The Effects of Mobile Natural-science Learning Based on the 5E Learning Cycle: A Case Study

Tzu-Chien Liu¹, Hsinyi Peng², Wen-Hsuan Wu³ and Ming-Sheng Lin⁴

¹Institute of Graduate Institute of Learning & Instruction, National Central University, Taiwan // ²Institute of Education, National Chiao Tung University, Taiwan // ³Taipei Municipal Shi-Dong Elementary School, Taiwan // ⁴Department of Nature Science, Taipei Municipal University of Education, Taiwan // ltcc@cc.nctu.edu.tw // sindypeng520@gmail.com // look305@tp.edu.tw // linms@tmue.edu.tw

ABSTRACT
This study has three major purposes, including designing mobile natural-science learning activities that rest on the 5E Learning Cycle, examining the effects of these learning activities on students’ performances of learning aquatic plants, and exploring students’ perceptions toward these learning activities. A case-study method is utilized and the science club with 46 fourth-grade students is selected as the study case in the study. Besides, a set of quantitative and qualitative data were collected from the case to document the learning effects of and the students’ perceptions of the learning activities, and to discuss factors underlying these effects and students’ perceptions. The results indicate that the learning activities can enhance students’ scientific performances, including both knowledge and understanding levels. Students’ perceptions of these learning activities appear to be positive. The study identifies two factors that are prominent in the positive effects: students’ engaging in “mobile-technology supported” observation during their scientific inquiry; and students’ engaging in “mobile-technology supported” manipulation during their scientific inquiry. Finally, the conclusions that our study has drawn could constitute a useful guide for educational practitioners concerned with the potentials of mobile computing in school settings.

Keywords
5E learning cycle, Mobile learning, Natural science learning, Case study

Rationale and significance of the study

The rapid development of wireless communication and of ubiquitous-computing technology has attracted the attention of researchers from multiple disciplines. Various studies have examined the use of such new technologies in school settings in an attempt to provide learners and educators with support that is more active and more adequate (Hoppe, Joiner, Milrad, & Sharples, 2003; Hwang, Tsai, & Yang, 2008). For example, Hoppe and colleagues (2003) argue that learning with wireless mobile computing supports “active, productive, creative and collaborative learning methods” (p. 255). However, integrating innovative technologies into school settings does not necessarily ensure successful learning (Liu, 2007). As new technology emerges, some researchers are obsessed with introducing it to educational settings. These researchers endeavor to develop innovative instructional models that mirror technology functions. This approach may contribute to the innovative use of learning technologies and instructional models; however, it may also prevent effective technology diffusion owing to the neglect of teachers’ inputs. Therefore, before the large-scale implementation of mobile technology takes place in schools, educational practitioners and researchers should collaborate on effective designs based on the needs of teachers (Cobcroft, Towers, Smith, & Bruns, 2006; Liu, 2007; Peng, Su, Chou, & Tsai, 2009).

The significance of this study lies in its collaborative efforts, from the research team and the school teachers, to develop mobile natural-science learning environments and activities that are based on instructional needs as well as on an integration of mobile technology and the 5E Learning Cycle. Given its innovative features, however, the current study emphasizes the practicability of learning activities in authentic settings; therefore, instructional needs of teachers remain the priority. These results can create a balance between science-learning pedagogies (such as the 5E Learning Cycle model described in the study) and mobile learning environments and can help teachers and practitioners get educational benefits from the balance.

The 5E Learning Cycle as major scientific pedagogy

This study uses the 5E Learning Cycle as the major pedagogy herein for the following reasons. First, the 5E Learning Cycle is seen as an effective hands-on, minds-on, inquiry-based scientific pedagogy, especially for enhancing understanding (Bybee & Landes, 1988; Bybee et al., 2006; Stamp & O’Brien, 2005). Second, the 5E Learning Cycle
is one of the widely-adopted pedagogies as an indoor activity in the natural-science teaching (Bybee et al., 2006). Third, applying the 5E Learning Cycle to outdoor activities may suffer from some limitations and mobile technologies can support the application of the 5E Learning Cycle to outdoor natural-science learning.

Several studies have provided a structure that classifies various levels of inquiry-based learning (e.g., Martin-Hauser, 2002; Windschitl, 2003). For example, on the basis of the styles and levels of students’ inquiry tasks, Windschitl (2003) outlines a hierarchy of levels of inquiry, consisting of confirmation, structured inquiry, guided inquiry, and open inquiry. In general, the 5E Learning Cycle is considered as a “guided inquiry” while the teacher provides only the materials and problems to investigate and students execute their own procedures to solve the problem under the guidance of teachers (Martin-Hauser, 2002; Windschitl, 2003).

