integrating technology into their daily teaching methods. Further, local primary school learners are ready to use technology for inquiry-based learning, as they demonstrate a basic information literacy competency that is important in the inquiry process. These surveys reveal that primary schools in Hong Kong have built a foundation for introducing educational innovations that integrate pedagogical designs for inquiry-based learning into technology-supported learning environments.

The study purposefully sampled a primary school in Hong Kong as its partner school. One experienced science teacher and one Primary 4 class with 27 students (15 female and 12 male) were invited from the partner school to participate. The science inquiry focused on a learning unit on rustproofing conducted in six lessons over 2 weeks for senior primary school learners. The following research questions were addressed.

1. How did the teacher develop and enact the principle-based pedagogical design?
2. What effect did the principle-based pedagogical design have in helping students to gain domain knowledge and inquiry skills in the seamless learning environment?
3. How did the students advance their domain knowledge and develop their inquiry skills?

To address these questions, our pedagogical design involved the adoption of the 5E inquiry-based learning model to guide the students’ science inquiry, and five instructional principles for pedagogical practice in a seamless learning environment supported by a social network (i.e., Edmodo). These principles are elaborated in the remainder of this section.

5E inquiry-based learning model

According to EDB (2008), the focus of science education is to promote students’ scientific thinking through inquiry-based learning approaches. Although open inquiry provides optimal opportunities for students’ cognitive development and scientific reasoning, teacher-guided inquiry may provide better opportunities for students to focus on the development of particular science concepts (Song & Looi, 2012). To balance the two inquiry approaches, we developed a 5E inquiry-based pedagogical model as follows: (a) “engage” in inquiry topics and questions, (b) ‘explore’ the inquiry methods and processes, (c) “explain” the inquiry analyses and outcomes, (d) “evaluate” the inquiry processes and outcomes and (e) “extend” the inquiry topics and questions. The process is cyclic and progressive but not linear, and may not involve all of the components in each learning cycle.
Five instructional principles

To explicate the processes and dynamics of science inquiry for knowledge advancement using the inquiry-based pedagogical approach, we adapted five core instructional principles from a set of progressive inquiry principles (Song & Looi, 2012) and other related research (Scardamalia, 2002; Yeo & Tan, 2010). These principles are premised on social constructivist principles, and include (a) working on real problems, (b) encouraging diverse ideas, (c) providing collaborative opportunities, (d) using authoritative sources constructively and (e) performing a formative assessment (see Table 1).

<table>
<thead>
<tr>
<th>Principles</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working on real problems</td>
<td>Setting up real-life problems rather than abstract concepts (Scardamalia, 2002; Song &amp; Looi, 2012).</td>
</tr>
<tr>
<td>Encouraging diverse ideas</td>
<td>Encouraging students to express their ideas voluntarily. There is no right or wrong answer. Every idea is valued and unique (Song &amp; Looi, 2012).</td>
</tr>
<tr>
<td>Providing collaborative opportunities</td>
<td>Emphasis on the importance of collective effort and responsibility in the learning process (Scardamalia, 2002; Song &amp; Looi, 2012).</td>
</tr>
<tr>
<td>Using authoritative sources constructively</td>
<td>The meaningful use of authoritative sources for continual science meaning-making (Yeo &amp; Tan, 2010).</td>
</tr>
<tr>
<td>Performing a formative assessment</td>
<td>Provision of peer assessment and teacher feedback concurrently in the collaborative process (Scardamalia, 2002; Song &amp; Looi, 2012).</td>
</tr>
</tbody>
</table>

Teacher principle-based understanding

Before the beginning of the study, the teacher received two 1.5-hour training sessions from two researchers. In the first session, the researchers prompted and discussed the inquiry-based learning model and five instructional principles with the teacher using PowerPoint slides. The researchers then asked the teacher to reflect and pose questions. In the second session, the teacher chose one of his lessons to elaborate how he would conduct it using instructional principles, and discussed his pedagogical design with the researchers.

