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A Problem-based Ubiquitous Learning Approach to Improving the Questioning Abilities of Elementary School Students

Pi-Hsia Hung[1], Gwo-Jen Hwang[2*], Yueh-Hsun Lee[1], Tsung-Hsun Wu[1], Bahtijar Vogel[3], Marcelo Milrad[3] and Emil Johansson[3]

[1]Department of Education, National University of Tainan, Taiwan // [2]Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taiwan // [3]Department of Media Technology, Linnaeus University, Sweden // hungps@mail.nutn.edu.tw // gjhwang.academic@gmail.com // asdgary.asd@yahoo.com.tw // tnwuts@tn.edu.tw // bahtijar.vogel@lnu.se // marcelo.milrad@lnu.se // emil.johansson@lnu.se

[*]Corresponding author

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ABSTRACT

The purpose of this study is to investigate the effects of a ubiquitous problem-based learning system (UPBLS) on students' question-raising performance in field inquiry activities. An experiment was conducted on an elementary school natural science course. A total of 43 sixth and fifth grade elementary students divided into experienced and novice groups participated in the field observation activities with on-line discussion over a period of seven months to evaluate the changes in their questioning ability. Moreover, a rubric for evaluating the students' questioning ability was developed and validated. Supported by UPBLS, the students collected the required wetland ecology data in three wetland field observation activities. The experimental results show that the students' questioning abilities significantly improved during the learning process. Moreover, it was found that both the experienced and the novice students had similar progress trends, implying that the proposed approach is helpful for improving the questioning abilities of students with different levels of prior knowledge.

Keywords

Scientific inquiry, Ubiquitous learning, Problem-based learning, Questioning ability

Introduction

Questioning has been recognized as being an important ability for scientific inquiry and knowledge construction (Scardamalia, 2002; Tan & Seah, 2011). Educators have indicated that fostering students' scientific questioning skills needs to be heightened in the 21st century since the impact of science and technology significantly affects many aspects of our daily lives (Tan & Seah, 2011). That is, sufficient and proper practice of asking questions could possibly lead students into a positive cycle that enhances their questioning ability, which is helpful to them in terms of improving their domain knowledge (Scardamalia, 2002). Therefore, it is important to situate students in a questioning practicing environment that provides rich information for them to make observations and investigations in order to solve problems.

Problem-based learning (PBL), which focuses on spontaneity, collaboration, and flexible problem-solving skills, is such an approach that engages students in problem-solving scenarios. In the past decades, PBL has become increasingly popular in settings from K-12 to undergraduate education (Barrows, 2000; Dochy et al., 2003; Gallagher et al., 1992; Hmelo, Holton, & Kolodner, 2000; Torp & Sage, 2002; Williams & Hmelo, 1998). According to the definition of Hung, Jonassen and Liu (2008), PBL is an instructional approach that initiates students' learning by creating a need to solve an authentic problem. During the problem solving process, students construct domain knowledge and develop both problem-solving skills and self-directed learning skills while working toward a solution to a problem. A number of researchers have confirmed the benefits and effectiveness of PBL (Dolmans, Schmidt, & Gijselaers, 1995; Evenson & Hmelo, 2000; Hmelo-Silver, 2004).

In the past decade, the popularity of computer and information technology has further enabled PBL to be applied to various learning areas with different learning supports (Lu, Lajoie, & Wiseman, 2010; Resta & Laferrière, 2007; Rienties et al., 2012). In recent years, owing to the speedy advancement and popularity of wireless communication and mobile technologies, ubiquitous learning environments that integrate real-world and digital-world resources and learning scenarios have provided a new opportunity for implementing technology-enhanced PBL activities (Sharples, Milrad, Arnedillo-Sánchez, & Vavoula, 2009). This innovative pedagogical method, which is defined as ubiquitous problem-based learning (UPBL), has been confirmed as a potential and productive learning approach (Hung et al., 2012). Without the constraints of a physical space or specific time for learning, ubiquitous learning further strengthens the superiority of PBL. Among the learning areas to which the technology-enhanced PBL activities have been applied, science is one of the most general and suitable subjects, especially for conducting inquiry-based activities in the field (Hung, Lin, & Hwang, 2010).

However, one of the key elements of solving problems, that is, students' questioning ability, has seldom been investigated. Questioning ability, referring to the skills of exploring environments, understanding contexts, organizing information, and finally proposing a valuable and answerable driving question, has been recognized as an important component of scientific literacy and the cornerstone of scientific inquiry (Chin, 2002; Hofstein, Novon, Kipnis, & Mamlok-Naaman, 2005). Researchers have pointed out that computer and network technologies are likely to provide a good alternative for improving the quality of questioning since students might be more willing to express their opinions and raise questions in technology-based environments than in traditional classrooms (Hu & Chiou, 2012). Therefore, it could be worthwhile to apply the UPBL approach to improving the questioning ability of students.

In addition to technology-based environments, students' experience is also the main variable affecting the learning progress within inquiry activities. An experienced student, compared to a novice, might be defined as someone who has spent many hours training or solving problems in inquiry learning, and has acquired more knowledge that affects what they notice, the information they remember and recall, as well as how they reason and solve problems (Bransford, Brown, & Cocking, 2000; Petcovic & Libarkin, 2007). Without considering students' inquiry experience, a learning approach may only benefit some of the students. However, few studies have taken students' experience into account when proposing systems or approaches for supporting scientific inquiry activities. Therefore, it is worth investigating whether there is a significant difference between the questioning ability progress of the experienced and novice learners in the inquiry activities using the UPBL.

In the meantime, researchers have emphasized the importance of situating students in authentic learning environments (Brown, Collins, & Duguid, 1989; Hwang, Wu, Zhuang, & Huang, 2013), and have indicated the potential of using mobile, wireless communication and sensing technologies (such as QR-codes or Global Positioning Systems) in providing learning supports to students in real-world explorations (Hwang, Tsai, & Yang, 2008). Along these lines, the purpose of this present study is to build up a ubiquitous learning platform for students, and investigate the effect of promoting questioning ability in the problem-based scientific inquiry activities. Moreover, a scoring rubric was developed, which played the important role of guiding and encouraging the students to propose quality questions in the field trip as well as evaluating their questioning ability (Creswell, 2009; Neuman, 2004; Fan & Lê, 2011). Accordingly, the following research questions are investigated:

- Do the rubrics used to assess questioning ability have reasonable reliability and validity?
- Can the UPBL approach improve students' questioning ability in the inquiry activities?
- Is there a significant difference between the questioning ability progress of the experienced and novice learners in the inquiry activities using the UPBL?

Literature review

Questioning ability

Researchers have indicated the importance of the role of questioning ability in students' scientific inquiry and knowledge building performance (Chin & Kayalvizhi, 2002; Scardamalia, 2002; Tan & Seah, 2011). Similarly, the ability to ask good questions is also regarded as an essential component of thinking skills, making individuals critical consumers of scientific knowledge and practical problem-solvers (Pizzini & Shepardson, 1991). The posing or formation of a good question by students not only activates their prior knowledge, but also helps them elaborate on their knowledge. This is the heart of what doing science is all about (Dkeidek, Mamlok-Naaman, & Hofstein, 2011; Schmidt, 1993). In addition, researchers have indicated that different kinds of problems to be coped with would direct the learning process and influence the learning performance of students (Scardamalia & Bereiter, 1992; Sockalingam & Schmidt, 2011). Therefore, in an inquiry-based science curriculum supported by the knowledge building pedagogy, it is important for students to cultivate the abilities of exploring, confirming, or conducting procedures in inquiry activities.

