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SPECIAL ISSUE ON PERSONALIZED LEARNING

Fostering personalized learning in science inquiry supported by mobile technologies

Yanjie Song · Lung-Hsiang Wong · Chee-Kit Looi

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Abstract In this paper, we present a mobile technology-assisted seamless learning process design where students were facilitated to develop their personalized and diversified understanding in a primary school's science topic of the life cycles of various living things. A goal-based approach to experiential learning model was adopted as the pedagogical design to support the student's personalized learning process. We chose to report the student's inquiry into the life cycles of the spinach plant and the butterfly to pinpoint the how the student's personalized learning was fostered in the experiential learning. The learning process consisted of (a) in-class enculturation and question posing; (b) out-of-class field trip observation; (c) on site reflection after observation; (c) data collection and conceptualization of life cycles in the field trip; (d) the hands-on experimentation of growing the spinach plant and rearing a butterfly after the trip at home; (e) creation of animations and composition based on the hands-on experience individually either at home or in class to re-conceptualize the life cycles of the spinach plant and the butterfly, and (f) sharing and evaluation of their work in class. Each student was assigned a smartphone on a 1:1, 24 $\times$ 7 basis, which was used by individuals to mediate their seamless learning experience across multiple contexts. Through our analysis of the learning content, processes and products, we illuminate how the goal-based approach applied to mobile-assisted experiential learning facilitates students' personalized learning and helps them to fulfill their agency in such learning experiences.

Keywords Personalized learning · Experiential learning · Goal-based approach · Mobile technologies · Seamless learning · Field trip

Y. Song (✉) · L.-H. Wong · C.-K. Looi
Learning Sciences Lab, National Institute of Singapore, 1 Nanyang Walk,
Singapore 637616, Singapore
e-mail: yanjie.song@nie.edu.sg

L.-H. Wong
e-mail: lunghsiang.wong@nie.edu.sg

C.-K. Looi
e-mail: cheekit.looi@nie.edu.sg

Introduction

Educational field trips and learning trails offer students opportunities in exploring and meaning-making in authentic settings beyond formal classroom instructions by leveraging on the unique characteristics of mobile technologies, namely, individuality, connectivity, context sensitivity, mobility and immediacy.

With the development of new technologies, and the individual's increasing need for continuous access to knowledge, the borders between learning, leisure and home activities are diminishing. Education is faced with the challenges of new paradigms of teaching and learning, such as personalized learning—an emerging topic in technology enhanced learning research. Learners are different in gender, social roles, culture, education background, ways of learning, knowledge, attention and interests. It is of vital importance to provide them with learning contents and teaching tactics according to their individual needs. To support students during their learning process, we need to capture the context in which they operate.

The focus of this paper is to describe how personalized learning in science inquiry was fostered in a class of Primary four students in a Singaporean school through a process of experiential learning in a mobile learning environment (MLE). The domain topic to cover was the "life cycles" of various organisms. Students involved in the study were assigned a smartphone on 1:1 (one-device-per-student), 24 × 7 (24 h a day, 7 days a week) basis throughout the study period. The learning process design is congruent with Wong and Looi's (2011) advocate of facilitating students' seamless learning experience by extending the supposedly one-off activity design into ongoing, "cross-time and cross-location" constructivist learning. In other words, it was intended to address the potential pitfall of such episodic activities where students were provided with the opportunity to interact with the environment but might not be subsequently supported in deepening their understanding through textual (and other forms of) knowledge (Pea and Maldonado 2006). In our design, after the outdoor activities, students were given additional weeks for follow-up activities to advance their learning by carrying out relevant hands-on tasks and further artifact creations to reinforce their reflections and demonstrate their personalized, meaning making processes on their earlier outdoor learning trail on a farm. The entire cross-context, cross-time learning processes were mediated and supported by the smartphone assigned to each student. The mobile device could be characterized as a "learning hub" that integrates all the personal learning tools, resources and self-created artifacts at one place (Zhang et al. 2010), thus providing students a sense of the "continuous nature of learning" across multiple contexts.

The organization of the paper is as follows: we first introduce the literature related to personalized learning and experiential learning. Next, we present the study context, design and research methods, followed by results and discussions. The paper ends with a conclusion.

Relevant literature

Personalized learning

Personalized learning has the potential to refocus education on the individual rather than schools (O'Donoghue 2009). Personalized learning aims to develop individualized learning programs for each student with the intent to engage him/her in the learning process to optimize each child's learning potential and success. It means a shift from learning that receives the same educational inputs and opportunities to one in which all students have undergone to unique learning experiences and the access to learning resources based on their individual needs. Personalized form of instruction is related to differentiated instruction.

Differentiated instruction is a pedagogy premised on the instructional approaches that should vary and be adapted to individual and diverse students' needs (Tomlinson 2000). To cater for differentiated learning, teachers need to address the three characteristics of students: readiness, interest, and learning profile for each student (Tomlinson 2000). Readiness refers to a student's knowledge, understanding, and skill related to a particular sequence of learning; interest refers to the topics that evoke students' curiosity and passion in which they want to invest time and energy to learn about; and learning profile refers to how a student learns best by offering different choices for showing mastery of learning. The curriculum can be differentiated according to the student characteristics in three elements: the content, the process and the product (Tomlinson 2000). In differentiated instruction, students gain increased ownership of their own learning. This does not mean that differentiated instruction is to offer individualized instruction without involving collaborative or whole class learning activities.

Nevertheless, personalization is different from differentiation and individualization in that personalization requires a major shift in focus from teacher-centered approach to an authentic, student-centered approach. Personalized forms of learning provide an approach tailored to the abilities, preferences, interests, and other diverse needs of the individual students. Thus it empowers the students with more autonomy to develop their own learning paths and with more room for creativity, collaboration, content creation, multi-modal learning and problem-solving, and to become active, and responsible agents in the learning process (Looi et al. 2009). Furthermore, individualized learning usually refers to a learner carrying out learning tasks on his/her own, while a personalized learning experience might also involve social/collaborative learning activities at certain stages of the learning process. To distill personalized learning, Rudd (2008) proposes that personalization should "increase learner choice and voice" in which learners have the power and control over their learning. "Increase learner choice" means that learners have the opportunities to make decisions on the agenda of actions made by the teacher; and "increase learning voice" means that learners have the opportunities to initiate the agendas for action, and are co-designers for their education with the educators. Developing personalized learning curriculum is no easy task. Teachers face the challenges of investing time and effort in designing learning activities that provide unique learning experiences and material for diverse individual needs.