Seamless learning environment supported by a social network—Edmodo

This study took place in a seamless learning environment. The teacher provided pedagogical support in implementing the 5E model and five instructional principles for inquiry-based learning. The seamless learning environment comprised digital technologies that allowed students to access learning resources and interact with peers in inquiry-based learning. Inside the digital classroom, each student was given a mobile computing device comprising a tablet PC with Internet connectivity and an embedded camera. The social network Edmodo (see Figure 2), was used as a learning communication platform to support the students’ learning at the individual, group and whole-class levels both inside and outside the classroom. Edmodo is a secure microblogging medium conducive to collaborative knowledge construction (Ma, Ko, Chu, & Song, 2012). It can be used across formal and informal learning settings, allowing students to collaborate, communicate, submit assignments and upload and download files, and teachers to share lecture notes with students, connect to useful websites, upload and download learning references for students, create online quizzes and release news and events. The platform can run on different operating systems (e.g., iOS or Android).

![Figure 2. Interface of Edmodo for the Primary 4 science class](image)
The learning activities organisation plan

The principle-based pedagogical design included an organisation plan of the learning activities (see Table 2) and the actual enactment of the learning unit plan on rustproofing, which comprised six lessons and activities that Primary 4 students carried out at home or between lessons over two weeks. According to the plan, the students formed six groups of four or five members each and were expected to collaboratively lead their own experimental inquiries into an “expert rustproofing design” project. Two prompts were provided on Edmodo during the experimentation process. First, the ‘Forms for Experimental Rustproofing Designs’ prompt asked students to record their inquiry plans. The students were required to fill out three design methods with hypotheses (Appendix I), and each student was required to take on a responsibility in the design. Second, the ‘Observational Forms for Rustproofing Experiments’ prompt helped students to monitor their experimental process and scaffold their reflections. The students were required to document the rustproofing process over a week and to include the observers’ names (Appendix II). Both of the Edmodo forms were linked to GoogleDocs, which allowed the students to fill them in directly.

Table 2. Learning activities organisation plan for the rustproofing learning unit

<table>
<thead>
<tr>
<th>No.</th>
<th>Aim</th>
<th>Activity</th>
<th>Means of interaction</th>
<th>Teaching and learning resources</th>
</tr>
</thead>
</table>
| Lesson 1 | To engage students on the topic of rustproofing | - Storytelling was used to make students understand why they needed to rustproof and to arouse their curiosity on how to do so.  
- Individual students were required to discover rustproofing methods and prepare to share their discoveries with group members in the next lesson. | F2F + online | LCD projector, Tablet PCs, Internet, Social network: Edmodo |
| At home | To discover rustproofing methods individually | - Individual students continued researching rustproofing methods and uploaded their findings to Edmodo to share with their peers.  
- The students posted questions to Edmodo and commented on or responded to other students’ posts. | Online learning | Desktop, laptop, iPad, iPhone, etc. Edmodo |
| Lessons 2 and 3 | To determine the three best experimental rustproofing designs in groups | - Each group member shared and explained his or her findings on the experimental rustproofing designs.  
- The three best experimental rustproofing designs were discussed and worked out by combining every member’s ideas.  
- The three best experimental designs were filled in on the ‘Forms for Experimental Rustproofing Designs’, prepared by the teacher on Edmodo to share with peers. | F2F + online | LCD projector, Tablet PC Edmodo |
| At home | To plan and prepare the material for the rustproofing experiment in the next session | - Students could post their questions to Edmodo. They could also comment on or respond to other students’ posts. | Online | Desktop, laptop, iPad, iPhone, etc. Edmodo |
| Lessons 4 and 5 | To conduct the experiment based on the proposed experimental designs in groups | - Each group conducted three rustproofing experiments by placing three iron clips into three plastic cups full of water and certain other materials.  
- The cups containing the clips and materials were placed on windowsills. | F2F + online | Three iron clips provided by the teacher for the students to conduct the experiments. Students brought the rustproofing materials from home, including the plastic cups. |
To observe and document the changes of the clips in the plastic cups

- Group members observed and took pictures each day to document the changes in the clips in the different cups and filled out the ‘Observational Forms for Rustproofing Experiments’ on Edmodo.