Question type has been extensively studied in questioning research. Since different kinds of questions can challenge and stimulate the mind to different extents, questions can be classified according to the level of thought required to answer them. Furthermore, questions can even direct the learning process to different extents (Chin & Osborne, 2008; Scardamalia & Bereiter, 1992; Watts, Gould, & Alsop, 1997). Scardamalia and Bereiter (1992) found that a lack of domain-specific prior knowledge may influence the kinds of questions that students ask. Their study defined three question types: basic information questions, uneducated guess questions, and wonderment questions. The difference between "basic information" and "wonderment" questions depends on students' familiarity with the topic. Graesser, Person, and Huber (1992) developed a taxonomy of questions according to cognitive science including eighteen types, while Pizzini and Shepardson (1991) suggested three categories of questions: input, processing and output, using cognitive levels as a criterion. Yet another perspective on classifying students' questions was offered by Watts, Gould, and Alsop (1997), who described three categories of students' questions in the process of conceptual change: consolidation questions, exploration questions, and elaboration questions. Along with their progress in terms of the types of question posed, students will also improve their questioning ability. In the beginning, they just attempt to confirm explanations, then seek to expand their knowledge, and in the end they can examine claims and counterclaims or reconcile different understandings. However, while more than half of the "raw" questions students ask do not at first lend themselves to practical investigations (Symington, 1980; Roth & Roychoudhury, 1993), it is workable to translate such questions into investigable ones with help from the teacher. Moreover, students who have experience of asking questions through the inquiry approach have been found to significantly outperform others with regard to their ability to ask more and better questions (Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005).

Novice and experienced learners

Mobile and ubiquitous learning, as an innovative learning strategy, seems to be a promising learning approach to support situated learning with peer communications, however, these new learning scenarios might be too complex for the students because of the requirement of integral skills application ability and sufficient prior knowledge (Hwang, Shi, & Chu, 2011). Some previous studies have pointed out that domain-specific prior knowledge might be a factor that limits the quality of questions at the beginning stage of problem-based learning (Miyake & Norman, 1979). On the other hand, researchers have indicated that students who have experience of asking questions through the inquiry approach significantly outperform those who have no such experience (Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005). Experience, according to the literature (Ertmer & Newby, 1996; Spires & Donley, 1998), is generally regarded as one of the most crucial elements for successful and efficient learning. Researchers have indicated that naïve and expert learners display many different learning characteristics, no matter whether they learn in traditional or digital instructional environments (Chen, Fan, & Macredie, 2006; Williams & Noyes, 2007). Several studies have reported that experienced students often perform better than novice students with regard to both learning processes and learning results, implying the necessity of offering novice students proper supports for fostering the required abilities (Chi, Glaser, & Farr, 1988; Artino, 2008). Nevertheless, few quantitative studies have been conducted to investigate the impacts of learning experience or prior knowledge on students' learning performance in u-learning, not to mention the analysis of higher order thinking behaviors, such as problem solving or question raising (Simmons & Lunetta, 1993), which need proper learning supports as well as sufficient practice. Problem solving strategies acquired from experienced learners could be useful to naïve learners. Furthermore, from the perspective of cognitive psychology, cognitive activities are highly structured; that is, specific hierarchies or constructs for describing the relationships between knowledge items or concepts exist, showing the importance of learning design. This also implies the need to guide students to acquire basic or prior knowledge before learning advanced learning contents in designing school curricula. Moreover, it can be inferred that taking students' learning experiences or prior knowledge into account is important for designing u-learning activities.

Collaborative learning

In the past decades, collaborative learning has been seen as an effective teaching method and learning strategy (Jacob, 1999; Johnson & Johnson, 1999; McInnerney & Robert, 2004). A large number of studies have shown the benefits of collaborative learning in terms of improving learners' cognitive achievement, learning motivation, and peer relationships (Schoor & Bannert, 2011). Meanwhile, various collaborative learning techniques and instructional skills have been developed and applied in different learning situations, including Jigsaw II (Sahin, 2010; Slavin, 1986) and Learning Together (Johnson & Johnson, 1999), for fostering learning and elaborating teaching. After many years of evolution, science inquiry has been defined as a process of identifying and posing questions, searching for information, designing and carrying out scientific investigations, analyzing data and making conclusions, creating artifacts, and sharing and communicating findings (Krajcik et al., 1998; NRC, 1996; Sun & Looi, 2013). This learner-centered learning method emphasizes the application of classroom-learned knowledge to realistic scenes as well as the importance of concern for personal living surroundings and exploring novel and meaningful questions for practical use or thorough understanding.

Following the recent rapid advancements in information technology, computer-supported collaborative learning (CSCL) has become a potential direction for scaffolding students' critical thinking and problem solving (Salomon, Perkins, & Globerson, 1991; Jonassen, 1996).Many researchers have identified the potential of using computer systems to support collaborative learning activities (Fan & Lê, 2011; Mason & Watts, 2012; Morris, 2008; Vonderwell, Liang, & Alderman, 2007; Xie & Bradshaw, 2008).For example, several studies have employed the computer-supported collaborative learning (CSCL) approach to conducting PBL activities (Resta & Laferrière, 2007; Rienties et al., 2012), in which students can develop their collaborative learning skills through the activities of problem exploration, peer discussion, and problem solving in the process of PBL with the assistance of technological tools (Lu, Lajoie & Wiseman, 2010). Contrasted with the advantages of applying technology, there are still four challenges faced in the implementation of contemporary science CSCL environments, namely (1) Most applications do not seem to be robust enough to support social interaction, quick feedback and evaluation across distances and at different times; (2) Few applications are available to support synchronous collaboration; (3) With their flexibility limitations, most of these environments are not appropriate for a wide range of activities in different science subject areas; and (4) Most systems are not comprehensive enough to combine inquiry, modeling and collaborative learning approaches to facilitate students' development of critical learning skills in science (Dimitracopoulou et al., 1999; Sun & Looi, 2013).

With the development of technology, computer-supported environments are no longer limited to indoors. Furthermore, the use of mobile technologies has also become more popular for collaborative science inquiry because of the advantages of portability and information retrieval which can occur at any time and in any place (Hung, Hwang, Lee, & Wu, 2011; Hwang, Shih, & Chu, 2011; Shih, Chuang, & Hwang, 2010; Vogel, Spikol, Kurti, & Milrad, 2010). Students can not only discuss questions, exchange opinions, and share information with peers or instructors anytime and anywhere, but they can also acquire their learning experiences from real-world learning tasks (Looi et al., 2009; Wong, 2012). Researchers have indicated that, in a well-designed curriculum with effective technology supports and appropriate contextual environment settings, students are able to develop both competencies of scientific literacy and problem-solving skills during the learning process (Zhang et al., 2010, Hwang, Shi, & Chu, 2011). With the assistance of mobile and wireless communication technologies, learners can discuss with their peers in different places simultaneously and search for relevant data or useful information on the web to solve problems.

Development of a ubiquitous problem-based learning system (UPBLS)

In this study, a ubiquitous problem-based learning system (UPBLS) was developed based on the assumption that most novice students start learning by asking intuitively interesting questions, which may not at first seem to be realistic or scientifically relevant. It is expected that, with the help of mobile and wireless communication and sensing technologies, students are able to gain experience in the field and link what they have observed in the real world with what they have learned from the textbooks. Via accumulating experience of peer discussion, data collection, idea sharing, and reflective diary writing in the field trip, students are able to successfully refine their problems by adding scientific elements, until they finally become quality scientific problems. In the meantime, it is expected that the students' scientific inquiry competence can be improved as well (see Figure 1).