New technologies may help ease the teachers' stress and foster students' personalized learning (Livingstone 2007; Looi et al. 2009). Stroup and Petrosino (2003) categorize technology devices into two types -vertical and horizontal technologies. Vertical technologies refer to devices used mainly for teachers' needs in a prescribed setting, and horizontal technologies refer to devices used for students' personal needs across multiple contexts. Although a large number of educational technologies are still designed and used from the teachers' perspectives as vertical technologies, mobile technologies offer new opportunities to meet students' learning needs as horizontal technologies.

Mobile-assisted personalized learning

New technologies such as mobile technologies have the potential to enhance personalized learning due to its unique characteristics that contribute to learning distinctive from other forms of learning in mainly two aspects. First, learning occurs in environments that move with the learners; and secondly, learning is more personalized in continually reconstructed contexts (Looi et al. in press). Regarding the first aspect, a new focus is laid on continually reconstructed and learner-generated contexts (e.g., Laurillard 2007; Sharples et al. 2007), and on learner's increasing capability to physically move their own learning environments as they move (e.g., Barbosa and Geyer 2005). In this regard, Chan et al. (2006) put forward the notion of (mobile-assisted) seamless learning mediated by one-to-one (one-device-per-student), 24 × 7 setting to bridge formal and informal learning, thus making the learning experiences more personalized (Looi et al. 2009, 2010; Wong and Looi 2011; Wong 2012). These can hardly be achieved through the use of other computer technologies. Järvelä et al. (2007) carried out three experiments to explore possibilities that mobile tools and wireless networks provided for individual and collaborative learning in different contexts. The research findings show that mobile tools and wireless networks can provide multiple opportunities for bridging different kinds of learning contents and contexts as well as virtual and face-to-face learning interactions in higher education to foster individual and collaborative learning.

Regarding the second aspect, learning becomes more and more personalized in learner generated contexts because learners have increasing control over their learning goals achieved via the support of personalized mobile technologies (Jones and Issroff 2007; Sharples et al. 2007; Wong et al. 2011). Although personalized learning exists in online learning environments (e.g., Aroyo and Dicheva 2004; Huang et al. 2007; Wong and Looi 2009, 2010), personalized learning supported by mobile technologies renders learners a sense of ownership and control over their learning in the changing contexts (Laurillard 2007). Some studies indicate that home access to learning resources via the internet have increased opportunities for personalized learning and continuity of learning between home and school, and improve learner independence and motivation (Kerawalla et al. 2007; Livingstone 2007). Indeed, mobile learning offers a perspective that differs dramatically from personalized conventional e-learning in that it supports learning that recognizes the context and history of each individual learner and delivers learning to the learner when and where she/he wants it. For example, Song and Fox (2008) reported a 1-year multiple-case study of investigating into how undergraduate students used smartphones to support their English vocabulary learning anytime, anywhere, such as campus, transports, home, lecture rooms, dormitories and so on. In the study, three individual students from different disciplinary studies, namely, journalism, engineering and biotechnology were involved. The research results show that the students had a variety of smartphone uses based on their own learning goals and they developed personalized ways of vocabulary learning, and enhanced their efficiency in their personalized academic studies.

However, in reviewing the literature related to personalized learning supported by mobile technologies, the majority of the research has been rather technological-driven. Some studies have encouraged students to use existing social tools such as Facebook, Twitter and Dropbox on mobile applications to build and share their personalized learning experiences (Bowen 2011). Some studies are concerned with offering intelligent-based solutions (e.g., Chen and Chung 2008; Anderson et al. 2001; Meawad and Stubbs 2006). Other studies look into adaptive (usually context-aware) learning content retrieval and/or sequencing (e.g., Hwang et al. 2010; Ogata and Yano 2004; Zhao and Okamoto 2011). Petersen and Markiewicz (2009) criticized the latter type of studies for treating contextualization and personalization as synonyms. Instead, they distinguished the two concepts by considering personalization as part of contextualization. Much less work has been done on providing evidence of the process of personalized learning in environments that move with the learners and in the continuously reconstructed contexts of student-centred, experiential learning environments.

Experiential learning

Kolb's experiential learning model focuses on experience as the main force driving learning because "Learning is the process whereby knowledge is created through the transformation of experience" (1984, p. 38). Thus learning is a constructive process in context. It happens in a cyclical model consisting of four stages: concrete experience, reflective observation, abstract conceptualization, and testing in new situations (de Freitas and Neumann 2009; Kolb 1984; Lai et al. 2007). This model requires that learning scenarios, which may embed a series of different objectives, activities and outcomes, be integrated into the experiential pedagogical design. One issue to be addressed is to move away from a set of sequencing of learning to more options (Barton and Maharg 2007). That is, learning for each individual may take place in different ways, ultimately leading to greater opportunities for personalized, active and transformative learning experiences. These different routes for learning have the potential to provide students increased engagement and personalization with the assistance of mobile technologies, which is what our study is intended to explore.

Mobile-assisted experiential learning

Owing to the unique characteristics of individuality, connectivity, context sensitivity, mobility, and social interactivity (Squire and Klopfer 2007), mobile technologies have been increasingly used in educational applications with a contextual focus to support "field-trip" methodologies (Patten et al. 2006) of experiential learning. A variety of embedded functions such as camera, recording, note-taking and online and/or downloaded resources in the mobile devices have been used in the field trips to (a) support "concrete experience" by capturing the features of plants or animals to record the authentic phenomena; (b) support "reflective observation" by taking down "just-in-time" notes and recording timely observational information, and access online or downloaded resources to aid observation; (c) support "abstract conceptualization" by visiting and organizing the captured and recorded information when reporting the field trip observations, and (d) support "testing in new situations" by re-visiting the information and making use of the conceptualized knowledge gained in the field trip.

