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Formative Assessment Design for PDA Integrated Ecology Observation

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ABSTRACT

Ubiquitous computing and mobile technologies provide a new perspective for designing innovative outdoor learning experiences. The purpose of this study is to propose a formative assessment design for integrating PDAs into ecology observations. Three learning activities were conducted in this study. An action research approach was applied to continually revise the worksheet designs. Twenty-seven 5th and 6th graders' observation skills using PDAs, and their extended inquiry performance using e-diaries were assessed. An e-library, and online scoring and feedback systems were developed accordingly. The results suggest that the embedded formative assessment designs were effective for guiding and supporting the students' learning progress. The activity worksheets successfully helped the students focus their outdoor learning attention on the target tasks. The e-library provided reliable resources to clarify their observed descriptions, while the automatic scoring and feedback systems were especially helpful in sustaining the students' persistent effort. Most students demonstrated substantial improvements in their observation skills, and extended their inquiry abilities. The well designed online formative assessment embedded in the activity worksheet is very promising for PDA integrated learning.

Keywords

Personal digital assistant, mobile learning, formative assessment, cognitive load, ecology observation

Background and Motivation

During the past few decades, technological innovation has had a profound effect on learning designs. Many successful practices concerning computer and network technologies in education have been reported, such as the development and application of adaptive learning systems (Hwang, 2003; Tseng et al., 2008), computer-assisted testing systems (Yin et al., 2006), and web-based cooperative learning systems (Chu et al., 2009; Hwang, Yin, Hwang & Tsai, 2008). With the aid of wireless communication technology, educational practice can be embedded in everyday life. With the trend of educational media becoming more mobilized, portable, and individualized, the learning form is changing dramatically. Living in an era of knowledge explosion, people need to enhance their knowledge and skills continually to address immediate problems and to develop other abilities (Sharples, 2000). Therefore, learning is no longer confined to student status or to the classroom. On the contrary, it takes place throughout life and in a wide range of situations. That is, learning should be life-long and life-wide. Technology, then, plays a significant role in making learning more efficient and productive nowadays.

Outdoor teaching is widely recognized as one of the best alternative teaching methods for scientific observation learning. However, some outdoor teaching approaches are ineffective because students lack expert guidance and appropriate outdoor learning tools. With the advantages of portability and easy information access, the use of mobile technology is a growing trend in education. Therefore, the application of information technology in outdoor teaching has become an attractive research topic. Chen, Kao and Sheu (2003) have indicated that the mobile learning environment possesses many unique characteristics: urgency of learning need, initiative of knowledge acquisition, mobility of learning setting, interactivity of the learning process, situating of instructional activities, and integration of instructional content. The Personal Digital Assistant (PDA) is now a frequently used mobile device in education. PDAs allow students to access education flexibly. Students do not have to be in the classroom to retrieve knowledge. PDAs indeed make learning ubiquitously possible. Huang, Wu, Chu and Hwang (2008) have pointed out that PDAs offer great innovation in the delivery of education, allowing for personalization and customization according to student needs.

In the past few years, several studies concerning the use of PDAs and wireless communication networks in outdoor teaching have demonstrated the benefits of such an approach. For example, Chu, Hwang, Huang and Wu (2008) reported the use of mobile and wireless comunication technologies in the butterfly ecology garden for an outdoor activity of a Natural Science course in an elementary school. Hwang, Kuo, Yin and Chuang (in press) indicated that well designed learning paths are necessary for situating the students in a quality mobile learning environment. Researchers further showed that the development of Mindtools is helpful to students in improving their learning achievements in such mobile or ubiquitous learning environments (Chu, Hwang & Tsai, in press; Peng et al., 2009).

Most of the existing studies concerning mobile and ubiquitous learning mainly focus on the investigation of the effects of such an innovative learning scenario, as well as on the proposal of outdoor learning guiding strategies. Hwang, Tsai and Yang (2008) indicated that, in a mobile or ubiquitous learning environment, teachers can not only implement their instructional strategies from a brand new perspective, but can also make an attempt at new assessment strategies. Therefore, in this study, we propose a formative assessment strategy for mobile and ubiquitous learning using PDAs as a cognitive tool to provide guidance, information and feedback relevant to the outdoor learning tasks.