Based on the UPBL model (see Figure 1), the UPBLS is developed to optimize the collaboration of science learning communities. The central working area in UPBLS is composed of group tasks. Learners are able to edit their notes, diaries, and reports. Besides the central group task area, UPBLS provides three other mechanisms: an On-line discussion forum, an E-library, and a web-based visualization tool (called the Green Lab).The e-library provides rich and relevant data that stimulate students to learn and think more during the field trip. The green lab enables students to summarize and present their findings in the field, which helps them think from different aspects. Moreover, the questioning rubrics guide and encourage students to propose quality questions based on what they have observed and found during the learning activity.

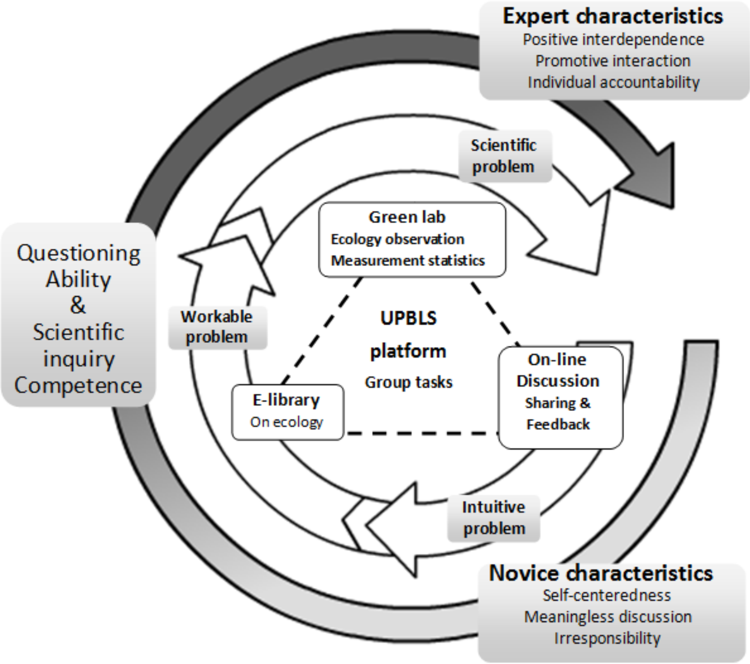


Figure 1. A triangular model of the UPBLS design

With these three functions, students are guided to accomplish their group tasks and to refine their research questions step by step. Combined with the central group task area and three other mechanisms, students can get access to the UPBL system not only via the computers in school after performing the inquiry activities, but also via smartphones during their field observations. The on-line discussion forum (see Figure 2) helps students reflect on, clarify, stimulate, and monitor their inquiries. Everyone who participates in the inquiry activities can respond to others' subjects or propose a new subject. The E-library (see Figure 3) contains an ecology database designed to help the learners to refine their questions. Students can search for information when describing or recording their findings of the organisms in their natural environment. They can also access the detailed information by means of QR codes through smartphones if they are interested in a particular creature.

Furthermore, measurement statistics are provided in the Green Lab (Vogel, Kurti, Milrad, & Kerren, 2011) in UPBLS to present the collected data (see Figure 4). The need for web-based visualization tools in this area indicates the importance of allowing learners in an interactive manner to explore, analyze and reflect on different representations of environmental data (Vogel, 2011). For instance, salinity, pH value, dissolved oxygen in water, turbidity and temperature were under investigation and were recorded in the database. Statistics will change along with the data recorded. Learners can search for the information they need in the Green Lab and utilize the acquired knowledge to formulate scientific questions or to work on their reports. The Green Lab was developed to update and share all ecological observation information. Moreover, it enables the visualization of different types of geo-tagged content and sensor data collected using mobile devices.

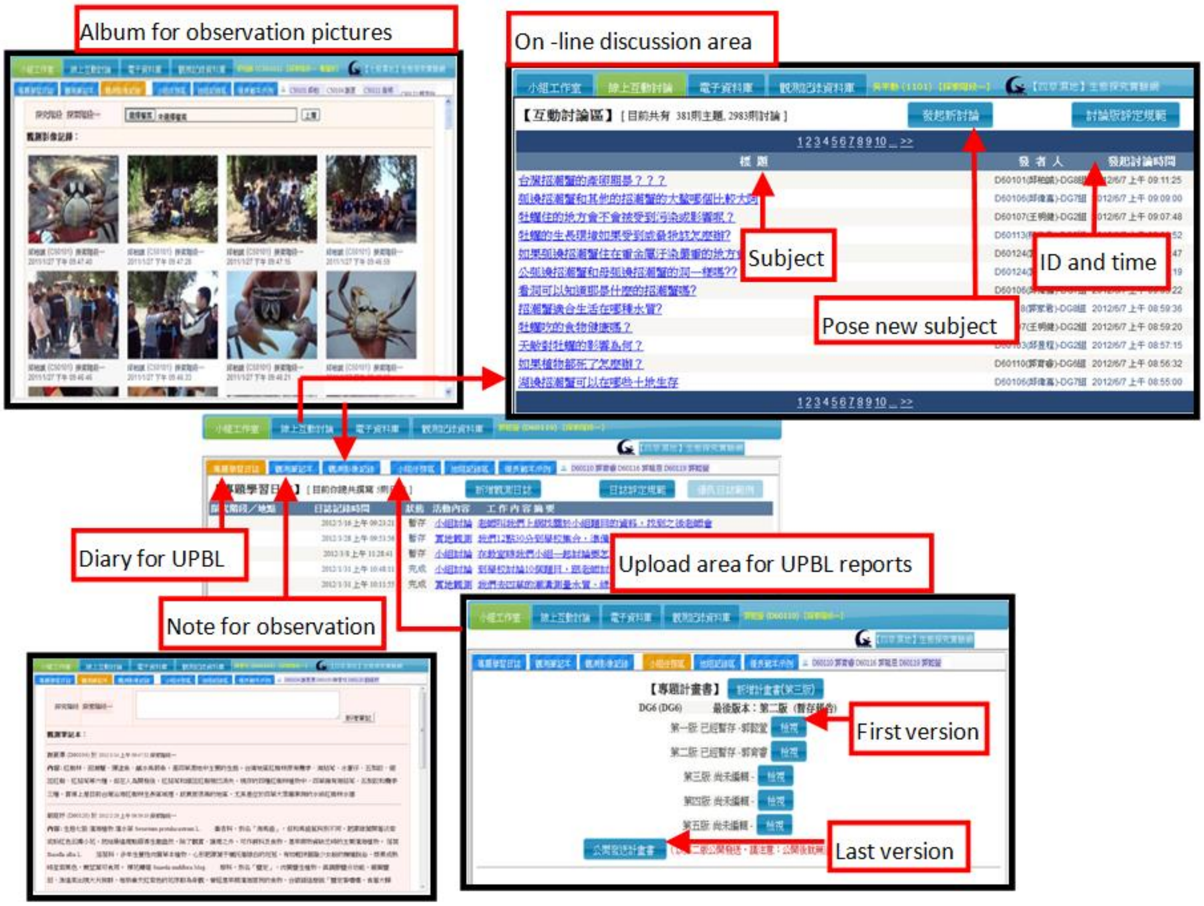
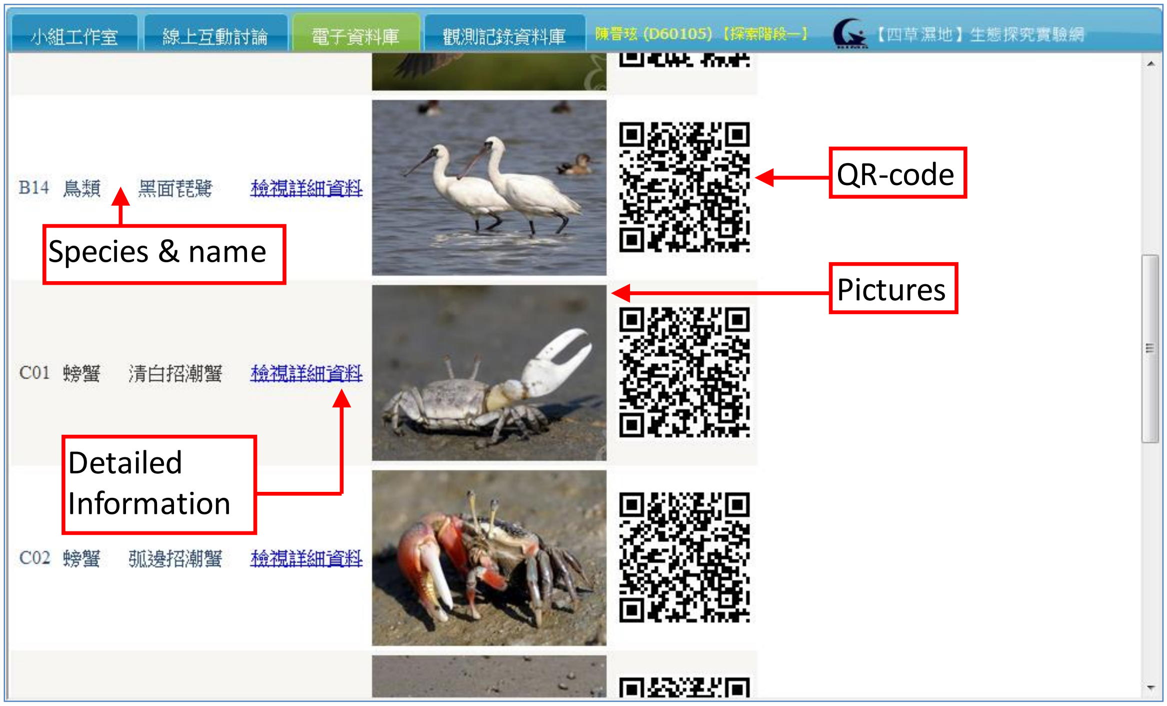