The 5E Learning Cycle, first created by Robert Karplus in the late 1950s and early 1960s, has been regarded as a general philosophy of teaching and learning with strong constructivist foundations. The 5E Learning Cycle consists of five phases: engagement, exploration, explanation, elaboration, and evaluation (Bybee & Landes, 1988; Bybee et al., 2006; Eisenkraft, 2003). It is a teaching-and-learning procedure consistent with the privileged status of inquiry and with the ways in which students naturally learn (Musheno & Lawson, 1999). The following paragraphs include explanations of both the 5E Learning Cycle phases and the major tasks for the teacher and students in each phase (Bybee & Landes, 1988; Bybee et al., 2006; Stamp & O’Brien, 2005).

Engagement phase (E1): The teacher assesses students’ prior knowledge and engages students in learning a new concept. The teacher also helps students make connections between prior and present knowledge, and helps to organize students’ thoughts about the learning outcomes of present activities.

Exploration phase (E2): The teacher provides students with a common base of activities reflective of present concepts, processes, and skills. Students complete activities by using prior knowledge to generate new ideas, to explore questions and possibilities, and to execute a preliminary investigation.

Explanation phase (E3): The teacher focuses students’ attention on a specific aspect of their “engagement” and “exploration” experiences, and provides opportunities for students to demonstrate their understanding or skills. The teacher can also use direct instruction and guide the students toward a deeper understanding of a concept.

Elaboration phase (E4): The teacher challenges and extends students’ conceptual understanding and skills. Students learn to develop broader and deeper understanding and skills, through the above three phases.

Evaluation phase (E5): The teacher evaluates students’ progress toward achieving the instructional goals. Students learn to assess their understanding and abilities.

Several studies have shown that the 5E Learning Cycle was successfully applied to a variety of grade levels (e.g., Barman, 1992; Barman, Cohen, & Shedd, 1993; Purser & Renner, 1983; Saunders & Shepardson, 1987; Stepans, Dyche, & Beiswenger, 1988). For example, in their study of an eighth-grade genetics class, Balci, Cakiroglu, and Tekkaya (2006) compared the effectiveness of the 5E Learning Cycle with the effectiveness of expository instruction. According to the authors’ conclusions, the activities for students in the 5E Learning Cycle helped them to activate their prior knowledge and to overcome struggling with their misconceptions. In addition to the knowledge gains, these students had the opportunity to explain, to argue, and to debate their ideas, practices that helped the students further extend the conceptual understanding.

Another study applied the 5E Learning Cycle to a teacher-development program in a food-safety curriculum (Beffa-Negrini, Cohen, Laus, & McLandsborough, 2007). Seventy-one secondary teachers registered for the program, which designed food-safety training activities based on the National Science Education Standards and the Biological Science Curriculum Study. The participating teachers went through 3 modules, each with 15 hours of web-based instruction, interactive discussion, and tools for conducting experiments or for critically evaluating projects. After analyzing the 38 matched pre-test and post-test evaluations, Beffa-Negrini et al. (2007) found that the teachers were satisfied with the program and that most of them felt better able to critically evaluate food-safety information on the Internet. By experiencing the 5E Learning Cycle’s approach to learning about food safety, and by using an inquiry-based approach, these teachers could continue to effectively instruct on the same topic.
However, even given the above premises, there are certain constraints that limit teachers’ application of the 5E Learning Cycle to their natural-science teaching, especially to the outdoor inquiry-based activities. In the context of natural-science teaching, teachers often conduct outdoor inquiry, visual presentations, lab activities, or a mix of all these activities. Many educators believe that the most feasible learning activities of natural science is outdoor inquiry, which takes science investigation outside the classroom (Chen, Kao, & Sheu, 2005; Tan, Liu, & Chang, 2007). However, sometimes outdoor inquiries are more challenging and less effective than expected, owing to students’ lack of suitable resources and immediate learning supports when teachers and students are scattered in different locations (Dillon et al., 2006). Mobile computing, when combined with wireless connections, can overcome the problems and then can support students’ outdoor inquiry-based learning (e.g., Lai, Yang, Chen, Ho, & Chan, 2007; Rogers et al., 2004; Tan et al., 2007). The following section illustrates recent studies that focus on developing mobile learning environments for scientific outdoor inquiry-based learning.

Mobile computers for supporting natural-science learning

In recent years, mobile devices, wireless communications, and network technologies have emerged and have been integrated into various learning contexts (Chen, Kinshuk, Wei, & Yang, 2008; Liu et al., 2003; Soloway, Norris, Blumenfeld, Fishman, & Marx, 2001). Mobile learning environments offer much educational potential that is not easily achieved in other learning environments (Cobcroft et al., 2006; Hwang et al., 2008; Liang et al., 2005; Liu, 2007; Peng, Chou, & Chang, 2008). Mobile devices not only enable both the teacher and students to employ computing power but also do so without seriously constraining either the teacher or students regarding time or location. These constraints continue to diminish as the wireless technologies seamlessly connect mobile devices to other computing devices. This promising computing power has appealed to educators and researchers in many disciplines, particularly in the natural sciences.