Formative assessment refers to assessment that is specifically intended to generate feedback on performance to improve and accelerate learning (Sadler, 1998). That is, knowing how students think in the process of learning makes it possible for teachers to help their students overcome conceptual difficulties and, in turn, improve their learning. Good feedback practice can help students to clarify what good performance is, facilitate the development of reflection in learning, and deliver high quality information to students about their learning (Nico, & Macfarlane-Dick, 2006). Black and William (1998) concluded that if feedback based on formative assessment is closely connected to instruction and provides information about how to improve performance, it would have a great positive effect on students' learning. Feedback given as part of formative assessment helps learners to achieve their goals. Moreover, students should also be trained in how to interpret feedback, how to make connections between the feedback and the characteristics of the work they produce, and how they can improve their work in the future.

The purpose of this study is to propose a formative assessment design for integrating PDAs into ecology observations. The PDAs in this study not only function as portable notebooks and walking encyclopedias, but also serve as an online assessment tool. The formative assessments are embedded in the activity worksheets for the PDA integrated ecology observations. The collected responses include students' observation records of field trips on the PDAs and the extended inquiries in their e-diaries on the website. In short, the formative assessment embedded in the worksheets provides a bi-directional process between the teachers (the researchers in this study) and the students to focus on, recognize, and respond to the learning.

Rationale for worksheet design

Cognitive Load Theory (CLT) is an established theory in the field of learning and instruction. Research shows that students learn more and better from strongly guided learning than from discovery (Sweller, van Merriënboer, & Paas, 1998). In addition, Kirschner, Sweller and Clark (2006) confirmed that students who learn via discovery show no signs of superior quality of learning. They point out that a heavy working memory load resulting from exploration (a discovery technique) causes a much larger cognitive load, leading to poor learning. The ease with which information may be processed in working memory is a prime concern of CLT. Working memory load may be affected by the intrinsic nature of the learning tasks (intrinsic cognitive load), the manner in which the tasks are presented (extraneous cognitive load), or the amount of cognitive resources that learners willingly invest in schema construction and automation (germane cognitive load) (Sweller et al., 1998; Paas, Renkl, & Sweller, 2003). These three types of cognitive load theory are defined and discussed in the following paragraphs.

Intrinsic Cognitive Load Instructional Design

Intrinsic cognitive load is associated with the interaction between the nature of the materials being learned and the proficiency level of the students (Sweller et al., 1998; Paas et al., 2003). Hence, the prerequisite knowledge needed to be learned, or the wide open ecology environment, could be sources of intrinsic cognitive load. In other words, the intrinsic cognitive load depends on the inherent difficulty of the learning material, for example, how many elements there are and how they interact with each other. The materials used in this study were three process worksheets with learning guidelines that students needed to know about the three field trips to different wetland ecological systems of mangroves. The use of the process worksheets helped break the learning activities into smaller learning tasks of different natures. The worksheets indicated the upcoming events as well as the order and the nature of the activities. The first process worksheet guided students to observe and describe the mangrove wetland ecological system they saw. The second phase was to instruct students to use the database to support what they had observed. The final worksheet guided students to compare and contrast the things they had seen. In short, each process worksheet guided students' attention to different target tasks related to exploring the mangrove wetland ecological system.

Extraneous Cognitive Load Instructional Design

Extraneous cognitive load is associated with processes that are not directly necessary for learning and can be altered by instructional interventions (Sweller et al. 1998; Paas et al. 2003). Extraneous cognitive load depends on the way the instructional message is designed, that is, how materials are organized and presented. When designing instruction, steps must be taken to reduce extraneous cognitive load and to avoid overloading an individual's capacity. For example, information presentation during instruction should be limited to only necessary data and features to maximize and facilitate learning. Taking into consideration theories about working memory and considering theories about how information is encoded provide a context for exploring ways in which learning takes place. The PDA application could be a source of extraneous cognitive load for ecology observation learning. Therefore, in this study, the researchers intervened with the use of PDAs. The PDAs in this study also provided an e-library giving basic descriptions of the creatures in the mangrove wetland ecological system. In addition, the multiple-choice and short-answer questions listed in the PDAs guided students to only focus on the information they needed to know. Finally, the PDAs provided instantaneous in-the-field feedback to the students.