However, in many cases, the prior research on mobile-assisted field trips has emphasized students' experiential learning in limited, episodic time spans of the activities, and making summative assessment in terms of pre- and post-tests and questionnaire surveys (e.g., Chu et al. 2010; Lai et al. 2007). For instance, Lai et al. (2007) conducted an experiment to explore the possibilities that mobile technologies could provide for fifth grade students in their experiential learning. In the experiment, a mobile technology system on a PDA (Personal Digital Assistant) was developed to facilitate the 90-min experiential learning in a school garden to study a type of plant. The target students followed the designed learning flow consisting of six stages: photo taking, sensory experience, further observation, comparison, question proposing and final report (Lai et al. 2007). Although these studies claim that they have applied the experiential learning model, in general, student learning experiences are not continuous, but come to a halt right after the field trip or after the students have completed their report. According to Falk (2004), conceptual knowledge gains can hardly be achieved in short visits of an unfamiliar context, where prior knowledge and understandings can be consolidated and reinforced. Personalized learning may not be fostered in such a learning environment.

One exceptional study attempted to evaluate the possibilities of implementing mobile learning across school and museum settings in a long term (Vavoula et al. 2009). In the study, the students made use of a platform—MyArtSpace on mobile phones for inquiry learning. It is claimed that the platform allowed students to collect information during a school field trip to a museum, which was automatically sent to a website where they could view, share and present it back in the classroom. In the evaluation of the trial use of MyArtSpace platform at micro (issues of usability), meso (educational effectiveness) and macro (impact of the mobile technology on museum visits practice) levels, questionnaire surveys and teacher and student interviews were conducted. However, it is found that neither the design and results of questionnaire surveys nor the design and results of the interviews were described, analyzed and presented in details. How the students constructed knowledge supported by the mobile technology, what evidence showed that students improved their knowledge gains in the learning across school and museum settings and how personalized learning was achieved remained unknown.

The issues and challenges identified from the mobile-assisted experiential learning work suggest to us we need to incorporate other approaches into experiential learning to sustain the learning experience and support personalized learning.

Goal-based approach

Despite being well-advocated by educators, experiential learning is not without limitations. First, it lacks a mechanism for making students focused on the learning objectives in context (Miettinen 2000). Second, students may lack the skills and pay insufficient attention to abstracting concepts from experience (Lai et al. 2007). These hurdles may be overcome using goal-based approach to the design of experiential learning premised on the constructivist theory (Schank et al. 1994). The important aspects of the goal-based approach are to focus on the learning goals that should be intrinsically motivating, and the role that the learner plays. The criteria for the design of learning scenarios are: thematic coherence (the process of achieving the goal is thematically consistent with the goal itself), authenticity (the design must be authentic to produce varied opportunities for learning the target skills and knowledge.), empowerment (the design puts students in control to increase the sense of agency), responsiveness (prompt feedback is provided to help students acquire skills and knowledge), pedagogical goal support (the proposed design is compatible with and supports the acquisition of skills and knowledge), and pedagogical goal resources (students are provided with appropriate help needed.). By applying the goal-based approach to experiential learning, we aim to help students focus on their learning objectives, increase their agency and develop skills in abstracting concepts in their personalized learning process.

In the light of the above studies, adopting goal-based approach to experiential learning, this study aims at investigating what aspects of personalized learning supported by mobile technologies for science inquiry into life cycles in both formal and informal settings were fostered using a Primary 4 class in a Singaporean school as an example. Specifically, we would like to examine the evidences that show how the students are being engaged in personalized learning.

This study

Research context

This study was situated in a 3-year research project "Leveraging mobile technology for sustainable seamless learning in Singapore schools", adopting design-based research methods. In the project, we co-designed with the teachers a mobilized curriculum for science learning in Primary 3 and 4, which supported student learning across formal and informal settings mediated by 1:1 technologies, and which fostered self-directed and personalized learning (Looi et al. 2009, 2010; Zhang et al. 2010). Fourteen girls and twenty-three boys from the same class were involved in the study. To develop primary students' personalized learning in science inquiry in and out of schools has been advocated in Primary Science Syllabus by Ministry of Education in Singapore (http://www.moe.gov.sg/education/syllabuses/sciences/files/science-primary-2008.pdf). The syllabus encourages teachers to employ varied pedagogical approaches to facilitate the inquiry process.

Although personalized inquiry may provide the opportunities for student cognitive development and scientific reasoning, appropriate pedagogical guidance and resources provision are needed to provide the optimal opportunities for students to focus learning on the development of particular science concepts; otherwise they may be engaged in inquiry without making their own discoveries. In turn, the research project adopted a goal-based approach to experiential learning supported by mobile technologies, which aimed at transforming the traditional IRE (Initiation, Response and Evaluation) pattern (Cazden 1986) which is still prevalent in schools in Singapore (Jacobson et al. 2010) into a constructive meaning-making process (Jonassen et al. 2008). Teachers are encouraged to use various strategies such as field trips to engage students in meaningful learning experiences and to cultivate their interest and curiosity in science. According to MOE (2008), a field trip provides opportunities for students to explore, discover and experience science in everyday life. The curriculum content consists of five themes that relate students' everyday experiences and commonly observed phenomena in nature, namely, diversity, life cycles, energy, systems and interactions. The purpose is to enable students to appreciate the links between different themes or topics, and to allow the integration of scientific ideas.

In examining student experiential learning of the theme of Life Cycles in 3 weeks, this study seeks to understand how student personalized learning was nurtured in science inquiry supported by the mobile technology, namely smartphones and the tools on them. Forty students in a Primary 4 class, with an average age of 10 years, were involved in the study led by a female teacher. At the time of the study, the teacher of the class had been working in the school for about 6 years. She had some experiences in leading field trip studies, but visiting the farm was new to her. The teacher set the general learning tasks and facilitated the students based on their produced work. The students were familiar with the use of the tools on the mobile device prior to the field trip because they had participated in the study for 1 year. The objectives of learning the theme were to make students understand the life cycles of animals and plants, and the importance of cycles to everyday life.

Smartphones were assigned to the thirty-seven students in 1:1, 24 $\times$ 7 basis, which served as "learning hubs" for individuals to mediate their seamless learning experience across the multiple contexts of school, farm and home. The 3G-enabled smartphone provided the students ease of access and research into the resources on the websites during the trip. The students' usage behaviors were updated on the server at real time. This helped the teachers monitor the students' progress on the go. In the field trip, the students were encouraged to focus on observing the life cycles of butterfly and the spinach plant, but they were also allowed to observe the life cycles of other animals and plants on the farm. Thus, the role of the teacher was to set the general learning tasks and to facilitate the students based on the artefacts created by them.