Figure 2. The interface of group tasks and on-line discussion



B14 鳥類 黑面琵鷺 檢視詳細資料

C01 螃蟹 清白招潮蟹 檢視詳細資料

C02 螃蟹 弧邊招潮蟹 檢視詳細資料

Figure 3. The interface of the E-library

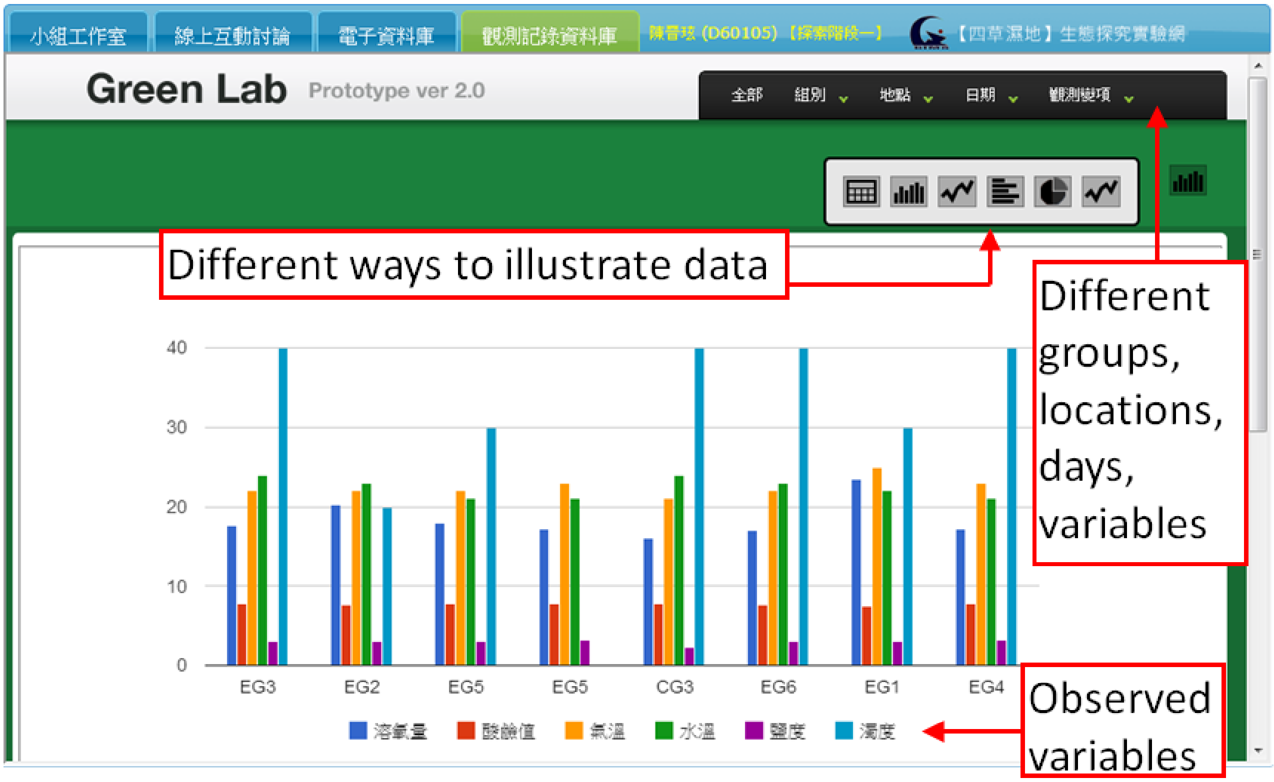


Figure 4. The Green Lab interface

Research design

Based on the UPBLS triangle model, the research combined both the collaborative learning and ubiquitous learning approaches. Therefore, collaboration with the advantage of ubiquitous technology to propose and refine problems is the main concept embedded in the research inquiry activities. Learners can not only carry out ecological observations, collect data and record information in the inquiry activities, but can also keep on-line learning diaries, carry out on-line discussion and apply measurement statistics in group reports after the inquiry activities. Through this learning approach, the learners can first propose intuitive problems that they are interested in after gathering and receiving all ecological information and then refine them gradually to become workable, such that finally, a scientific problem can be proposed. To assess the learners' progress in terms of their questioning ability and inquiry competence, scoring rubrics for questioning ability and scientific inquiry literacy assessment, Computerized Scientific Inquiry Literacy Assessment (CSILA), were applied.

Participants

A total of 43 sixth and fifth graders participated in the UPBL program, of whom 25 sixth graders were defined as experienced students who had gone through six months of inquiry activities before the experiment (Hung, Hwang, Lee, & Wu, 2011).The other 18 5th grade pupils, who had never joined any inquiry activity before the experiment, were categorized as novices. That is, the students were categorized into the two groups mainly based on their prior inquiry activity experience instead of their scientific inquiry literacy or learning performance.