F2F

Table PC with embedded camera

Lesson 6

To explain and share group work and award the group that achieved the best rustproofing results

- The groups presented and explained their experimental results to the other groups. Each group showed three experimental designs for protecting the iron clips from rust.
- Each group commented on the other groups’ work and chose the group that achieved the best rustproofing results.
- A badge was awarded to the best group.

LCD projector, Tablet PC

Edmodo

At home

To consolidate the rustproofing knowledge

- Students were required to complete a worksheet on the topic of rustproofing on Edmodo.
- Students posted questions to Edmodo.

Desktop, laptop, iPad, iPhone, etc.

Edmodo

Data collection and analysis

To understand the effects of the principle-based pedagogical design on students’ domain knowledge of rustproofing and inquiry-based learning skills, and on how the students advanced their domain knowledge and inquiry strategies, we collected the following data.

- Data on the development and implementation of the pedagogical design, including posts on Edmodo, the learning activities organisation plan, lesson videos, group experimental design forms, group experimental observational forms, the assignment and teacher interviews and reflections.

- Data on the effects of principle-based pedagogical design on domain knowledge gains, including pre- and post-domain tests and assignments. The pre- and post-domain tests were identical and consisted of 20 multiple-choice questions and five open-ended questions on rustproofing. The assignments took the form of worksheets on rustproofing knowledge (Appendix III). The students submitted their assignment directly to Edmodo, and the teacher commented on their work directly to provide immediate feedback. The data on the effects of the principle-based pedagogical design on student inquiry skills included pre- and post-questionnaire surveys on perception changes towards inquiry learning skills before and after the inquiry-based learning approach. The questionnaire focused on students’ perceptions of inquiry learning skills, and comprised 12 items rated on a five-point Likert scale (with 5 indicating strong agreement and 1 indicating strong disagreement). The 12 items were designed to address the five inquiry skills under the 5E inquiry-based learning model, with items 1-3 addressing the “questioning” skill; items 4-5 addressing the “exploring” skill; items 8-11 addressing the “explaining” skill; items 6-7 addressing the “evaluating” skill and item 12 addressing the “extending” skill. The Cronbach’s alpha reliability scores were 0.849 and 0.902 for the pre-test and post-test, respectively, implying that the questionnaire was reliable.

- Data on how the students advanced their domain knowledge, including group experimental designs (experimental design forms on Edmodo), group experimental results/products (observational forms on Edmodo) and group artefacts (photos documenting the experimental process), and data on how the students advanced their inquiry skills, including posts on Edmodo, lesson videos, teacher and student interviews and field notes.

Table 3 shows the data sources used to investigate the three research questions.

<table>
<thead>
<tr>
<th>Data</th>
<th>Research questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre- and post-domain tests</td>
<td>*Q1</td>
</tr>
<tr>
<td>Pre- and post-questionnaire surveys</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 3. Data sources for analysis
Results

Development and implementation of the principle-based pedagogical design

The data analysis results on the development of the principle-based design show that the learning activities organisation plan included the five elements of the inquiry-based learning model in a seamless environment. The inquiry learning activities went from engaging students on the topic of rustproofing, to exploring rustproofing methods and making hypotheses for the experimental designs, to evaluating the experimental rustproofing designs through active experimentation and explaining and sharing the designs and finally to consolidating and extending the rustproofing knowledge to help the students to become rustproofing ‘experts’. The entire inquiry process was carried out seamlessly between classes and the students’ homes with the support of the social network platform (Edmodo).

The data analysis results on the implementation of the principle-based pedagogical design indicate that the teacher premised the rustproofing learning activities organisation plan on the five instructional principles (see Table 1). The demonstration of the five inquiry-based elements and five instructional principles in a seamless learning environment during the enactment of the rustproofing learning unit is illustrated in Table 4.
Table 4. Principle-based pedagogical implementation of inquiry-based learning in a seamless learning environment