Mobile system for supporting personalized life cycles inquiry in multiple locations

We developed a mobile learning environment (MLE) system that was designed to support students' personalized inquiry process. The system comprised the following components which were co-designed by the researchers and teachers:

- *KW*L: In the KWL tool provided in the MLE system for the students to reflect before and after the learning process, K stands for "what I know", W stands for "what I want to know", and L stands for "what I have learned". Before the field trip, the students reflected on and filled out "*K*" and "*W*" on the MLE system to establish their own learning goals. In the field trip, the students focused on the "*L*" (what I have learned) in KWL questions. In the meantime, they also revisited their "K" and "W" before the field trip.
- Instructions: Instructions on how learning activities would be carried out and what resources were available for access were provided for the students to refer to.
- Websites: Building up towards the field trip, the students accessed the instructions of the learning activities and websites with learning resources related to the life cycles on the mobile devices;
- Worksheets (Microsoft Word files): Worksheets were provided on the mobile devices for the students to reflect on what they had observed;
- Picture-taking tool & PPT (Microsoft PowerPoint files): Students could use the camera embedded in the mobile device to take pictures about the plant, butterfly and other animal life cycles.
- Sketchy™ & Composition: Using Sketchy™ (an animation tool accessible on the MLE system), students could externalize their understanding of the plant and butterfly life cycles during and after their observations, and draw their field trip experience to compose sketchy compositions.

Goal-based approach to experiential learning

Based on Kolb (1984) cyclical model, we developed our own experiential learning model termed as e-ORDER, comprising of six cyclical stages:

(a) Enculturation: Understanding the learning goals and strategies for the field trip and posing questions;
(b) Observation: Observing life cycles in the field trip;
(c) Reflection: Reflecting what has been observed;
(d) Data collection and conceptualization: Collecting data during reflective observation, and abstracting the concept of life cycles by making use of the collected data in the field trip;
(e) Experimentation: Doing hands-on experiments related to life cycles;
(f) Re-conceptualization and evaluation: Re-conceptualizing the notion of life cycles to gain a deeper understanding, share and evaluate these concepts with peers.

Among these stages, (b), (c), (d) and (e) correspond to the four stages of "concrete experience", "reflective observation", "abstract conceptualization" and "testing in new situation" respectively. In order to enable the experiential learning process to be more comprehensively carried out in practical situations, we incorporate (a) and (f) in the beginning and the end of an e-ORDER cycle with the purposes of "learning preparation" and "learning consolidation" respectively. These stages were not sequential but cyclical, working as pedagogical scaffolds for the students to pursue experiential learning across multiple locations. We adopted a goal-based approach (Schank et al. 1994) to design learning scenarios in student experiential learning activities related to e-ORDER, focusing on the following aspects:

- Thematic coherence: The designed learning activities in experiential learning need to be coherent in thematic scenarios;
- Authenticity: The learning activities need to be authentic and close to students' life;
- Empowerment: The learning activities need to arouse students' curiosity and interest;
- Pedagogical goal support: The e-ORDER was used as pedagogical scaffolds to guide student learning activities;
- Pedagogical goal resources: The learning resources and tools were used as scaffolds for students' personalized learning processes.

For example, in the learning scenarios of animal life cycles, we designed three thematic scenarios of (a) pre-field trip of doing *KW* tasks about the life cycle of an animal the students wanted to observe using the KWL tool and understanding instructions of the field trip; (b) during-field trip of observation, reflection, data collection and conceptualization of the life cycle of the animal; and (c) after-field trip of doing hands-on experiment, re-conceptualization and evaluation of the life cycle of the animal. These scenarios will be elaborated in the next section. The learning activities in the learning scenarios were authentic in that all the activities were concerned with students' own choice of the animal they were interested, participation in and reflection of the experiential learning in real life. These authentic activities triggered students' curiosity in learning and increased their agency in inquiry into the life cycle of the animal. The e-ORDER model could be used to guide the students when they were deviated from their learning goals. For example, when the student finished observing and collecting data of the life cycle of the butterfly, and did not know what to do next, he might refer to the e-ORDER model uploaded on in MLE to conceptualize the life cycle of the butterfly. If he still did not know how to conceptualize the life cycle of it, he might also refer to the pedagogical goal resources provided on the website in the MLE system. The way the MLE system supported the e-ORDER model for the goal-based approach to experiential learning shown in Fig. 1.

Co-designed mobilized curriculum for the thematic unit—life cycles

In view of the goal-based approach to experiential learning in encouraging students' personalized learning, the researcher and the teachers discussed and co-designed the pre-, during- and after- field trip learning activities for different physical spaces, making use of the designed mobile learning system as shown in Table 1.

Data collection

The data that we collected included: (a) students' artifacts in the forms of students' PPT about life cycles immediately after the field trip; students' Sketchy animations about life cycles after the experiment, their Sketchy compositions, and students' captured data that were automatically uploaded to the MLE system, (b) students' responses about KWL and worksheets, and (c) history of students' visited websites, and (d) video clips and pictures taken by the researchers before, during and after the field trips.