Germane Cognitive Load Instructional Design

Germane cognitive load is associated with processes that are directly relevant to learning, such as schema construction and automation (Sweller et al. 1998; Paas et al. 2003). It is the beneficial load imposed by instructional designs that lead to a better learning outcome. For example, practice, inference, and reflection on the learning task are helpful for schema construction, but they can only be used if working memory has remaining capacity. Some instructional manipulations that stimulate students' schema construction processes are adopted in this study. The worksheet provided sections for students to take notes and raise questions autonomously for the extended inquiry after the field trip. The scoring feedback especially motivates students to elaborate records, raise questions, deepen reflections and extend inquiries.

The three-layer framework of observation worksheet design

The PDA integrated ecology observation activities provided in this study supported the participants' learning through a three-layer observation worksheet design. Based on the Cognitive Load Theory, the worksheet design (see Figure 1) broke the learning objectives into three layers in order to balance the student's cognitive load and challenge step by step.

For the first layer, the worksheet started with multiple-choice and short-answer questions to clarify the students' basic knowledge. Adaptive online feedback was provided for incorrect responses. The questions served as a basic guidance for the expected observation learning. The second layer worksheet extended the learning tasks to enhance students' observation skills by using PDAs to take notes autonomously. The learning system not only allows the students to take notes about their observations, but also documents the time each note is taken. For example, the left part of Figure 2 shows that a student took 6 notes within 2 hours. The student mentioned that he was so excited to take the boat passing through the green tunnel of mangroves. He noticed the leaping fish, fighting crabs, and beautiful scenery. He wondered how many different kinds of crabs are in the mangroves. Students were encouraged to take notes or pictures and raise questions about the objects they observed beyond the worksheet's questions for their second observation activity. The third layer worksheet requested students to make notes on the PDAs to carry out independent inquiries and to present the discussions or answers in their e-diaries, especially for the questions they raised in the field. The right part of Figure 2 presents one student's notes retrieved from the PDA while he was working on his e-diary with a computer. In this extended learning activity, the students were guided to search for information in the e-library when they did not get the correct or sufficiently detailed answers.