Several studies have developed mobile learning environments to support scientific outdoor inquiry-based learning and have shown that these environments positively affect various learning outcomes (Chen, Kao, & Sheu, 2003; Lai et al., 2007; Rogers et al., 2004; Tan et al., 2007). For example, by using a personal digital assistant (PDA), Chen and colleagues (2003) developed a “bird-watching learning” (BWL) system to scaffold students’ learning and observational skills. In their study, the BWL system can serve as a tool for enhancing students’ curiosity, as a tool for discovery, and as a tool for independent learning. A formative evaluation of the BWL system indicated that young learners who used the system improved their learning, above and beyond what would normally be expected.

Lai and colleagues (2007) developed a “mobile-learning passport” (MLP) system to motivate and guide students’ learning in school gardens. The system can be easily operated in a wireless handheld device. The results show that students were motivated and agreed that the MLP system enhanced their learning. Rogers and colleagues (2004) focus on designing and delivering digital information to students undertaking scientific inquiry in wooded areas. Their study shows that well-organized digital information, when integrated in mobile devices, can optimize reflection and interpretation in learning. Last, Tan et al. (2007) proposed an Environment of Ubiquitous Learning with Educational Resources (EULER) based on radio-frequency identification (RFID), the Internet, ubiquitous computing, embedded systems, and database technologies to effectively present information about subjects ranging from historical relics to rare animals and geological landscapes. After the 16-week intervention, students who used EULER outperformed the control-group students regarding both post-test achievement and grades.

All of these studies showed that mobile learning environments can enhance natural-science, outdoor, inquiry-based learning. Moreover, these studies have dedicated themselves to developing various innovative learning technologies. However, most of these studies have based their developed innovative learning environment on certain learning activities and have imposed a research agenda on teachers. Under such a situation, the teachers assume little ownership in curriculum development or in teaching agenda. For example, teachers may have no opportunity to modify the mobile learning environment or learning activities to fit their own specific instructional requirements if necessary. The interest conflicts between researchers and teachers sometimes may expand, rather than close, gaps between theory and practice. The present study addresses this issue and focuses on the following related issue: teachers’ instructional/practical efforts to develop learning environments and learning activities that facilitate the effective integration of mobile technology into teaching and learning practices.
Research purposes and questions

There are three purposes of this study: (1) designing mobile natural-science learning activities that rest on the 5E Learning Cycle, (2) understanding the effects of and students’ perceptions toward these learning activities, and (3) discussing factors underlying learning effects and students’ perceptions. To achieve these goals, a mobile learning environment and learning activities are developed based on teachers’ requirements. Next, the current study collected both quantitative and qualitative data from the mobile learning activities and from related feedback of students.

The research questions are as follows:
1. What are the effects of the mobile learning activities on students’ knowledge levels and understanding levels of aquatic plants? And why?
2. What are the perceptions that the students have with regard to the learning environments and the mobile learning activities? And why?

Methods

The current study uses the case-study method. A case study is considered “an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 1994, p. 13). That means, a case study is an empirical and holistic inquiry that explores a social unit, a single instance, or a phenomenon within a natural setting (Yin, 1994; Merriam, 1998). Therefore, this approach is particularly appropriate for exploring the possible effects that wireless and mobile technologies have on teaching and learning (Liu, 2007).

Participants and the context

This study took place in an elementary school in Taipei City, Taiwan, which had been constructing an ecological pool for years. With financial support from the Taipei City Government’s Department of Education, the school planned to establish a mobile learning environment devoted to natural-science instruction on aquatic plants. This plan motivated the school to collaborate with the current research team. In order to advance students’ learning of aquatic plants, the current study designed, developed, and implemented both the mobile learning activities and the learning materials in the wireless environment for a 14-week after-school science club.

The science club, consisting of a total of 46 fourth-grade students (including 24 males and 22 females), is considered the case to be studied. The students’ participation rested on their use of the ecological-pool website (described in the following section) and a tablet personal computer (tabletPC) supported by the Taipei City government. Before attending the club, these students had learned and acquired a basic understanding of aquatic plants in their science classes. Besides, they were well-informed about the instruction formats and voluntarily participated in the club. In order to examine the effects of learning activities and possible factors underlying these effects, the researchers collected and analyzed dataset regarding students’ performances, perspectives, reflections, and opinions about the instruction.