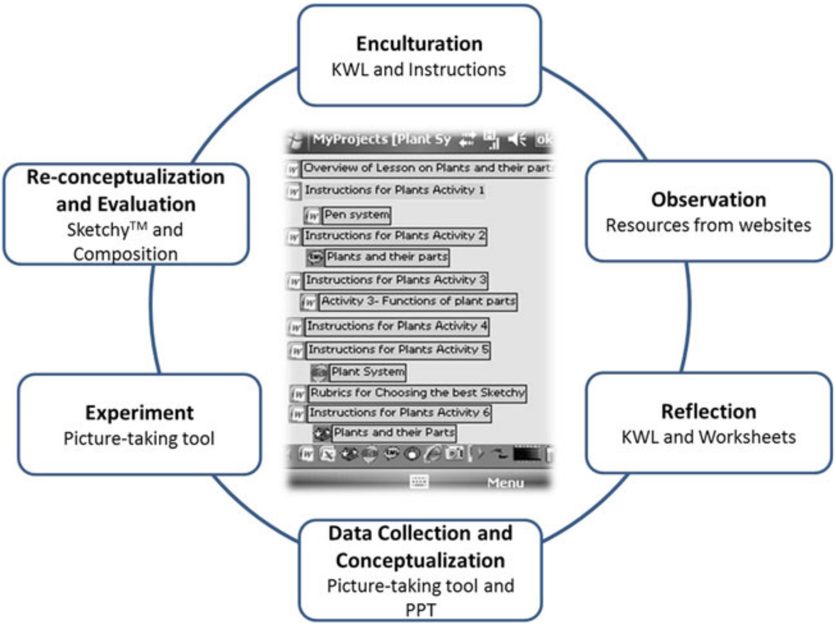


Fig. 1 e-ORDER supported by Mobile Learning Environment (MLE) system

Data analysis

One purpose of this research is to identify evidence of student learning in the experiential learning environment based on the main source of data—artifacts (students' captured pictures, students' learning portfolios, PPTs, sketchy animations and compositions) created by the students. We referred to students' KWL and worksheets to triangulate the data. We also referred to the video clips and pictures taken by the researchers during the field trip to understand students' learning process if necessary. In our scan of the literature, we could not find an existing framework in mobile educational research literature that could be used for coding and categorizing the data. Therefore, we used an open coding method (Corbin and Strauss 2008) to code the artifacts, KWL work and worksheets. The unit of analysis was an individual artifact, KWL work and worksheet from the data sources that specifically related to evidence of student learning. A researcher helped organize the data into different folders, and the first two co-authors were the coders. We coded the data on a case-by-case basis, in conjunction with constant comparative method of analysis (Merriam 1998) across the data obtained from the participants. The coded artifacts included: students' artifacts taken during observation, PPTs about the life cycle of a butterfly or a plant, students' sketchy animation and compositions, student learning portfolios. The coded KWL includes a range of animals and plants that the students "know", "wonder" and "have learned". The coded worksheets include the written stages/life cycles of an animal and some knowledge about growing a plant. We then classified the coded data into broader themes or categories (Merriam 1998) and compared the coded results with each other in terms of the students' different personalized understandings of life cycles. These coded categories offered a good overview and comparable information about students' personalized learning outcomes. However, the results did not enable the examination of the evolutionary process

Table 1 Mobilized curriculum for the thematic unit—life cycles

Learning scenarios	e-ORDER (pedagogical scaffolds)	MLE system (learning process scaffolds)	Goals	Physical space
Pre-field trip: doing *KW* tasks about the life cycle of an animal and/or a plant using the KWL tool and understanding instructions of the field trip	Enculturation	*KW*L and instructions	To enable the students establish their own goals, and understand the learning trails facilitated by the teacher in class, and by the facilitators on the farm; the students filled out *“K” and “W”* in class or at home	Class, home and farm
During field trip: observation, reflection, data collection and conceptualization of the life cycle of the animal and/or the plant the students chose	Observation	Websites	To see, sense and touch the organisms and to observe the full life cycles of the kang kong (Chinese spinach) plant and butterflies, and also observe other plants and animals.	Farm
	Reflection	KW*L* and worksheets	To reflect what they have learned by filling out the *“L”* on the KWL tool, and working on the worksheets related to the observation	
	Data collection and conceptualization	Picture-taking tool and PPT	To capture pictures about the spinach plant and butterfly life cycles as well as other plants and animals; then make a PPT about the life cycle of a plant and an animal to externalize their conceptual understanding	
After-field trip: doing hands-on experiment, re-conceptualization and evaluation of the life cycle of the animal and/or the plant	Experiment	Picture-taking tool	To conduct hands-on experiments of growing a spinach pet bottle hydroponics and rearing a butterfly with a butterfly kit they purchased (students could grow other plants or animals at home) and record the stages of the changes	Home
	Re-conceptualization and evaluation	Sketchy animation and sketchy composition	To draw the Sketchy animation of life cycles of a plant and a butterfly after the experiment (students could draw life cycles of other plants or animals as well); to express what they have observed in the field trip via a Sketchy composition or a piece of procedural writing	Home or class

of students' personalized learning. Therefore, contextualizing strategies (Maxwell 2005) were also adopted to investigate this process to show evidence of student personalized learning by (a) tracing students' learning path through the artifacts and slides created by the students and KWL work in different learning activities from the beginning to the end of the field trip, (b) presenting different learning portfolios uploaded to the MLE system, (c) demonstrating different learning paces through students' captured pictures, and worksheet and videos and pictures taken by the researchers, and (d) indicating different observational goals and understanding of life cycles through various data sources.

Results

In this section, we present and discuss the research findings concerning the evidence which showed student personalized learning.

Student-driven learning paths about life cycles

Because the students were allowed not only to observe the life cycles of not only a butterfly and spinach plant, but also to observe the life cycles of other animals and plants, their learning paths about life cycles were varied based on individual preference, readiness and capabilities. The learning paths about life cycles of a butterfly and the spinach plant were classified into four categories as follows:

(a) Observing a butterfly (in the field trip)—Searching information about butterflies (in the field trip and at home)—Creating PPTs about the life cycle of the butterfly (in class)—Creating Sketchy animation of a butterfly (at home or school)—Sharing Sketchy animation (in class)

Some students observed the butterflies closely, read the information provided on the website and listened to the facilitators' explanations of the growing stages of a butterfly. After the field trip, the students created PPTs about life cycles of a butterfly in class, trying to make use of the pictures taken in the field trip. Albeit having captured photos during the farm trip, the students were given the option of using either their own photos or searching and downloading relevant photos from the Internet to represent their understanding of the life cycles of the butterfly (e.g., see Fig. 2). They shared their PPTs in class and commented on each other's work. The PPTs showed their diverse interests in the different types of butterflies.

After the class, the students who did not purchase the butterfly kit on the farm skipped the experiment of rearing a butterfly. They reflected on what they had learned from the field trip and from the sharing in class drew Sketchy animations of the life cycle of a butterfly (see Figs. 3 (a) and (b)). The Sketchy animations showed that the life cycle that the students drew were similar to what they found from the resources provided to them on the MLE system (http://butterflygroup.files.wordpress.com/2008/12/bf.jpg).

Figure 3a shows that the labeling of the butterfly cycle was problematic in that the students mixed the general process of an organism: egg-lava-pupa-adult with the specific life cycle of a butterfly: egg-caterpillar-chrysalis-adult butterfly. In Fig. 3b, the students did not label the cycle clearly.