<table>
<thead>
<tr>
<th>Implementation of the organisation plan</th>
<th>Inquiry elements</th>
<th>Instructional principles</th>
<th>Seamless learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson 1</td>
<td>Engage: Engaging in the topic of rustproofing</td>
<td>P1</td>
<td>Class</td>
</tr>
<tr>
<td>At home</td>
<td>Explore: Exploring rustproofing methods</td>
<td>P4</td>
<td>Home</td>
</tr>
<tr>
<td>Lessons 2 and 3</td>
<td>Explain: Sharing and planning rustproofing experiments and making hypotheses in groups</td>
<td>P2 and P3</td>
<td>Class</td>
</tr>
<tr>
<td>At home</td>
<td>Engage: Preparing and coordinating the rustproofing experiments</td>
<td>P1 and P3</td>
<td>Home</td>
</tr>
<tr>
<td>Lessons 4 and 5</td>
<td>Evaluate: Evaluating the hypotheses through conducting experiments</td>
<td>P1, P3 and P5</td>
<td>Class</td>
</tr>
<tr>
<td>Breaks between lessons</td>
<td>Evaluate: Observing and documenting the rustproofing process</td>
<td>P1, P3 and P5</td>
<td>Breaks</td>
</tr>
<tr>
<td>Lesson 6</td>
<td>Explain: Explaining and sharing group work</td>
<td>P2, P3 and P5</td>
<td>Class</td>
</tr>
<tr>
<td>At home</td>
<td>Extend: Consolidating and extending knowledge related to rustproofing</td>
<td>P5</td>
<td>Home</td>
</tr>
</tbody>
</table>

Note: P1 = working on real problems; P2 = encouraging diverse ideas; P3 = providing collaborative opportunities; P4 = using authoritative sources constructively; P5 = performing a formative assessment.

Table 4 shows that the teacher flexibly adopted different principles at different stages of the science inquiry. We also asked the teacher to reflect on his pedagogical plan and enactment process and outcomes based on guided questions on the inquiry-based learning approach and instructional principles, and arranged a time to interview him to hear his reflections. Some of the questions (Q) and excerpts from his reflections (R) are presented as follows:

Q1: When teaching the rustproofing learning unit, do you think it is important for the students to conduct hands-on experiments in an authentic environment? Why?

RI: If I told the students the reasons for rusting and how to prevent rusting directly, it would take 3 minutes. However, by providing opportunities for the students to lead their own science inquiry, they not only tested their own hypotheses in the experiments, but also underwent a process of discovery and collaboration: to identify problems in their everyday lives, raise questions to explore resources and conduct experiments to solve the problems.

Q2: Did you encourage the students to express their diverse ideas in their inquiry? How?

R2: I valued each student’s questions. How? Digital technology and the Internet extend our learning spaces. I seldom asked students to ask questions face to face in class. They could post their questions anytime, anywhere to the Edmodo social network platform, both inside and outside the classroom. They can get quick feedback from their peers or from me. If I found that many students were concerned about a problem, I would discuss the problem in class. Using Edmodo, all students’ questions are treated equally and their learning is extended beyond the classroom. This can be called seamless learning.

It is worth noting that the teacher’s good understanding of inquiry-based pedagogies and the principles of working on real problems and encouraging diverse ideas allowed him to apply the instructional principles in his pedagogical practices in multiple contexts, with the support of the social network platform.

Effect on students’ domain knowledge gains and inquiry skills development

We investigated the effect of principle-based pedagogical design on students’ domain knowledge gains through pre- and post-domain tests on rustproofing. Table 5 shows the results of the tests. Significant differences were found between the pre- and post-domain test results (pre-average score = 11.64; post-average score = 22.50, p < 0.05). We can thus conclude that the students made significant advancements in their rustproofing knowledge after their inquiry.