The mobile learning environment

The current study’s mobile learning environment consisted of two major components: one was an Ecological Pool website that was on the server and that connected powerful campus access points to one another; and the other constituted the tabletPCs used by each participating student. Such a learning environment enables the teacher and the students to use the resources of the website in any place (such as the ecological pool and the laboratory) at the school via the students’ tabletPCs.

In order to provide an easy delivery platform that teachers can use for their science teaching, under the support of the research team, a group of the school teachers developed the “Ecological Pool” website (in Chinese). All the information on this website echoed the instructional requests from science teachers at the school. These resources provide hands-on problem solving as well as reinforce concepts and understanding. They can be used for class
instruction, outdoor inquiry, lab activities, individual or small group study, and assessment, in a ready-made format for downloading.

Figure 1 shows the homepage of the Ecological Pool website demonstrating the actual scene of the school’s ecological pool. Users can choose a spot to enter a specific aquatic-plant section. Figure 2 presents the third section in the ecological pool. In each section, pictorials illustrate the characteristics of the plants and help students identify those characteristics. Students are able to read specific information by clicking on the portion of the pictorials or the suggested scientific terms. This function enables students to carry out inquiry without memorizing the scientific terms of the plants.

Figure 1. The homepage of the Ecological Pool website

Figure 2. The webpage of the third section in the ecological pool

Figure 3 displays the information about the *Nuphar shimadai*: this information features illustrated collections of close-ups that correspond to each important part of a plant and that are clickable for enlarged views. The bottom-right corner provides a comprehensive reading of the *Nuphar shimadai* and shows a picture of the plant taken directly from the school’s ecological pool. The use of close-ups and of detailed information enabled students to easily locate the corresponding plant in the ecological pool. Figure 4 presents a glossary that defines the plants’ scientific terms in relation to the parts of plants, which either easily confuse students (such as a tuber and a bulb) or are not observable (such as an air-cell chamber and a lenticel). The teacher could use these materials to guide students for the compare-contrast process of identifying how these plants are alike and different. This process sometimes required students’ advanced possession of evaluating and synthesizing skills.
Figure 3. The webpage introduces the *Nuphar shimadai*

Figure 4. The glossary for the aquatic plants

Figure 5. The repository of activity sheets
Figure 5 presents a repository of learning-activity sheets, which is organized in accordance with instructional goals and with learning units. For their individual learning, students can download the activity sheets listed on the left column, while the ones on the right are designed for group work.

**The mobile learning activities**

In this study, seven learning activities are designed and developed based on teachers’ instructional requirements, the tenets of the 5E Learning Cycle and the school’s existing learning resources. Before the seven learning activities took place, one 40-minute technology orientation was offered to familiarize students with the mobile environment. Figure 6 shows the implementation process of these seven learning activities. As the figure shows, the five phases of the 5E Learning Cycle serve as the foundations of the seven activities. With learning devices, wireless connections, and the Ecological Pool website, the seven learning activities are executable without constraints of time or location.

In order to better illuminate the activity design, the following paragraphs describe in greater detail one activity: namely, activity six, which concerns “Submerged-type” aquatic plants. During this activity, the students learned at the ecological pool from phase E1 to half-way through phase E4, and then, they learned at the laboratory from the last half of E4 to all of E5.

![Figure 6. The implementation of a mobile learning activity](image1)

![Figure 7. The flow chart of the sixth learning activity](image2)

Figure 7 displays specifically the implementation of activity six, which best demonstrates the use of the 5E Learning Cycle within mobile-learning contexts (refer to Appendix 1 for the procedure, the time, and the location of activity six). Figure 7 also explains the 5E Learning Cycle phases and the tasks for the teacher and the students in each phase. The instructional goals were that students should learn the specific forms and the specific habitats of the “emergent-type” aquatic plants and that the whole lesson should take 160 minutes (which included four 40-minute classes). Besides individual learning, students also have the opportunities to conduct inquiry with their team members. For instance, in the “Elaboration” phase of activity six, students work in groups to complete their activity sheets via observation, reading materials on the website, conducting experiments, and sharing findings.
Research design and data collection

In the current study, the quantitative data and the qualitative data were collected from six different data sources, as described below.

1. A Knowledge Test: Students took a knowledge test regarding their knowledge levels of aquatic plants (such as recall or recognition of aquatic-plant facts) before and after their science-club learning. This knowledge test used an open-ended format that required students to write down as many aquatic plants as possible and to further categorize these plants into specific types: “free-floating type,” “floating-leaf type,” “submerged-type,” and “emergent-type.” A student would receive 0 points when he or she would fail to write down the correct aquatic-plant term; a student would receive 1 point for applying a correct term to a wrong type, and 2 points for applying a correct term to its correct corresponding type.