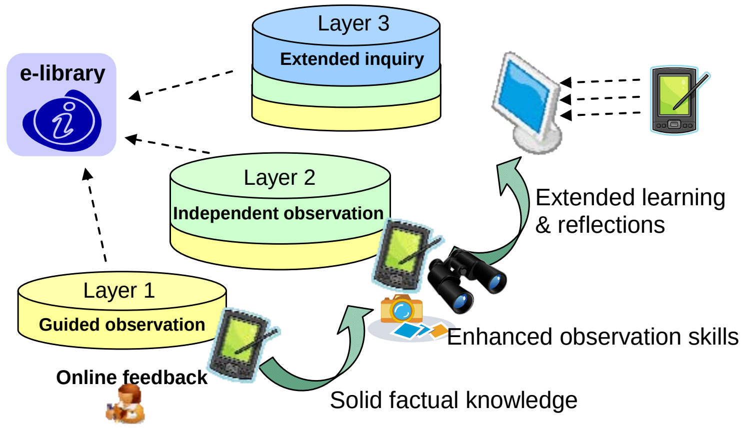

Figure 1. The three-layer observation worksheet design

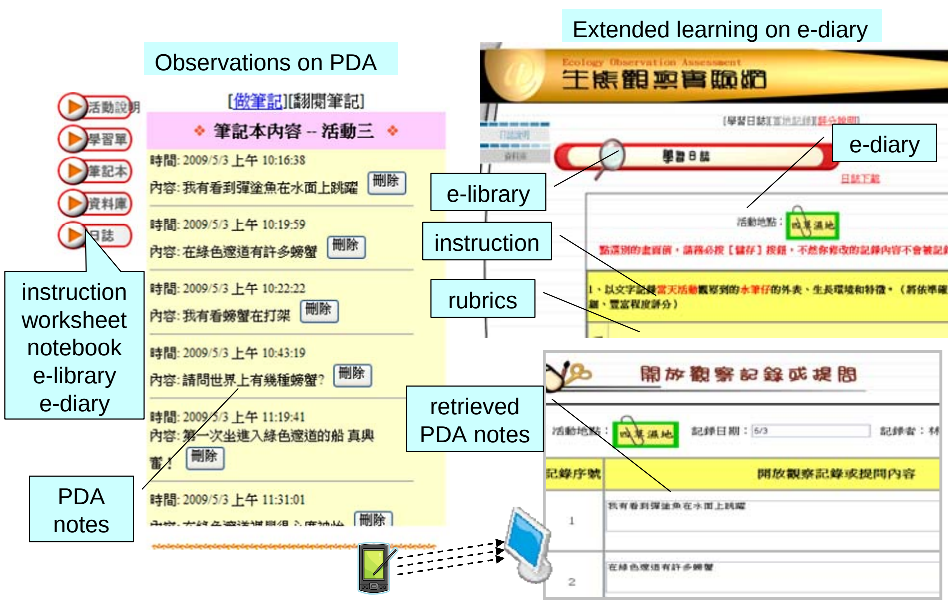

Figure 2. Snapshots of PDA notes and e-diaries

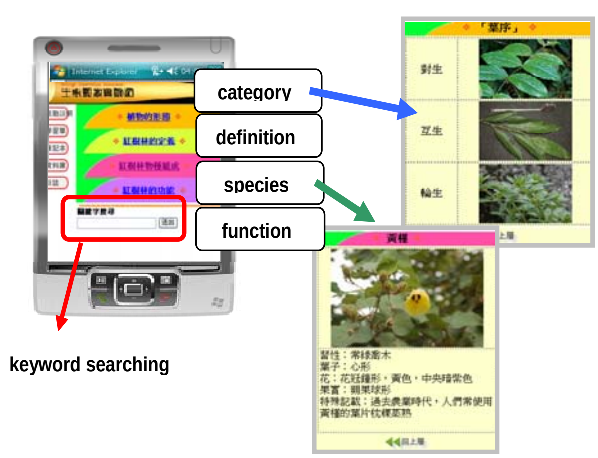

Figure 3. Snapshots of the e-library

Figure 3 presents snapshots of the e-library. Students can search for information by keyword. The e-library provides related pictures and descriptions (category and characteristics) of the target objects. In other words, the PDA integrated learning system combines an e-library, e-diary and online feedback to guide the observation activities step by step.

Formative assessment and data collection designs

Participants and procedures

Twenty-seven fifth- to sixth-grade students from two elementary schools in the southern part of Taiwan participated in this study. Five of the participants were fifth-graders (4 female and 1 male) and 22 were sixth-graders (13 female and 9 male). Three mangrove wetland field observation trips were arranged within four months. During the field trips, each of the participants was equipped with a PDA, a digital camera, and a telescope (examples are shown in Figure 2). The participants used the equipment to record what they saw, and followed the instructions on the process worksheets in the PDA to do independent learning in the field. After each field trip, the participants were asked to finish their diaries on the website the next school day, based on their observations. Students' responses on the PDAs and e-diaries were rated according to the rubrics (Lin, 2009). Both quantitative and qualitative results are discussed in this study.

Table 1: Descriptions of the three outdoor activities for the PDA integrated ecology observation

activity	site	time	objectives	Tasks included	feedback
1st	Chiku Wetland	6 hr	Guided observation	Multiple choice Short answer	Correctness & Factual information
2nd	Mangrove Pond	3 hr	Autonomous observation & e-library	Multiple choice True-false Constructed responses	Correctness & adaptive support
3rd	Sihcao Wetland	3 hr	Reflective and extended inquiry	Multiple-choice True-false Constructed responses	Automatic scoring for constructed responses

Figure 4. Photos of the PDA integrated mangrove observation learning activities

Table 1 shows the descriptions of the three outdoor activities of the PDA integrated ecology observations. For the first activity, the participants listened to a 40-minute lecture on mangrove forests and then started their observation journey. The observation targets were mainly guided by the worksheets. Both multiple-choice and short-answer questions were presented sequentially on the PDAs. Online feedback of the correctness of students' responses to the multiple-choice questions was provided. For the second and third activities, the students visited different sites for an extended learning experience. True-false questions were included in the second worksheet to facilitate students' elaborated observation skills. Moreover, the feedbacks (such as the correctness of the observations, factual information, adaptive supports, and score of each response) were provided for the short-answer items for the 2nd and 3rd worksheets. It was also suggested that the students search for detailed information in the e-library if they did not get the right answers. For each outdoor activity, the students were required to finish their e-diary within a week. Figure 4 provides some snapshots of the activities. The upper section of Figure 4 shows the ways that students used the PDAs and telescope when they were working on their worksheets. The lower section of Figure 4 shows examples of target observation objects (black faced spoon bill, crab, and mangrove plant). The richness of the ecology system was very appealing but distracting for most of the participants. The PDA provides well-structured scaffolding for students' observation learning. The online feedback helped the students clarify their knowledge, elaborate their descriptions and extend their inquiries sequentially.