Procedure and learning scenarios

Three UPBL field observation activities were arranged between November 2011 and May 2012, as shown in Table 1. CSILA was administered three times, once before the inquiry activities and twice after the activities, to assess the performance of the students' inquiry ability via evaluating their questioning performance. The reasons for conducting the test twice after the activity were to investigate the correlation patterns between the students' inquiry performance and questioning ability and to illustrate their progress trend. Following the first CSILA, the anchored instructions provided the students with an introduction to the wetland. Furthermore, instruction was given to help the students become familiar with the operations of the smartphones and scientific instruments. In the following three inquiry activities, the students were supported by UPBL to raise questions, gather data, discuss with team members, revise questions and finally share the outcomes with other teams. During the field observations, each participant was equipped with a smartphone, which was used to interact with the learning system as well as to gather information for accomplishing the PBL tasks.

Table 1. The UPBL research stages

Date	Stages	Activities
2011/11	Test 1	1st CSILA administered
2011/12	Anchored Instructions	a. Introduction of Sihcao Wetland b. Application of smartphone c. Operation of instruments
2011/12 | 2012/1	Inquiry Activity 1	a. First trip to three different locations of Sihcao Wetland to investigate the characteristics of the water b. Sharing initial thoughts about the inquiry problems
2012/1 | 2012/3	Inquiry Activity 2	a. Second trip to the Sihcao Wetland b. Sharing revised inquiry plans and measurement results
2012/3 | 2012/4	Inquiry Activity3	a. Third trip to Sihcao Wetland to execute group plans b. Sharing their preliminary results and revised plans
2012/4	Oral presentations	Face to face discussions
2012/4	Test 2	2nd CSILA administered
2012/5	Test 3	3rd CSILA administered

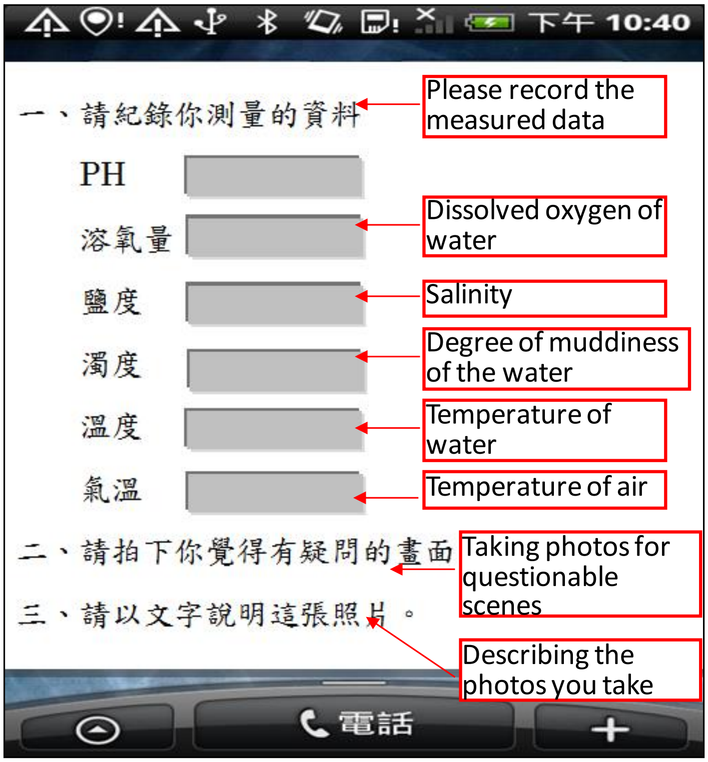
The students were supported by the ubiquitous learning system to complete the three stages of the inquiry tasks, as shown in Figure 5. To accomplish the inquiry tasks and raise specific scientific problems successfully, they were asked to collect two categories of data via making observations and measurement: (1) environmental data, such as the quality of water and air; and (2) information about the creatures in the ecological area. In each of the three stages, the students were scheduled to collect data. Moreover, the data to be collected in one stage depended on the findings and group discussion results of the previous stage.

Figure 5. Learning scenarios of the ubiquitous problem-based learning activity

In the first stage, the students were guided in the field to make observations and measurements to collect environmental data based on the worksheets displayed on the mobile devices, which aimed to intuitively situate them in question-raising scenarios. In the second stage, the students were asked to carry out on-line discussions and self-reflections on the group task platform after the field trips. Via information sharing and discussion, each group of students refined the questions they raised.

In the final stage, the students were asked to review the data they had measured and collected, including the statistical results, to find out the required scientific evidence for solving their scientific questions. After each field trip, individual students were asked to complete a learning diary on the website based on what they had observed and learned.

During the inquiry activities, the students could log into the website to complete the learning sheets, as shown in Figure 6. In addition to the group members, the data collected by the students were also shared with other groups. The students collected these data based on the working items displayed on the mobile devices as well as the questions raised by the teacher and themselves during the field trips by inputting the observed or measured data, taking notes and photos, and searching for data from the e-library. They could then share their findings with their team members.



一、請紀錄你測量的資料
PH
溶氧量
鹽度
濁度
溫度
氣溫
二、請拍下你覺得有疑問的畫面
三、請以文字說明這張照片。

Figure 6. Interface of the inquiry learning sheets on the mobile devices

Measuring tools

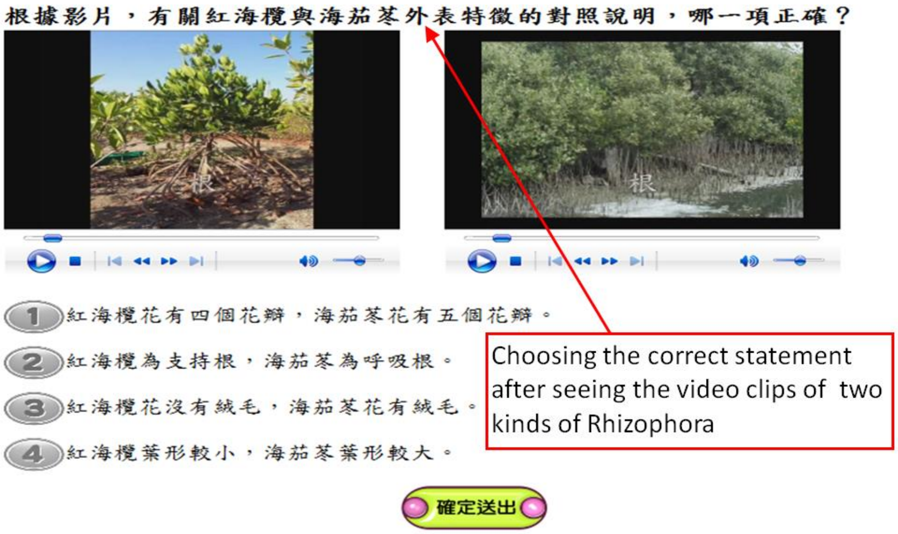
In this study, the Computerized Scientific Inquiry Literacy Assessment (CSILA), developed by Hung, Hwang, Lin, Hung and Wu (2010), was integrated into the field inquiry activities to investigate the students' scientific inquiry skills and progress. The facets included in CSILA are observation, inference and experiment design, with three different item types: observation of photos, movie clips and concept mapping. Each facet was divided into three levels: basic, proficient, and advanced. Figures 7 to 10 show the sample items of CSILA.