(b) Observing a butterfly (in the field trip)—Searching information about butterflies (in the field trip and at home)—Creating PPTs about the life cycle of the butterfly (in class)—Raising a butterfly (at home)—Creating Sketchy animations of a butterfly (at home)—Sharing Sketchy animations (in class)

Fig. 2 A student's PPT about the life cycle of a butterfly

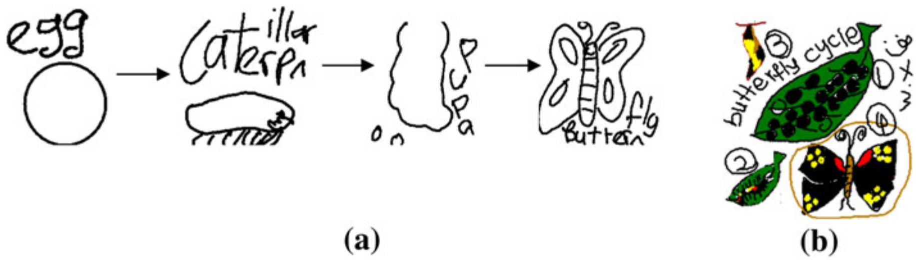


Fig. 3 **a** Sketchy animation of the butterfly life cycle by one student. **b** The life cycle of a butterfly by another student

In the experiential learning supported by the MLE system, some students paid more attention to the butterflies and purchased a butterfly kit to rear a butterfly at home in order to observe and capturing pictures of the growing process of a butterfly using the Smartphone (see Fig. 4).

They also created PPTs about the life cycle of a butterfly in class using the images they searched on the website of the mobile device. However it was noted that the life cycle of a butterfly some students did and labeled on the PPT was different from the one in the Sketchy animations [e.g., see Figs. 5 (a) and (b)]. In Fig. 5(b), the student labeled the life cycle of a butterfly in terms of egg-caterpillar-pupa-butterfly, which was considered not accurate because "larva" should be used to replace "caterpillar".

Figure 5b shows that the student could use more precise names to describe the butterfly lifecycles—egg-caterpillar-chrysalis-adult butterfly.

(c) Observing the spinach plant and other plants (in the field trip)—searching information about the spinach plant (in the field trip and at home)—Making sketchy animation of the spinach plant (at home)—Sharing sketchy animation(in class)

During the field trip, the students observed the spinach plant in a germination room attentively and used the Smartphone to take pictures of the plant as well as the descriptions of the growing states of the plant on the farm. In addition, they compared and contrasted the plants on the farm with the resources provided on the websites. Nevertheless, they did not do the experiment of growing the plant in hydroponics. After they returned home, they sketched the animation of the growing spinach plant, referring to the information on the website whenever necessary. They also shared their artifacts in class. It was found that some of the students who did not grow the plant by themselves sketched the growing process of the plant without any soil or nutrients. One student sketched the growth of the plant growing in soil only at the final stage (see Fig. 6).

Fig. 4 Documenting the growth of a butterfly

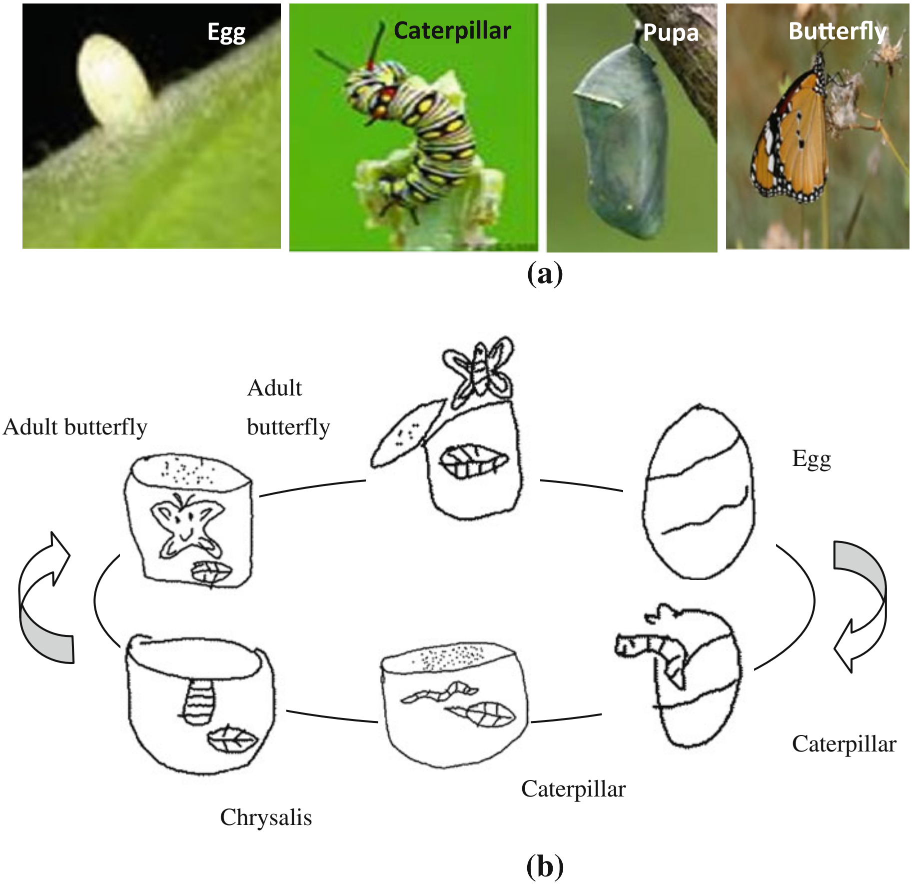


Fig. 5 **a** Four images showcased on student's PPT about the life cycle of a butterfly. **b** Sketchy animation of the butterfly life cycle after the experiment

(d) Observing the spinach plant and other plants (in the field trip)—growing a spinach plant (at home)—Making Sketchy animation of the spinach plant (at home)—Sharing sketchy animation and the real adult plant (in class)

Some students got the spinach pet bottle hydroponics (see Fig. 7) and grew it at home after the field trip.

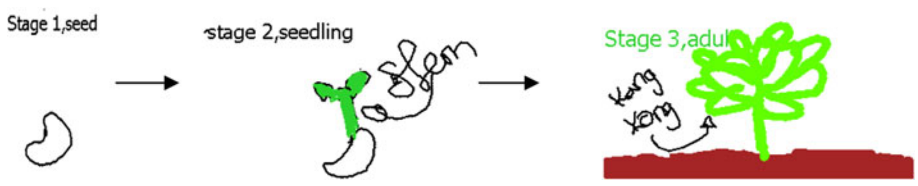


Fig. 6 The sketchy animation of the life cycle of a spinach plant

When the spinach plant grew into an adult plant, they sketched the growing process they observed using the mobile device. In Fig. 8a, although there are three stages in growing a spinach plant, the student observed the growing stages carefully, and sketched two pictures in the first two stages to show his understanding and observation of the process of the plant growth in a container filled with appropriate nutrients instead of soil. This indicates that the students who did the experiment gained better understanding of the conceptual knowledge of life cycles. After the plant had turned into an adult plant, the student took a picture of it using the smartphone (see Fig. 8b) and brought it to the class room for sharing.