Online feedback

Adaptive feedback for the responses to the learning tasks on the PDAs was provided to guide the outdoor learning activities. Figure 5 demonstrates an example of the instant online feedback to an object description item.

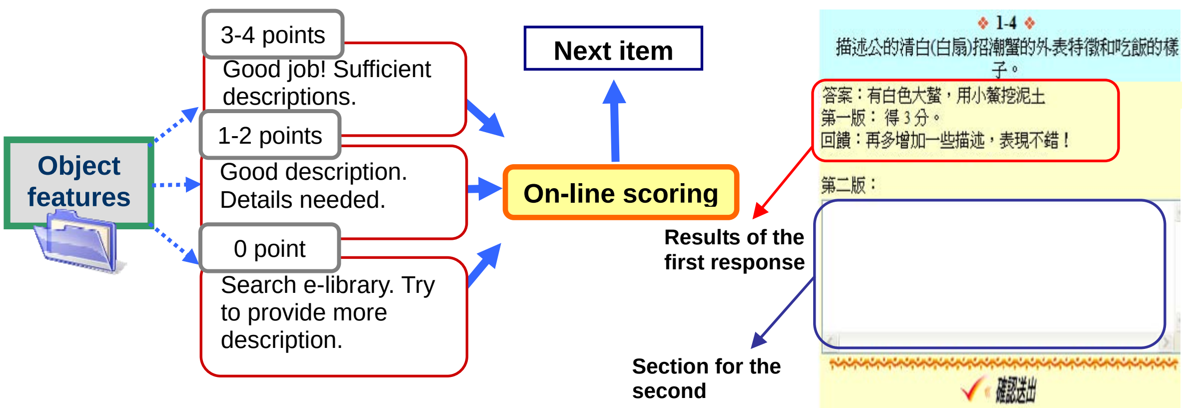

Figure 5. The feedback system for the learning tasks on the PDAs

Scoring for constructed responses

Three different types of tasks (multiple-choice questions, short-answer questions, and extended responses) for two cognitive levels of observation (guided and autonomous) were included in the worksheets. The PDA learning system provided immediate feedback to the multiple-choice questions and short-answer questions. In other words, factual information was provided, but the responses were not scored. The scored part consisted of the autonomous observation notes on the PDAs and the extended responses presented in the e-diaries. Participants' responses were scored regarding (1) the quantity of the observation notes and the questions raised, and (2) the quality of the observation descriptions, the ecological system relationships discussed, and persistent online searching for extended inquiry (Lin, 2009).

Findings and Discussion

Students' performance on the PDA integrated observation activities

The percentages correct for the two aspects of the three formative assessments are provided in Table 2. The results show a noticeable learning progress (from 0.47 to 0.76) for the participants. For the observation on PDA (see Figure 6), the scoring rate of records increased from 0.6 to 0.8 over the three ecology observation activities. In other words, the students became better at recording their observations, focusing on the target objects' special features. Also, the students were becoming more familiar with the scoring rubrics for relevant questions. At the very beginning, most of the students proposed only 1 on-task question (average scoring rate around 0.2). By the end, most students could raise three relevant questions (average scoring rate around 0.6). For the extended responses in the e-diaries, Figure 7 presents the students' progress profiles of extended inquiry. The students learned how to provide more autonomous observations. They were gaining experience of relating their observations to the ecology system. They also demonstrated better persistence in pursuing their own questions. Some students became very capable of using the online search tools for their extended inquiries.