Figure 7 is an observation facet item embedded with video clips for observing. Figure 8 is a fill-in-the-concept-map facet item. Students can drag the right side answers to fill in the blanks according to the instructions. Figure 9 is a scientific inference facet item. Students need to draw the inferences according to the description, illustration and representation of the item. Figure 10 shows a sample item of the experiment design facet, including the design, illustration, and process of the experiment.

As shown in Table 2, the total number of CSILA items is 56, including 18 items for Level 1, 21 items for Level 2, and 17 items for Level 3. The average difficulty (p value) of the items is 0.62 and the Cronbach's αof the measure is 0.71.

Table 2. CSILA item distribution specification

Content	Level 1	Level 2	Level 3
Observation	18	13	9
Inference		5	4
Experiment Design		3	4
Total	18	21	17


根據影片，有關紅海欖與海茄苳外表特徵的對照說明，哪一項正確？

1 紅海欖花有四個花瓣，海茄苳花有五個花瓣。

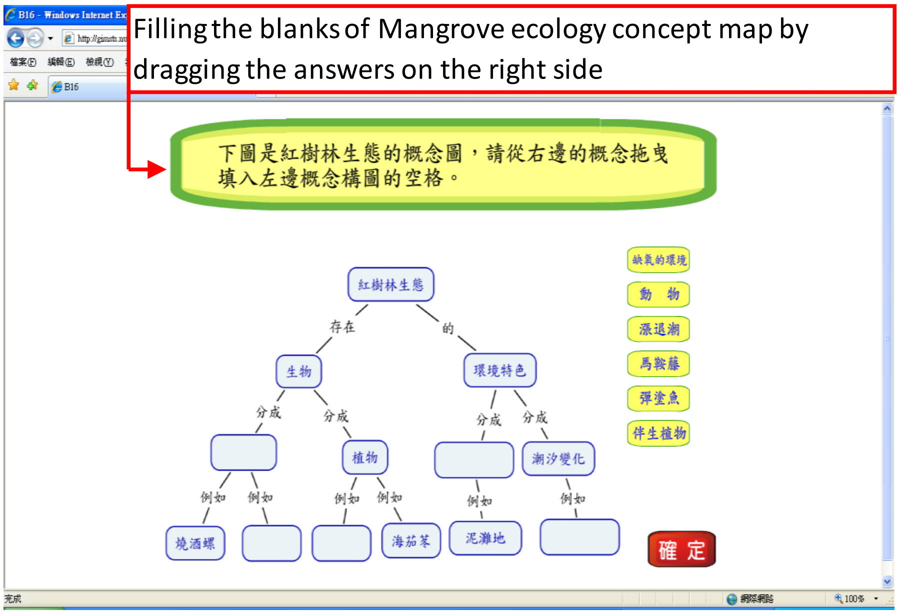
2 紅海欖為支持根，海茄苳為呼吸根。

3 紅海欖花沒有絨毛，海茄苳花有絨毛。

4 紅海欖葉形較小，海茄苳葉形較大。

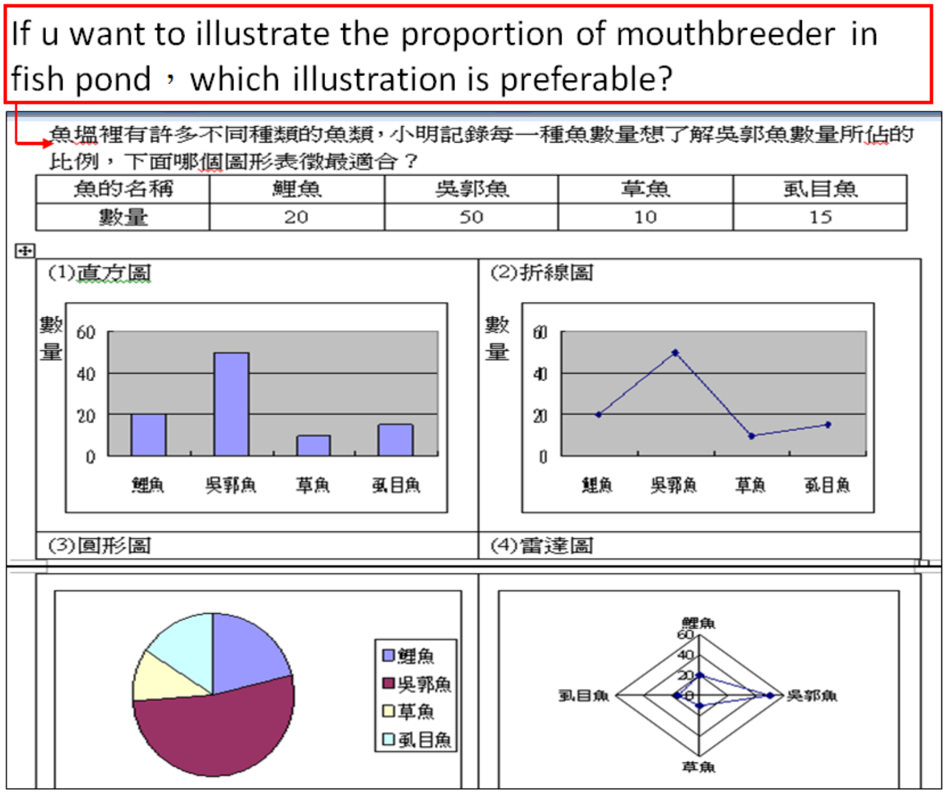
Choosing the correct statement after seeing the video clips of two kinds of Rhizophora

Figure 7. Sample item of the observation facet


Filling the blanks of Mangrove ecology concept map by dragging the answers on the right side

下圖是紅樹林生態的概念圖，請從右邊的概念拖曳填入左邊概念構圖的空格。

Figure 8. Sample item of the fill-in-the-concept-map facet

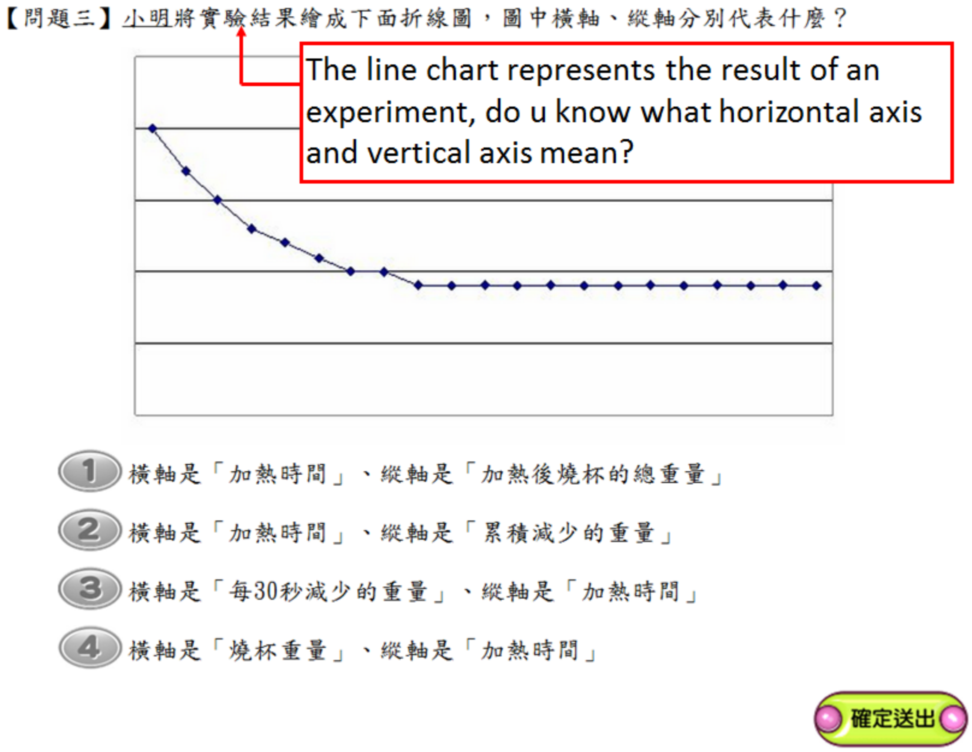


If u want to illustrate the proportion of mouthbreeder in fish pond，which illustration is preferable?