Table 5. Pre- and post-domain test results on the rustproofing learning unit

<table>
<thead>
<tr>
<th>Class</th>
<th>No. of students</th>
<th>Pre-test M</th>
<th>S.D.</th>
<th>Post-test M</th>
<th>S.D.</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>4C</td>
<td>27</td>
<td>11.64</td>
<td>2.652</td>
<td>22.50</td>
<td>3.837</td>
<td>14.854*</td>
</tr>
</tbody>
</table>

Note: Total test score = 40
*p < .05
In terms of the rustproofing learning unit assignments, the average scores for the 27 students were 79% (7.11 out of 9 questions in total). Although some of the students’ scores were not high, their worksheets revealed that in many cases marks were deducted due to incorrect rendering of Chinese characters rather than their content knowledge. Figures 3(a) and 3(b) show screen captures of two students’ worksheets marked by the teacher. Figure 3(a) shows that the student used the incorrect Chinese word “份 (part)” rather than “分 (component)” – the two words are the same in Pinyin, and their characters are also similar. Figure 3(b) shows that one student did not know how to write the Chinese word “滅 (extinguish).”

Figure 3. Screenshots of a student’s worksheet (a – left; b – right)

The effect of the principle-based pedagogical design on students’ inquiry skills was examined through pre- and post-questionnaire surveys. The results are shown in Table 6. They reveal that only the pre- and post-questionnaire results for item 1 (I know how to start thinking about how to solve a scientific problem) (mean = 4.35) and item 10 (I know how to explain my ideas to my peers when learning science) (mean = 4.16) showed significant differences. Items 1 and 2 relate to the “questioning” and “explaining” inquiry skills, respectively, and indicated an improvement in the students’ skills in raising questions and explaining ideas and concepts to peers.

Table 6. Pre- and post-questionnaire results on the rustproofing learning unit (translated version)

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I know how to start thinking about how to solve a scientific problem</td>
<td>3.77</td>
<td>4.35</td>
<td>4.573*</td>
</tr>
<tr>
<td>2. I know how to solve a scientific problem step by step</td>
<td>3.88</td>
<td>4.31</td>
<td>2.026</td>
</tr>
<tr>
<td>3. I know how to find scientific problems that I am interested in solving</td>
<td>4.08</td>
<td>4.15</td>
<td>0.440</td>
</tr>
<tr>
<td>4. I know where to find the information to solve a scientific problem</td>
<td>4.00</td>
<td>4.27</td>
<td>1.272</td>
</tr>
<tr>
<td>5. I know how to explore information/resources on my own when solving a scientific problem</td>
<td>3.96</td>
<td>4.08</td>
<td>0.486</td>
</tr>
<tr>
<td>6. I know how to improve the ways to solve a scientific problem</td>
<td>3.88</td>
<td>4.27</td>
<td>1.917</td>
</tr>
<tr>
<td>7. I know how to try different ways of solving a scientific problem</td>
<td>4.13</td>
<td>4.13</td>
<td>0.000</td>
</tr>
<tr>
<td>8. I know when to ask help from my peers when learning science</td>
<td>4.04</td>
<td>4.08</td>
<td>0.132</td>
</tr>
<tr>
<td>9. I know when to ask help from teachers when learning science</td>
<td>3.88</td>
<td>3.88</td>
<td>0.000</td>
</tr>
<tr>
<td>10. I know how to explain my ideas to my peers when learning science</td>
<td>3.72</td>
<td>4.16</td>
<td>2.290*</td>
</tr>
<tr>
<td>11. I know how to explain my ideas to my teacher when learning science</td>
<td>4.24</td>
<td>4.20</td>
<td>-0.146</td>
</tr>
<tr>
<td>12. I know how to work together with my peers to solve a scientific problem</td>
<td>3.88</td>
<td>4.29</td>
<td>2.005</td>
</tr>
<tr>
<td>Total</td>
<td>3.87</td>
<td>4.15</td>
<td>1.973</td>
</tr>
</tbody>
</table>

* p < .05

Ways that the students advanced their domain knowledge and developed their inquiry skills

We traced the artefact development of each student group in the rustproofing learning unit. Each group designed three methods. Among the 18 experimental methods proposed by the groups, only one method (i.e., using paint to coat the clip) was the same between two groups. All of the other methods were different from each other (see Table 7). In addition, after tracking the experiment outcomes, the degree of rusting in each method was evaluated and scored from 0 (no rusting) to 10 (most severe rusting), which is also shown in Table 7.
Table 7. Experimental designs and rustproofing outcomes by group