Table 2: The percentage correct of students' performance on the three activities

	1st (n=26)	2nd (n=23)	3rd(n=27)
Observation on PDA	0.39	0.49	0.69
Extended learning on e-diary	0.55	0.64	0.83
Total	0.47	0.56	0.76

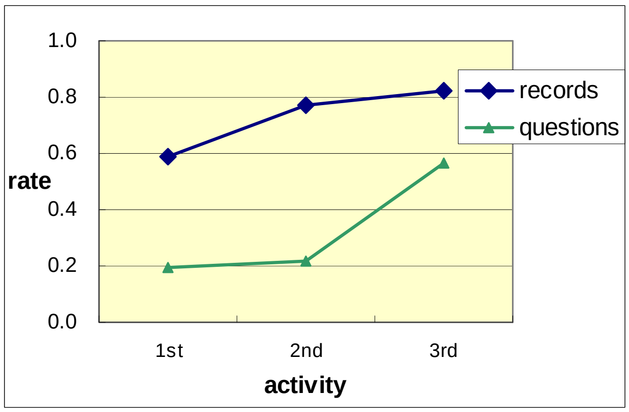

Figure 6. Students' performance profiles on observation recordes and questions on PDAs

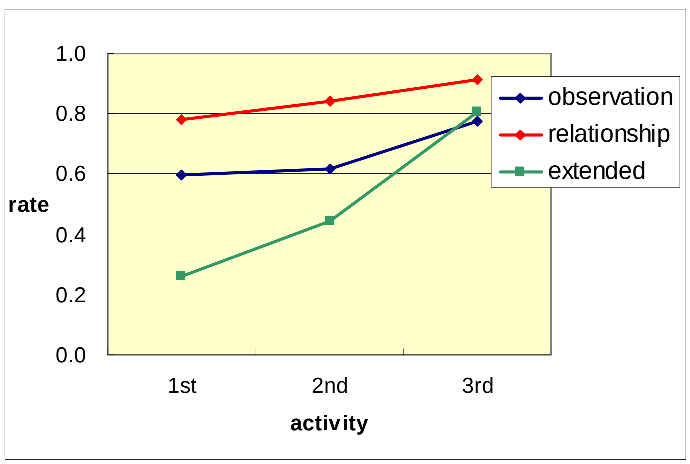

Figure 7. Students' progress profiles on extended learning in e-diaries

Contrasts of different learning profiles

Generally speaking, the students demonstrated substantial progress in both the quantity and quality aspects of the formative assessments. According to the students' learning profiles, we categorized them into different progress levels: great (n=21) and less (n=6) progress. The percentage correct of the first and third worksheets for the great progress group was 0.43 and 0.69 respectively. The percentage correct difference between the first and the third worksheets for the less progress group was 0.12 (see Figure 8). Figure 9 presents the contrast of two typical students' performance on questions raised from different progress groups. The upper section of Figure 9 is the question portfolio of a student who made great progress. This student asked ecology related questions from the very beginning. The questions raised were about how to differentiate two similar plants and why so many birds fly there every winter. The number of questions raised and solved increased in the second and third worksheets. The lower section of Figure 9 provides the question portfolio of a student who made less progress. The second portfolio demonstrated that the number of questions raised also increased sequentially, but some of the questions were not ecology related (e.g. Why use a PDA instead of a PC?), or were similar to the questions on the worksheet (e.g. What are the features of the fiddler crab?). To sum up, the students in the great progress group raised relatively more relevant questions and were persistent in successfully solving these questions.