魚塭裡有許多不同種類的魚類，小明記錄每一種魚數量想了解吳郭魚數量所佔的比例，下面哪個圖形表徵最適合？

魚的名稱	鯉魚	吳郭魚	草魚	虱目魚
數量	20	50	10	15

Figure 9. Sample item of the scientific inference facet



【問題三】小明將實驗結果繪成下面折線圖，圖中橫軸、縱軸分別代表什麼？

The line chart represents the result of an experiment, do u know what horizontal axis and vertical axis mean?

1. 橫軸是「加熱時間」、縱軸是「加熱後燒杯的總重量」
2. 橫軸是「加熱時間」、縱軸是「累積減少的重量」
3. 橫軸是「每30秒減少的重量」、縱軸是「加熱時間」
4. 橫軸是「燒杯重量」、縱軸是「加熱時間」

Figure 10. Sample item of the experiment design facet

Table 3. Scoring rubrics for questioning ability

Categories	Score	Content and Example
		Facet 1: Autonomous Question Posing
positive learning interaction	1	Posing questions that can promote learning, such as: strategies for collaboration Ex: What can we do when group members argue?
factual question	1	Posing questions that are based on prior knowledge or observation Ex: How does a wetland function?
procedural question	2	Posing questions about scientific experimental sequence Ex: How can we measure the humidity of soil?
Science concept-oriented question	3	Posing questions that are based on scientific concepts Ex: Does the humidity of a ditch affect the subsistence of crabs?
		Facet 2: Assistance for Others' Question Posing
positive learning interaction	1	Posing questions that can promote learning, such as: strategies for collaboration Ex: Question: Does anyone know how to measure the humidity of soil? Reply: I advise you to consult an expert
actual question	1	Posing questions that are based on prior knowledge or observation Ex: Does the answer differ from what the creature in the wetland needs?
procedural question	2	Posing questions about scientific experimental sequence Ex: Question: How can we measure the amount of dissolved oxygen? Reply: Can we steam the soil, then use the instrument to measure the water steamed from the soil?
Science concept- oriented question	3	Posing questions that are based on scientific concepts Ex: Question: How many kinds of fish are in the pond? Reply: Why do you take this question as an inquiry problem?
		Facet 3: Autonomous Question Correcting
accuracy/ elaboration	3	Posing questions or providing information that can help focus the learning content Ex: We have finished measuring the edge length of the pond, but how can we measure the depth of the pond?
promotion/ continuity	3	Posing questions or providing information that can help the group elevate or extend the inquiry problem Ex: What's the difference in water quality in the different areas? Because we found the water quality is different in two areas.
		Facet 4: Assistance for Others' Question Correcting
accuracy/ elaboration	3	Posing questions or providing information that can help focus the learning content Ex: You should study the habits of the crabs before identifying the species of crabs
promotion/ continuity	3	Posing questions or providing information that can help the group elevate or extend the inquiry problem Ex: Question: So should we insert the dissolved oxygen meter into the soil? Then can we measure the dissolved oxygen? Reply: No, it can't work! The dissolved oxygen meter is used for water! Not

On the other hand, the scoring rubrics in Table 3 were developed for assessing the students' questioning ability. Scholars have pointed out a number of pedagogic advantages of using grading rubrics, such as improving students' attention and performance in learning activities (Creswell, 2009; Neuman, 2004; Fan & Lê, 2011; Solan, & Linardopoulo, 2011). In inquiry activities, students engage socially in interactive activities, including information sharing, question posing, and discussion. Questions embedded in the conversations help learners co-construct knowledge (Chin &Brown, 2000; Chin, 2004). Therefore, it is important to encourage students to pose questions and respond to other groups' questions by taking the questioning issue into account when developing assessment rubrics (Chang, Wu, Weng, & Sung, 2012). Correcting or refining questions based on peers' feedback is another important issue for helping students make reflections and improvements (Yu, Liu, & Chan, 2005).Accordingly, the rubrics are divided into four facets: Autonomous question posing, Assistance for others' question posing, Autonomous question correcting, and Assistance for others' question correcting. The two facets "Autonomous question posing" and

"Assistance for others' question posing" have the same categories, as do the facets "Autonomous question correcting" and "Assistance for others' question correcting." Moreover, three questioning levels (i.e., factual, procedural, and science concept-oriented) were designed by referring to those proposed by Chin, Brown and Bruce (2002) and Allmond and Makar (2010).

Results

Reliability and validity of the scoring rubrics

Three raters were invited to assess the students' interactions in the learning system according to the rubrics defined in Table 3. The reliability of the rubrics is particularly high (r = .92) based on the ratings given by the three raters. On the other hand, it is found that questioning ability and inquiry ability show similar improvement trends (see Table 4). Therefore, inquiry ability is defined as an external criterion of validity of the questioning rubrics. As we can see in Table 5, the correlation matrix shows that questioning ability and inquiry ability have a moderately significant relationship (.37, .31 and .63, $p < .05$) in the three evaluations. The correlation coefficient suggests that the rubric questioning scores have appropriate validity. Furthermore, the correlation between the two abilities increases following the administration of CSILA after each activity. This increasing correlation can provide a reasonable pattern for the two abilities as validated evidence.

Table 4. Descriptive statistics of questioning and inquiry ability

Different form	Mean			SD
	Experienced	novice	total	
I1	0.36	-0.32	.02	.86
I2	0.63	-0.15	.24	.72
I3	1.35	0.37	.86	.75
Q1	7.79	3.33	5.56	5.81
Q2	13.64	11.24	12.44	8.14
Q3	24.85	15.81	20.33	11.17

Q = questioning ability; I = inquiry ability

Table 5. Correlation matrix of questioning ability and scientific inquiry ability

	I1	I2	I3	Q1	Q2
I2	.53**				
I3	.52**	.60**			
Q1	.37*	.29	.71**		
Q2	.43**	.31*	.55**	.68**	
Q3	.43**	.26	.63**	.69**	.82**

Q: questioning ability; I: inquiry ability (CSILA); $^{*}p < 0.05$. $^{**}p < 0.01$.

Improvements in the students' questioning ability

This study focuses not only on the development of a UPBL system, but also on proving its usefulness by investigating the progress of students' questioning abilities. To present this progress, the Hierarchical Linear Model (HLM) was used. HLM has the advantage of analyzing longitudinal data retrieved many times. Therefore, HLM was used to analyze the students' scores of questioning ability from three different time points. Differences in intercepts and growth rates between the experienced 6th graders and the novice 5th graders were tested. Table 6 shows the contrast of coefficients estimated by the unconditional models of HLM. The unconditional model results indicate that the average growth rate β10 of all participants is around 7.64 ($p < .01$). This suggests that both groups demonstrated substantial growth in their questioning abilities, and UPBL is significantly helpful for developing students' questioning performance. Furthermore, in order to clarify the difference in growth rate between these two groups, a group model of HLM was applied.