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of design</th>
<th>Hypothesis of rustproofing theories using the methods. (All of the following methods were hypothesised to prevent air from entering the cup or to prevent water from having direct contact with the clip.)</th>
<th>Degree of rusting</th>
</tr>
</thead>
<tbody>
<tr>
<td>G 1</td>
<td>(1)</td>
<td>Use Vaseline and paint to coat the clip and put oil into the cup along with the water.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>Use Vaseline to coat the clip.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>Use paint to coat the clip.</td>
<td>7</td>
</tr>
<tr>
<td>G 2</td>
<td>(1)</td>
<td>Use Vaseline to coat the clip and then wrap the clip with plastic wrap. Put oil and w-4 into the cup.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>Use Vaseline to coat the clip and then wrap the clip with plastic wrap. Put oil into the cup.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>Use Vaseline to coat the clip and then wrap the clip with plastic wrap.</td>
<td>3</td>
</tr>
<tr>
<td>G 3</td>
<td>(1)</td>
<td>Put the clip into a storage bag.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>Use Vaseline to coat the clip, and then use the dryer to dry the clip before putting it into the water.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>Use a candle to dry the clip after removing it from the water.</td>
<td>3</td>
</tr>
<tr>
<td>G 4</td>
<td>(1)</td>
<td>Wrap the clip with glue paper.</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>Wrap the clip with plastic wrap.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>Put oil into the cup.</td>
<td>2</td>
</tr>
<tr>
<td>G 5</td>
<td>(1)</td>
<td>Use Vaseline to coat the clip and then put oil and soya oil into the cup.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>Use Vaseline to coat the clip and then put oil into the cup.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>Wrap the clip with glue paper and then put the oil into the cup.</td>
<td>7</td>
</tr>
<tr>
<td>G 6</td>
<td>(1)</td>
<td>Use paint to coat the clip, seal the clip inside a bottle and then put the bottle into the water.</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>Use paint to coat the clip, use a dryer to dry the paint, seal the clip inside a bottle and then put the bottle into the water.</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>(3)</td>
<td>Use paint to coat the clip.</td>
<td>7</td>
</tr>
</tbody>
</table>

We also examined the students’ captured photos daily to keep an observational record of the three experiments in each group. We obtained some of the artefacts created by Group 2 as an example. Figure 4(a) shows a screenshot of the three experimental results on the first day using the three methods (see Table 7). Figure 4(b) shows a screenshot of the experimental results on the last day (1 week after). Figure 4(c) shows the degrees of rusting (0-10) in the group’s three methods, evaluated by the group itself, peers in other groups and the teacher (3, 0 and 0, respectively). These artefacts documented the students’ deepened understanding of rustproofing from experimental design through to observation, presentation and evaluation.

Figure 4. Photo of the first day of the experiment; photo of the second day of the experiment; photo of the experimental results evaluation (a – left; b – middle; c – right)

Group 2 was chosen as having the best experimental rustproofing design, and was awarded a badge declaring its members rustproofing “experts,” which encouraged the students to make further science inquiry. It is worth noting
that although the students captured photos of the experimental results each day, they rarely entered observational records on the degree of rusting into the “Observational Forms for Rustproofing Experiments.”

To examine how the students advanced their inquiry skills, we investigated students’ inquiry processes supported by Edmodo, where seamless learning across physical spaces (in the classroom and between lessons using tablet PCs, and at home using various devices) and individual and social spaces (online learning and class interactions) was documented. Figure 5 indicates the limited numbers of students’ posts on Edmodo relating to their science inquiry skills (questioning = 1.7%, exploring = 2.2%, explaining = 5.1%, evaluating = 3.9% and extending = 0%). However, other posting categories accounted for the majority of the contributions: coordinating the experimental designs and observations (47.9%), social interactions (23%), greetings (14%) and news sharing (8%). This indicates that the social network platform played an important role in students’ project work orchestration and establishment of intimate relationships.