2. An Understanding Test: Students took an understanding test regarding their understanding levels of aquatic plants (such as discussions, explanations, and restatements regarding aquatic plants) before and after their science-club learning. There are 24 multiple-choice items in the test (refer to the example item in the section “Results and Discussion”). The internal consistency reliability (KR-20) of the test is .71.

3. A Learning-activity Survey was filled out by students so that the research team could collect their overall perception of the learning activities. This survey was conducted after students finished all of the learning activities.

4. Students’ learning activities were observed and videotaped in various instructional settings.

5. The students were interviewed at the end of each club meeting, and all the interviews were recorded and transcribed for later analysis.

6. The students kept reflective journals after each learning activity.

After collecting data from observations, interviews, and reflective journals, the researchers coded the above datasets on the basis of attributes and dates; for instance, the reflective journal kept by student 03 on April 4th was coded as “S03-J0404,” and the observation data and interviews were coded as “O” and “I,” respectively.

Results and discussion

This section discusses results concerning (1) the effects of mobile learning activities and (2) students’ perceptions of the mobile learning activities. The presentation of these results rests on the analyses of qualitative data (such as students’ reflective journals).

The effects of mobile learning activities

In order to determine the effects of the seven mobile learning activities mentioned above, we used Bloom’s (1956) levels of cognitive learning behaviors to classify students’ learning. Students’ learning can correspond to the Knowledge level (recall or recognition of aquatic plant facts) or to the increasingly more complex and abstract Understanding level (discussions, explanations, and restatements regarding the aquatic plants).

The knowledge test

The present study performed a t-test to compare the mean scores that students received in the knowledge test before and after students’ engagement in learning activities. The results in Table 1 show that students’ mean scores (26.04) after learning activities were significantly higher than students’ mean scores (10.30) before learning activities (p < .001). This result confirms that students’ knowledge of aquatic plants increased and that the students could better identify correct aquatic-plant terms and the plants’ corresponding types after the mobile learning activities.

<table>
<thead>
<tr>
<th>Table 1. Students’ knowledge test scores regarding aquatic plants before and after learning activities (N=46)</th>
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<tbody>
<tr>
<td><strong>Before learning activities</strong></td>
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<tr>
<td>Mean</td>
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<tr>
<td>Knowledge test of aquatic plants</td>
</tr>
</tbody>
</table>

*** p < .001
The understanding test

Results of the t-test in Table 2 indicate that students’ scores after learning activities (M=19.04) were significantly higher than students’ test scores before learning activities (M=15.63) (p < .001) in the understanding test on aquatic plants. This analysis result means that students’ understanding of aquatic plants increased after their engagement in the learning activities.

<table>
<thead>
<tr>
<th>Table 2. Students’ understanding test scores regarding aquatic plants before and after learning activities (N=46)</th>
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<tr>
<td><strong>Before learning activities</strong></td>
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<tr>
<td>Mean</td>
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<tr>
<td>Understanding test on aquatic plants</td>
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</table>

**Possible factors underlying the effects of mobile learning activities**

According to the 5E Learning Cycle, students’ use of a hands-on inquiry process enhances not only the students’ understanding but also shifts in the students’ understanding (conceptual changes) (Bybee & Landes, 1988; Bybee et al., 2006). In the past, this pedagogy was often adopted as indoor learning activities (such as in a lab) (e.g., Barman, 1992; Barman, Cohen, & Shedd, 1993; Purser & Renner, 1983; Saunders & Shepardson, 1987; Stepans et al., 1988); yet the learning activities in this study have combined mobile learning environments developed by school teachers and the tenets of the 5E Learning Cycle, the goal being to help students conduct scientific-inquiry activities in various learning settings. Of these learning activities, mobile computing and wireless connection, owing to their convenience and immediacy, have made possible a flexible transition among various learning environments (such as an ecological pool, a science laboratory, and the Ecological Pool website). Each learning environment, in turn, would have its own distinctive resources to which the students could flexibly and easily adapt during the mobile learning activities. For instance, students could gain both micro and macro views of a water lily by combining a lab setting and an observation activity at the ecological pool. In the lab setting, students examined the air-cell chamber of water lilies through electronic microscopes; while at the ecological pool, the teacher guided the students as they explored the habitats, the relationships between the air-cell chamber and habitats, and the roles that water lilies played in the whole ecological system, from a macro perspective in the mobile environment. The following section treats the factors that might have resulted in positive learning effects, and does so on the basis of qualitative data collected from observation, students’ learning journals, and interviews.