In the group model, the experienced 6th graders and novice 5th graders were coded as 1 and 0 respectively. Table 7 shows the contrast of coefficients estimated by the HLM group model. According to these results, the initial difference β01 is around 3.00 ($p < .05$) and the growth rate β11 is around 2.29 ($p < .05$). This result suggests that the questioning ability of the experienced 6th graders was not only significantly better than that of the novice 5th graders at the initial stage, but that they also had higher growth rates throughout the whole learning process. Figure 11 displays the questioning ability progress slope contrast of the two groups. As we can see, it is obvious that the questioning ability growth rate of the experienced 6th graders was better than that of the novice 5th graders. In other words, combining the results of both the unconditional and conditioned HLM models from Tables 6 and 7, we can conclude that all students benefited from UPBL, but that the experienced 6th graders had greater improvement in their questioning abilities than the novice 5th graders.

Table 6. The contrasts of coefficients estimated by the unconditional HLM models (N = 49)

Fixed Effect		Model 1(unconditional)				
		Coe.	SE	*t*	*df*	*p*
Intercept	β00	5.38	0.69	7.78	42	0.00
Slope	β10	7.64	0.62	12.38	42	0.00

Table 7. The contrasts of coefficients estimated by the conditioned HLM model (N = 43)

Fixed Effect		Model (group)				
		Coe.	SE	*t*	*df*	*p*
Intercept	β00	3.64	0.78	4.67	41	0.00
	β01	3.00	1.25	2.41	41	0.02
Slope	β10	6.31	0.69	9.10	41	0.00
	β11	2.29	1.13	2.04	41	0.04

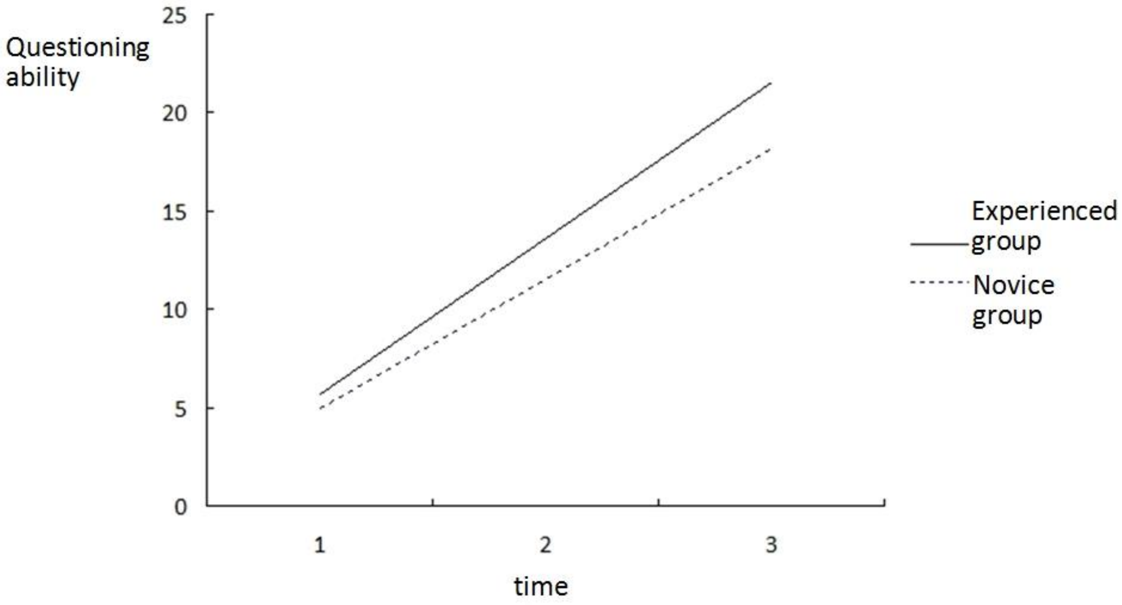


Figure 11. The growth slopes of the two groups

Discussion and conclusions

Promoting the questioning ability of students has been recognized as being an important and challenging educational objective (Chin, Brown, & Bruce, 2002; Scardamalia, 2002; Tan & Seah, 2011). In this study, a ubiquitous problem-based learning system, UPBLS, is proposed for conducting in-field inquiry learning activities by providing learning guidance, an online discussion forum, an e-library and a green lab. The experimental results show that the rubrics used to assess questioning ability had reasonable reliability and validity; moreover, the UPBL approach was helpful to both experienced and novice students in improving their questioning ability. This finding is quite different from those reported by previous u-learning studies in which the technology-enhanced learning only benefited the experienced students (Chi, Glaser, & Farr, 1988; Artino, 2008). It is predictable that experienced students perform better than novice students in the beginning of the inquiry activities; however, the progress of both groups is in fact a more important and essential issue to be investigated and verified. The finding of this study (i.e., both experienced and novice students were benefited) verifies that the UPBL approach can be applied to different levels of students. This also implies that, in a properly designed inquiry activity, if the students have enough time to become familiar with the learning system, their questioning ability can be gradually improved.

On the other hand, another finding that the experienced students had greater improvement than the novices in this study also implies that providing additional supports for novice students is needed. Such supports could be specially designed interfaces, system functions, learning guidance, feedback, or supplementary materials. As most studies related to adaptive or personalized learning mainly provide personal supports based on students' knowledge levels, preferences or learning styles (Chiou et al., 2010; Hwang, Sung, Hung, Huang, & Tsai, 2012), it is necessary to develop adaptive learning models by taking learning experience into account.

From the ecology-investigating activity, it was also found that UPBLS functions as both a learning tool and a stimulus for question raising and peer interactions. In addition to the e-library which serves as the database from where students can obtain the required information, the album and representation of reports shared with all participants can also inspire students to come up with ideas. Besides learning functions, on-line discussion makes it convenient for students to have a chance to ask questions and respond to each other. With the aid of the UPBLS, students can not only initiate their intuitive questions, refine them into workable ones, and then finally shape up their scientific research plans, but also develop their collaborative learning competence from self-centeredness, meaningless discussion, and irresponsibility to positive interdependence, promotional interaction and individual accountability.

In addition to the ubiquitous learning platform, the questioning rubrics also played an important role in the scientific inquiry, as indicated by many researchers (Chin, Brown, & Bruce, 2002; Millar & Osborne, 1998; Scardamalia, 2002; Shodell, 1995; Tan & Seah, 2011). It not only was used to evaluate the questioning performance of the students, but also provided clear criteria and objectives to guide them to propose quality questions. Based on significantly high scorer reliability and moderate validity gained by correlating CSILA scores with the questioning rubrics score, the effective verification of the experimental results is valid.

There are, however, some limitations to the present study. First, the sample size was not large enough to support further analysis, such as comparing the learning performances of the students with different learning styles, genders and knowledge levels. Second, to apply the platform to other learning activities, the content of the e-library might require significant modifications. Furthermore, the conclusions cannot be generalized to other applications with participants of different ages.

To sum up, from the experimental results, it is concluded that the use of mobile/ubiquitous technologies in the field trip with the problem-based learning approach has provided effective supports and encouragement for improving the students' inquiry and questioning abilities. Moreover, the proposed approach can benefit both novice and experienced students. Currently, we are planning to assess other important competences by conducting more in-field activities with UPBLS, including collaboration abilities, inquiry abilities and problem-solving abilities. Moreover, we also plan to upgrade UPBLS by implementing an automatic scoring function to provide immediate feedback to individual students.

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