<table>
<thead>
<tr>
<th>Inquiry skills</th>
<th>No. (%) of postings on Edmodo</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questioning</td>
<td>7 (1.7%)</td>
<td>What shall I use in order not to make the oil not spill over?</td>
</tr>
<tr>
<td>Exploring</td>
<td>9 (2.2%)</td>
<td>How many ways are there to prevent rusting (with Hyperlink)?</td>
</tr>
<tr>
<td>Explaining</td>
<td>21 (5.1%)</td>
<td>This is the method of using oil to prevent rusting (Hyperlink: iron rusting- Wiki – Wikipedia – the free encyclopedia)</td>
</tr>
<tr>
<td>Evaluating</td>
<td>16 (3.9%)</td>
<td>Good!</td>
</tr>
<tr>
<td>Extending</td>
<td>1 (0)</td>
<td>Gilded iron or metal can prevent rusting</td>
</tr>
<tr>
<td>Others</td>
<td>355 (86.7%)</td>
<td>196 (47.9%) Chu L, don’t forget to bring the hair dryer.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>94 (23%) You get my phone Ho Y?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>61 (14.9%) Good morning everyone!</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 (2%) The second group got the honor of “Rustproof Experts”.</td>
</tr>
<tr>
<td>Total postings</td>
<td>409 (100%)</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 5. Categories of students’ posts on Edmodo related to rustproofing and other inquiry skills*

We also interviewed a group of students using the questions guided by the five elements in the inquiry-based learning model to understand their rustproofing inquiry processes. The students expressed great passion for leading their own rustproofing research in real life (supported by Edmodo), where their inquiry experience bridged seamlessly across different spaces. One student made the following statement.

In the past, in science class, we only learned from textbooks. It was boring. Now, we can explore and discuss the best ways for our experimental designs on rustproofing. It is interesting that we can do hands-on experiments ourselves, observe the process of the rustproofing process and take pictures [of the clip rusting results] day by day . . . If I learned [rustproofing] from textbooks, it would be easy for me to forget what I have learned. But doing hands-on experiments makes it difficult to forget the methods and principles [of rustproofing]. I understand the rustproofing theories better.

The students’ interview results indicate that they acquired solid domain knowledge and developed inquiry skills from the experience of hands-on experimental design and practice.
Discussion

Principle-based pedagogical design—gains

This study attempted to develop and implement a principle-based pedagogical design for inquiry-based learning in the seamless learning environment of a Hong Kong primary school. The results show that a teacher with training experience and a good understanding of the principles and inquiry-based learning model was better able to plan and enact student-centred inquiry activities in which students had control over their own learning. This echoes the findings in previous studies that suggest that enhancing teachers’ inquiry-based pedagogical competence in a technology-supported learning environment requires teachers to understand the basic theoretical principles behind inquiry-based pedagogies and how to apply the principles to pedagogical practices (Scardamalia, 2002; Song & Looi, 2012, Zhang et al., 2011). In our study, the students showed improvements in their domain knowledge learning and inquiry skills, especially in terms of “questioning” and “explanation,” which are considered essential elements of inquiry-based learning (Hakkarainen, 2003).

However, students cannot develop a meta-cognitive awareness of inquiry strategies without adequate scaffolding (Lakkala et al., 2005). Our study adopted a guided inquiry-based learning model by providing prompts (“Forms for Experimental Rustproofing Designs” and “Observational Forms for Rustproofing Experiments”) for the students’ experimental designs and observations. Although each group of students generated different experimental designs and hypotheses, they were all on the right track in the inquiry. According to Lin and Lehman (1999), metacognitive skill development is typically fostered by providing students with opportunities to reflect on and monitor their learning performance and revise their investigative strategies. In this regulative process, students are reflective inquirers looking to accomplish projects and gain a deeper understanding of domain knowledge and inquiry skills (Loh et al., 2001). Further, in the “Forms for Experimental Rustproofing Designs,” the students were required to take on different responsibilities in completing the experiment, which increased their awareness of taking collective responsibility for advancing the group’s knowledge (Scardamalia, 2002; Zhang et al., 2011).