Some other students also brought their adult plants to the classroom. They compared the actual sizes of the plants and discussed why those were different. By synthesizing the information acquired from the internet, and the farm facilitator, and their own observation in the field trip, they drew conclusions that the speed of the plant's growth depended on conditions of how much nutrient and water was filled in the container, and how much sunshine the plant received, and what the temperature was. Thus after the students went through the experience of observing the entire life cycle unfolded before their eyes, and they took part in all the stages of development the life cycle of the plant such as feeding and watering, they were able to learn the life cycles in a greater depth. Apart from achieving a better understanding in the stages of life cycles as stages, they had also gained the knowledge of the process of how the stages in the life cycles could ensure continuity of the survival of the organism.

Fig. 7 Spinach pet bottle hydroponics

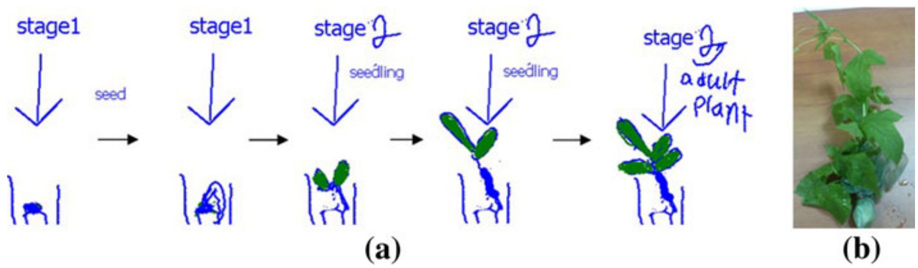


Fig. 8 **a** Sketchy animation of the life cycle of a spinach plant. **b** The real adult plant

Personalized portfolios

All the students participating in the study had their personalized portfolios stored on the web server that could be accessed via the smartphone. The differences lay in the learning content, processes and products. The learning content was comprised of varied animal and plant life cycles. Animal life cycles included: butterfly, ant, cockroach, fish, chicken, bird, and mosquito life cycles; and the plant life cycles included: spinach, fruit and flower life cycles. Therefore, their learning processes were also varied. Some did hands-on experiments; some did not do. They chose their own ways to do the science inquiry across contexts. In the light of this, the products they produced were versatile and multi-modal (pictures, texts or both). Each of them had their own personalized portfolio with a different flow of the activities (see Fig. 9 for examples).

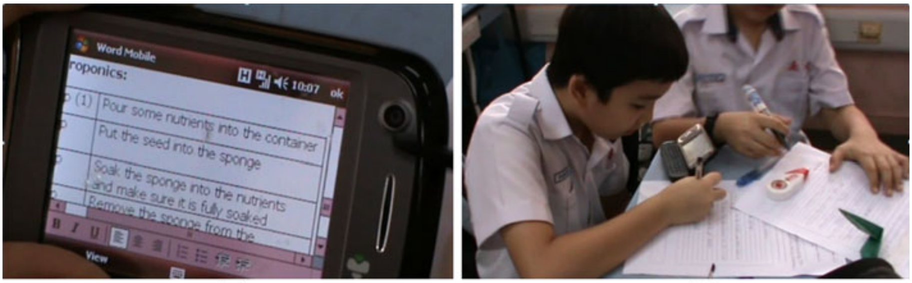
Student-driven learning pace

Although the students had a series of tasks to do, in many cases, they could choose when, where and how to complete the tasks, as supported by the MLE system under the e-ORDER model. This allowed the students to work at their own pace based on their abilities. For example, before the students grew the spinach plant, they watched a video on the procedures in setting up the pet bottle hydroponics on the MLE system and were asked to complete a procedural writing task in class. The students were required to summarize the procedures of setting up the pet bottle hydroponics using summary skills. One student carried out the task and wrote the procedures on the Smartphone at home (see Fig. 10a). Back in class, the student improved his writing in class on paper. He referred to the writing on the mobile device, and realized that the procedural word "lastly" should be added to his paper writing. So he made the change in his procedural writing on the paper (see Fig. 10b). This indicates that in the course of writing, the student could control the pace for his own writing by performing the task at home first and revised the writing on paper in class.

Differentiated learning goals and understandings of life cycles

The results of the study also show that the students' learning goals in life cycles of the butterfly and plants were differentiated. It was found that the students who reared a

Fig. 9 Personalized portfolios of three individual students



(a) (b)

Fig. 10 **a** Procedural writing on the smartphone at home. **b** Procedural writing on paper in class

butterfly themselves were better able to explain why the egg, the caterpillar, the chrysalis and the butterfly were of the same breed based on their own observational experiences. They were also engaged in richer discussions such as identification of butterfly blood and unique diet. This knowledge was beyond the textbooks and learning resources provided. The following is an excerpt of the interview with a student about how he distinguished the types of butterflies when they looked at the pictures over the screen:

Researcher	Do you think that the egg, the caterpillar, and the chrysalis belong to the same type of species?
Student	Yes
Researcher	How do you know?
Student	The color looks the same
Researcher	Which color look the same?
Student	(Pointing to the screen) This one got black stripes (referring to the caterpillar) and this one also got a bit (referring to the butterfly)
Researcher	Ok. Then how do you know that the Chrysalis belongs to this butterfly
Student	(Pointing to the Chrysalis) This color looks the wings of butterfly

Some students had other learning goals. In a student's "W (what I want to know.)" of KWL on the MLE system, a student stated, "What plants does a butterfly go?". After his observation on the farm, the student noted down "L (what I have learned.)" on the KWL, stating "a butterfly usually goes to buddleia, lantana, sunflower …". This means that the student's curiosity about a butterfly's preferred plants drove him to explore, inquiry and achieve his learning goals in the field trip. Another student gained deeper knowledge in her "K (what I know.)". In her "K", she mentioned, "A butterfly lays eggs". After the observation on the farm, she added, "Butterflies choose the leaves they eat to lay eggs."