First, students’ efforts to observe aquatic plants by using adequate support of mobile devices might have helped the students correct their related misconceptions, in turn, strengthening the students’ understanding of aquatic matters. While learning in these mobile learning activities, students had opportunities to observe or to manipulate scientific resources. The data collected from students’ reflective journals and from interviews confirm that the use of resources and the guidance on the Ecological Pool website had positive effects on student learning. For example, students (11, 15, and 22) were able to identify the stems and stalks of “free-floating type” aquatic plants after reading articles on the website and observing the plants. Another example took place in the activity “Water lily, lotus, pond lily.” Before this activity, most students were confused about the characteristics that distinguish lotuses from water lilies, and some students even believed that the two were the same type of plant. In this activity, students carried out their inquiry guided by the website, and they could successfully identify the differences between lotuses and water lilies afterwards. Student 37 and her teammate discovered leaf differences (hairy thorn-like growths on lotuses, and sawtooth-like leaves on water lilies) (J0609), and student 45 and her teammate concluded that the lotus is categorized as an “emergent type” of aquatic plant, while the water lily is categorized as a “floating-leaf type” aquatic plant (J0609).

One factor underlying positive effects of knowledge acquisition and conceptual change lies in students’ hands-on experiences in the learning activities. For example, in the fourth activity of “free-floating type” aquatic plants, students used electronic microscopes and projected images of the cilia and the air-cell chambers of certain aquatic plants onto the electronic whiteboard. This experience provided the students a common base of activities to identify current concepts, misconceptions, processes, and skills. Writing in the reflective journal, student 34 identified one of his misconceptions: “This activity challenged my previous assumption about salvinia natans. The hundreds of air-cell chambers on the surface of salvinia natans really shocked me because, before the activity, I supposed there were
none…. I jotted down all my findings on the activity sheet and was ready to share them with other classmates” (J0428).

Another factor underlying positive learning effects might be students’ prolonged engagement in the mobile learning activities. The teacher discovered that students loved the observation activities at the ecological pool and they loved to share their findings after the inquiry. Moreover, instances of these trends received frequent mention in students’ reflective journals: for example, student 21 wrote, “These tasks kept me very busy, but I really enjoyed this unique learning experience!” (J0510). Student 22 mentioned, “Even though there were many mosquito bites on my legs, I still felt a sense of accomplishment after figuring out the answers through the use of the website and through the observation at the pool” (J0510), while student 09 characterized his inquiry as a “joyful experience of treasure hunting” (J0607). More detailed discussions of students’ feedback are presented in the section “Students’ perceptions of the mobile learning activity.”

Having discussed the above factors’ role in positive learning effects, this study acknowledges limitations in its activity design and in its implementation, and does so on the basis of students’ understanding tests, interviews, and observation logs.

First, even though these mobile learning activities heavily emphasized observation during students’ inquiry process, specimens of several plant categories, such as lotus roots, lotus seeds, and lotus seedpods, were not available for observation during the research period. Therefore, students could learn about these categories only through readings posted on the website. The lack of in-depth observations resulted in a low correct rate (59%), which was significantly lower than the average correct rate (79%), in one of the understanding-test items: “What is the function of the ‘holes’ in the lotus root?” In-depth interviews also showed that students retained their misconceptions after the learning activities. For example, two students (student 17 and student 34) who had chosen the wrong answer of option 2 (As holders for lotus seeds) conjectured that the round shape of those holes would match that of lotus seeds. These students’ responses might have derived from their inability to observe the growth of these plants. These findings suggest the importance of matching the curriculum to seasonal patterns, in order to promote students’ learning by observation.

Next, although the mobile learning environment, developed by the team of school teachers, can meet teachers’ instructional needs, and it is easy to operate and maintain, it might be with somewhat limited technical stability. For instance, in the early stages (activity 1) of this study’s activities, certain technical problems (e.g., disconnection) hampered the processes of learning. Although the solutions of the technical problems were soon identified—solutions including the promotion of student tutors and better preparation before the activities, the technical problems still may negatively influence students’ learning.

Students’ perceptions of the mobile learning activities

After collecting the data from the learning-activity surveys and the after-project interviews regarding students’ experiences in the learning activities, we described in detail (1) the students’ overall impressions of learning activities and (2) the students’ perceptions of the mobile devices and (3) the students’ perceptions of the learning activities. The following subsections present these detailed descriptions.

Students’ overall impressions

The results indicate that students’ overall impressions of the activities were positive: twenty-nine (64%) out of forty-five students who completed a Learning-activity Survey expressed that they greatly liked or liked the activities, and sixteen (36%) students expressed that they moderately liked the activities. We then analyzed the students’ motives that had been associated with the students’ aptitudes.

The current study investigated students’ motives by providing the students with a survey question for which they could select one or more predefined options (see Table 3). Twenty-two students (49%) felt that their opportunity to use a tabletPC throughout the learning activities was a source of motivation. Sixteen students (36%) responded that their being able to observe the “real” aquatic plants in the ecological pool was essential, while one-third of the
students felt that they had gained knowledge of aquatic plants and that the activity design and the teacher’s delivery of the activities were interesting.