In this study, the Edmodo social network platform provided a seamless learning environment for the students to coordinate the inquiry projects and establish a rapport in groups and with peers, which played an important role in advancing their rustproofing knowledge and developing their inquiry strategies. In addition, the students could share their groups’ products with their peers at any time and anywhere on the platform, which allowed them to evaluate other groups’ work and construct knowledge collaboratively. The embedded peer group assessment in the pedagogical design meant that the assessment responsibility was turned over to the students, helping them to develop increased agency when evaluating their own learning progress (Zhang et al., 2011). The students could also submit assignments to the platform and obtain the teacher’s feedback in a timely manner, which encouraged them to learn. This study contributes to the literature on the use of principle-based pedagogical design for guided inquiry-based learning in science in a seamless learning environment at primary level. Nevertheless, it also has some limitations.

Principle-based pedagogical design—losses

We identified several issues and limitations to be addressed in future work. First, in terms of the five instructional principles adopted in the research, the teacher was not able to grasp the gist of the principle of using authoritative information constructively in his reflections. Some students copied and pasted information from the Internet directly without acknowledging the source. However, the teacher believed that as long as he asked the students to explore learning resources on the Internet, he was adhering to the principle. He did not further scaffold the students on making constructive use of sources. According to Yeo and Tan (2010), the constructive use of authoritative sources involves the interpretation of meaning in context and plays an important role in deepening and expanding students’ science domain knowledge. Hence, in our next cycle of research, we must elaborate this principle to the teacher. Second, the teacher designed the ‘Observational Forms for Rustproofing Experiments’ (see Appendix II) for the students to document the daily degree of rust over five consecutive weekdays. The findings show that none of the six groups completed this task. The ‘Degree of rusting of the iron clip: 0/10’ item might have been too abstract for Primary 4 students to estimate and record. Nevertheless, the students took some pictures to document the daily rusting process during their break time. In providing scaffolds such as prompts, we suggest that the teacher must
consider the students’ level and cater to their needs. Finally, the results of the research cannot be generalised due to the short time span. Further interactive studies are required to investigate whether the five instructional principles suffice for developing teachers’ principle-based understanding of inquiry-based learning, whether the inquiry-based learning model must be refined and how to make better use of social network technology to support seamless learning environments.

Conclusions and future work

This study explores the use of a principle-based pedagogical design for inquiry-based learning in a seamless learning environment, with resource access and peer interactions initiated in classrooms and extended to online interactions. The inquiry-based learning approach was integrated into the domain knowledge learning process to promote students’ development of inquiry skills. The results demonstrate the effective development and implementation of the pedagogical design in a rustproofing learning unit and the positive effect of the design on students’ domain knowledge gains and inquiry skills. The results reveal the need for further research to accumulate experience and scale-up pedagogical interventions within and across schools. The future scale-up of research efforts should be planned under the “design-based implementation” and “designing for diffusion” approaches (Dearing & Kreuter, 2010; Penuel, Fishman, & Cheng, 2011) to build capacity among teachers in the within- and cross-school settings. Further research will instil in target teachers a positive perception of the research efforts that address persistent practice problems from multiple perspectives during the capacity scale-up across the Hong Kong primary school sector.

References


**Appendix I**
Forms for experimental rustproofing designs

<table>
<thead>
<tr>
<th>Group:</th>
</tr>
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<tbody>
<tr>
<td>Group members:</td>
</tr>
<tr>
<td>1.</td>
</tr>
<tr>
<td>2.</td>
</tr>
<tr>
<td>...</td>
</tr>
</tbody>
</table>

*Experimental design 1 (Experimental designs 2 and 3 used the same forms as experimental design 1.)*

<table>
<thead>
<tr>
<th>Material</th>
<th>Student in charge</th>
<th>Hypotheses of rustproofing theories</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
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<tr>
<td>...</td>
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</tbody>
</table>

Design diagrams (in order)

**Appendix II**
Observational forms for rustproofing experiments

<table>
<thead>
<tr>
<th>Observation date</th>
</tr>
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<tbody>
<tr>
<td></td>
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<td></td>
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</table>

<table>
<thead>
<tr>
<th>Observation time</th>
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<tr>
<td></td>
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<tr>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Observer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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</tbody>
</table>

Experimental design 1 (Also experimental designs 2 and 3)

Degree of rusting of the iron clip: 0/10