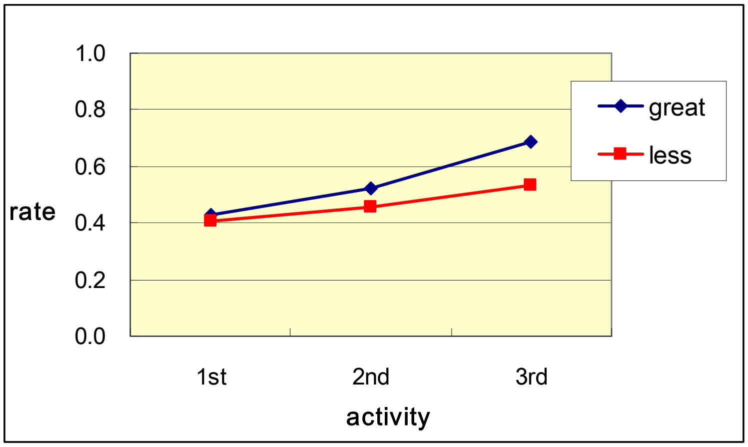

Figure 8. The contrast of different progress profiles of PDA integrated learning

Great progress		Examples of question raised	
1st trip	Focusing on an interesting object	Q 提問: 1.牽牛花和馬鞍藤要如何分辨呢？ 2.為甚麼黑面琵鷺要來七股過冬呢？ S 提問: 2.因為這裡糧食豐沛，氣候適中，所以黑面琵鷺喜歡來這裡過冬。 [1. How to differentiate two similar plants? 2. Why do so many birds fly here every winter?]	2 questions raised and 1 question solved
2nd trip	Conducting an inquiry on scientific questions	Q 提問: 請問賞鳥亭前，白白的是啥鳥？ 銀合歡的花啥時開？ S 提問: 1.白鷺鷥 2.冬天	2 questions raised and 2 questions solved
3rd trip	Recording detailed features of mangrove Searching online effectively	Q 提問問題: 1.看到一隻名字叫凶狠不知道叫啥咪的招潮蟹？ 2.銀合歡繁植能力不是很強嘛，為啥很少有入侵紅海欖的銀合歡？ 3.白鷺斯的家不是在這裡嗎，為啥都沒看到他的影子阿？ 4.綠色隧道有啥歷史？ S 提問答案: 1.凶狠圓軸蟹 2.因為紅樹林鹽分太重了，不適合銀河歡生長，所以就算有伊小部分不 3.因為白鷺鷥早上都出去覓食，晚上才會回來休息。 4.它是台灣最古老的紅樹林	4 questions raised and 4 questions solved
Less progress		**Example of learning profiles**	
1st trip	No proposing any question	Q 提問: 沒有 S 提問: 沒有	No question raised
2nd trip	Raising irrelevant questions	Q 提問問: 為什麼不要用電腦，要用PDA呢？ 大白鷺為什麼是白色的？ 潮汐是什麼？ S 提: 不知道 [Why use a PDA instead of a PC?]	3 questions raised but not solved
3rd trip	Raising questions similar to worksheet questions	Q 提問問: 1.網紋招潮蟹的外型又是什麼？ 2.清白招潮蟹的外型是什麼？ 3.為什麼上次沒有水筆仔？ S 提問答案: 1.中型蟹類，背甲寬3.9cm，甲殼、步足褐色，背甲具有深色的網狀花紋，故稱之。雄性 顆粒呈橘紅色 2.小型蟹類，背甲寬1-2cm，全身白色為主，故稱之，但背甲的顏色會隨環境改變而有灰 變化，大量群棲	3 questions raised and 2 questions solved

Figure 9. Contrast of the quantity and quality of questions raised by different progress groups

Conclusion

Outdoor activities are very exciting for most elementary school students. However, the unlimited learning space could also be very confusing or result in cognitive overload for novice learners. In this study, a formative assessment design embedded in PDA integrated worksheets is proposed. The PDAs functioned as both instruction and assessment tools. The three-layer assessment design successfully guided students to clarify basic knowledge, focus on critical expected observation details, and then extend their learning step by step. The assessment designs were revised continuously using an action research approach. The online scoring and feedback systems were especially helpful to motivate students' persistent engagement. The results of this study suggest that PDAs are an effective cognitive tool for ecology observation activities, as well as a good method to help students with extended inquiry. About 80 % of the participating students demonstrated great progress in their observation skills. However, around 20 % of the students may need more specific and intensive support in order to achieve better progress. Therefore, attention should be paid to understanding the needs of those with inadequate progress in future studies.

To maximize student success, assessment must be seen as an instructional tool for use while learning is occurring, and as an accountability tool to determine if learning has occurred. Because both purposes are important, they must be in balance. Formative assessment links teaching, learning and assessment. This study reasonably confirms Black and William's contention by applying the suggestions in a PDA integrated context. The online feedback makes the performance standards of ecology observation learning visible and attainable to students. However, larger sample size studies will be needed for this study's validity generalization.

Developing students' understanding of the natural world by moving them from naïve conceptions to scientifically justifiable conceptions is the major goal of science education. So, getting students to provide evidence for their concepts about their observations is very important for portraying their learning progress (conceptual change). In other words, integrating concept mapping tools into the formative assessment design of mobile science learning is a promising direction for further studies.

Acknowledgments

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