Table 3. Students’ overall impressions of the learning activities (N=45)

<table>
<thead>
<tr>
<th>Motive</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>I was motivated by my opportunity to use a tabletPC.</td>
<td>22</td>
</tr>
<tr>
<td>I could observe the aquatic plants in the ecology garden.</td>
<td>16</td>
</tr>
<tr>
<td>I think I have gained knowledge of aquatic plants in the learning activities.</td>
<td>15</td>
</tr>
<tr>
<td>I felt that the learning activities were interesting.</td>
<td>14</td>
</tr>
<tr>
<td>I enjoyed the way my teacher taught in this class.</td>
<td>11</td>
</tr>
</tbody>
</table>

Students’ perceptions of the mobile devices

Because the tabletPCs had played a vital role in the class activities, we investigated students’ perceptions of the mobile-learning devices by collecting and analyzing students’ reflective journals and in-depth interviews. Some students had viewed their tabletPCs as a tool (e.g., a reference tool) for studying aquatic plants (students 07, 08, 09, and 24), and other students even had regarded it as a handy dictionary for all plants (students 17 and 41). For example, student 09 stated, “The tabletPC is very important to our class activity. I can look up a specific aquatic plant via the website and display the features when I’m at the ecological pool; also, the information that comes up can help me understand why a specific plant is unique” (I0626). Another student (student 41) mentioned that the features of a tabletPC are akin to those of a dictionary: “If we had a hard time locating a certain aquatic plant, we could always search for online information using the tabletPC” (I0626).

Students’ preferences regarding the mobile learning activities and lectures

From students’ reflective journals, the researchers were able to understand students’ perceptions and preferences regarding the two instructional modes (the mobile learning activities in the current study and the lectures that students often take in ordinary classrooms). The results show that, of the forty-three students who completed the journals, twenty-four students (56%) preferred the mobile learning activities to lectures, nine students (21%) liked both of the modes, and ten students (23%) preferred lectures. The following sections describe in detail students’ preferences and feedback.

Why students preferred mobile learning activities. Some students variously characterized the mobile learning activities as more “personal,” “collaborative,” and “hands-on” than were the lectures. For example, students 10, 30, and 35 found the mobile learning activities more “interesting and interactive” than the teacher’s lectures. Student 10 stated, “The mobile learning activities help me appreciate the hands-on experiences through observation” (J0524), and students 30 and 35 raised similar points. For example, student 30 stated, “We prefer learning with our teammates and having an inquiry-type learning experience. We’ve built a close relationship by solving problems and completing our assignments together” (J0526). Some students believed that they had gained knowledge not by memorizing facts about plants, but by observing authentic aquatic plants (students 07, 09, and 39), and one student, student 28, mentioned that he sometimes felt like a researcher conducting scientific inquiry and that this feeling motivated him to search for resources beyond class requirements (J0526).

Why students preferred both mobile learning activities and lectures. Some students liked both mobile learning activities and lectures. For example, student 29 said, “The lectures can help me understand the concepts; however, the mobile learning activities can help build up thinking skills” (J0524). Student 06 believed that “I can gain knowledge quickly from lectures, while I can feel a sense of accomplishment by looking for resources to solve problems myself” (J0524). Student 11 pointed out, “Lectures are good sources of knowledge, as mobile learning activities create a relaxed learning atmosphere for collaboration.” As such, some students suggested an ultimate learning arrangement where a combination of these two modes can provide an adequate mixture of independent and collaborative learning experiences for students with diverse learning styles (e.g., S06-J0524, S17-J0524, and S40-J0526).
Why students preferred lectures. Students 13 and 20 mentioned similar points, with student 13 declaring, “The inquiry-type learning is very time consuming. Sometimes my teammates come up with different solutions, and we’re not even sure whether or not these are the correct ones. This made me feel as though I’d spent my time inefficiently; therefore, I prefer the direct instruction from the teacher—it’s much easier and right-to-the-point” (J0524). Student 01 and 03 echoed the above statement. Student 01 said, “It’s easier to catch the key points from the teacher’s lecture … so that I can finish the activity sheet promptly.” Student 03 pointed out, “I liked lectures because they’re easier” (J0524).

The results revealed that most students’ perceptions of mobile learning activities were very positive because the students viewed their mobile-learning devices as an integral part of their learning. It was apparent that most students preferred mobile learning activities to lectures because of such activities’ ability to promote hands-on tasks, observation, and inquiry-based experiences, whose characteristics have matched the important characteristics of mobile learning activities. Even so, it is worth noting that there were still a few students not ready to the learning strategies (e.g., hands-on inquiry or observation) required by the mobile learning activities. For that reason, in order to accommodate students’ learning styles, the teacher can deliver essential knowledge via lectures and can introduce the more hands-on and exploratory modes of mobile learning activities.

Conclusions

This study designed and developed mobile natural-science learning activities based on teachers’ instructional requirements, the tenets of the 5E Learning Cycle, and the school’s existing learning resources. The purposes of this study were to report the learning effects of and students’ perceptions toward learning activities that rest on the tenets of the 5E Learning Cycle and possible factors underlying these positive effects and students’ perceptions. From our findings, we have drawn the following conclusions and suggestions for educational practitioners and researchers regarding the integration of mobile computing into future teaching and learning settings.

First, the present study’s learning environment consisted of one computer, several wireless access points, a website containing learning materials and activity sheets, and several mobile devices for students. The study has shown us that constraints on time and on location diminish as technology seamlessly interweaves scientific-learning pedagogies (such as the 5E Learning Cycle model) with mobile learning environments, especially for students’ observation activities at the ecological pools. Such findings echo assertions that the mobile computing, combined with wireless connections, can overcome problems arising during students’ outdoor activities and can enhance the quality of outdoor, natural-science, inquiry-based learning (Lai et al., 2007; Rogers et al., 2004). As more innovative features mobile technology become available, however, not all of them fit instructional goals or learning needs in the school settings. For example, students use the global positioning system (GPS) to locate and gather information at various locations in some studies. Yet in the current study, until this point, there seems no need to involve GPS because of its limited size of the ecological pool as well as its difficulties in locating moving targets (e.g., plants) on the pool. The complexity of developing and maintaining such a system might have affected teachers’ aversion to use mobile technology. Also, we believe that, via the compare-contrast process of identifying plants guided by the website, students can gain deeper levels of knowledge and understanding of the aquatic plants than merely following the directions of GPS. Therefore, when introducing technology into classrooms, researchers should consider the potential of the technology that, for most educators and practitioners, is more useful, easier to use and more accessible in their daily practices.

Second, we have shown that the 5E Learning Cycle model is an effective hands-on and inquiry-based scientific pedagogy that enhances students’ scientific knowledge and understanding. When combined with mobile computing, the model seems to create opportunities in which teachers can design unique learning experiences that transition smoothly from indoor inquiries to outdoor inquiries. The results of the study suggest that, in general, the mobile learning activities based the 5E Learning Cycle model can effectively increase students’ knowledge and understanding of aquatic plants and improve students’ learning motivation. Future research and teaching would do well to reference this best-practice scenario, in which we detail the design and the procedures of the 5E Learning Cycle phases as well as the roles of, and the tasks for, the teacher and the students in each phase in the mobile learning contexts.
Third, the current study’s case presents an in-depth view of learning in the mobile learning activities that rested on the 5E Learning Cycle; however, the study’s use of a case may also limit the generalizability of the study’s findings. Based on the analysis of learning effects and factors already discussed here, future studies may extend the current study’s findings to other classes or disciplines, or may use alternative research methods (such as field-experiment methods) to present a more thorough picture of effective integration of mobile technology into teaching and learning practices.

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References


Appendix 1. The phases and the procedures of the 5E Learning Cycle for Activity Six

<table>
<thead>
<tr>
<th>Phase</th>
<th>Procedure</th>
<th>Time (Minutes)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engagement</td>
<td>The teacher assesses students’ prior knowledge and engages students in a new concept by having them browse the Ecological Pool website. Students familiarize themselves with the thirteen emergent-type aquatic plants and fill out the pre-activity sheet online. The teacher also helps them connect their past and present knowledge.</td>
<td>15</td>
<td>Ecological pool</td>
</tr>
<tr>
<td>Exploration</td>
<td>Students carry out their preliminary investigation of “emergent-type” aquatic plants by filling out the activity sheet via observation at the ecological pool or search for information on the website. The teacher provides students with a common base of activities within concepts discussed at the Engagement phase.</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Explanation</td>
<td>The teacher guides the discussion on the activity sheet and helps students locate the exact spots of these thirteen emergent-type aquatic plants.</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Elaboration</td>
<td>Working in groups of two, students refine their activity sheets through observation and access the website. Students are encouraged to demonstrate and explain their understanding of the “emergent-type” aquatic plants. Students work in groups to incise the leafstalk of plants. They fill out the activity sheet online after conducting research on the question “Do roots of aquatic plants decay in water?”</td>
<td>40</td>
<td>Science laboratory</td>
</tr>
<tr>
<td></td>
<td>Students watch the video “The World of Water Plants” to reinforce their learning.</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Evaluation</td>
<td>The teacher evaluates students’ activity sheets. Students learn to assess their understanding via group discussion.</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>