In addition, from the student sketchy compositions, personalized learning goals and understanding of life cycles were also demonstrated. Some students described the whole field trip experience vividly; some students described things happening in the butterfly lodge, focusing on how to protect the butterflies or set the butterfly away. Figure 11 includes images chosen from a Sketchy composition by a student, which shows that the student saw butterflies were in the cage (a); then he set the butterflies away in front of the teacher (b); and he explained to the teacher, "Teacher, I'm open the cage and the butterfly flew away" (c); finally he told the teacher the truth, "I just want it [them] to be free". This shows that the students had a better understanding of the importance of life cycles in everyday life.

(a) (b) (c) (d)

Fig. 11 The Sketchy composition of a student

Discussion

The results of this study demonstrate the evidence of students' personalized learning scaffolded by goal-based approach to experiential learning 'e-ORDER' and supported by 'MLE system'. In what ways were the aspects of personalized learning fostered? In this section, we will describe the interactions between students' personalized learning, the e-ORDER and MLE system.

Personalized learning and e-ORDER

Student personalized learning occurred in the study was influenced by the e-ORDER. It provided scaffolds for students to be engaged in the entire learning experience. Within each stage of e-ORDER, the goal is suggested and yet there is much space for personalization of the actual learning activities by the student. Hence, students demonstrated their own learning paths about life cycles, maintained their personal portfolios, determined their own learning pace, and developed differentiated learning goals and understandings of life cycles. These have not been adequately supported and developed in previous mobile-assisted experiential learning research (e.g., Lai et al. 2007; Vavoula et al. 2009). It is noted that students' personalized learning was influenced partly by how they made use of the scaffolds of e-ORDER with the stages of (a) enculturation, (b) observation, (c) reflection, (d) data collection and conceptualization, (e) experimentation and (f) re-conceptualization and evaluation.

In terms of their learning paths, some students did not undergo the last two stages. That is, their learning paths did not include "Raising a butterfly (at home)", or "growing a spinach plant (at home) and sharing the real adult plant (in class)". This indicates that they skipped the opportunity to do hands-on experiments, and re-conceptualization and evaluation of their study. Although the students who did not carry out the experiment at home also reflected and conceptualized their learning by creating PPTs and making sketchy animations, the findings show that their understanding of the cycles of the butterfly and the spinach plant did not seem to be as good as the students who completed all the stages of e-ORDER. The former group of students tended to copy the resources provided on the MLE system when they created PPTs about the life cycles of the butterfly, and could not label the stages of the life cycles of the butterfly clearly; also, when they made sketchy animation of the spinach plant, they tended to sketch the growing stages of the plant without any soil or nutrients. Conversely, the latter group of students learned to correct erroneous labeling stages of the butterfly in their PPTs in their sketchy animations. This indicates that these students gained deeper conceptual understanding of the stages of the life cycles of the butterfly after they raised they butterfly at home. It also suggests that in the e-ORDER model of experiential learning, “experimentation” played an important role in students’ understanding of conceptual knowledge. In addition, the students who grew a spinach plant at home had the ownership and control over their own learning, deepened their conceptual understanding of the growing process of the plant, and recognized the importance of life cycles for the sustainability of organism in the living world. These findings contribute to the literature on mobile-assisted personalized experiential learning.

In terms of personalized portfolios, because the e-ORDER model allowed the students to conduct inquiry into the life cycle based on their goals, readiness, interest, and capability, with “increased learner choice and voice”, their portfolios were different regarding content, processes and products uploaded on the MLE system. These personalized portfolios recorded each student’s learning trails which rendered the student’s ownership of his/her own learning. It also helped the teachers to understand students’ interest, strength and weakness so that a more adaptive personalized curriculum could be developed to meet varied students’ needs.

Regarding student-driven learning pace, differentiated learning goals and understanding of life cycles, due to the flexibility the tasks in the learning scenarios guided by the e-ORDER, students could choose their own learning space according to their learning abilities and preferences. In addition, their learning goals were different, which contributed to different understandings of life cycles in everyday life.

Personalized learning and affordances of the MLE system

We view our design from the perspective of a curricular activity system as the minimal unit of “impactful, adoptable” packaging of technology for a school (Roschelle et al. 2010). In such an activity system, learning activities are designed for teachers, students, and other agents (such as field trip facilitators) to facilitate or participate in. The responsibility for supporting such activities is distributed across class talk, field trips, technology, software, paper curriculum and student-created representations. The designers of a curricular activity system seek to engineer an aligned set of related components that coherently support the desired curricular goal. In our design, each component foregrounds personalization, providing the flexibility for the student to learn in her or his own way which is novice in current mobile-assisted experiential, personalized learning.

We further investigated how the following affordances of the MLE system were used by the students, many of which were emergent usages (i.e., not prescribed by the researchers or the teacher) to support and enhance the students’ personalized learning:

- Allowing anytime, anywhere seamless learning: On the MLE system, the students could make their learning happen across multiple contexts. Artifacts captured in one context can be accessed and built upon in another context (Wong et al. in-press; Wong and Looi in-press). This indicates that their mobile devices had become the mediating tool to concretize the context bridging of learning.
- Making thinking visible using Sketchy™: The students could make their thinking visible using Sketchy™ which encouraged students’ agency in actively reifying their personalized learning experiences.
- Providing multimedia information access: The ease of use and ubiquitous web resources on the MLE system provided opportunities for the students to refer to the resources just-in-time and -place, which fostered personalized learning.

- Enabling reflections anytime, anywhere: the KWL on the MLE system helped the students to reflect what they knew, what they wanted to know and what they learned in their learning process.
- Integrating digital and non-digital work: The smartphone serves as the hub for student-created representations. At the same time, the curricular activity system includes other forms of non-digital work which the student treats as resources in her or his own learning.
- Doing mobile-based formative assessment: The work posted by the students in their portfolios could be accessed by the teacher. The teacher's feedback motivated the students to do more and better work to build up their portfolios.

The interactions between students' personalized learning, the e-ORDER and MLE system helped the students to achieve better understanding of the life cycles of animals and plants, and to realize that the theme of life cycles of animals and plants are closely related to other themes such as energy and systems. This, in turn, helped the students develop integrated scientific ideas which are in alignment with the goals of the science curriculum.

Limitations of the study

A methodological issue is the complexity of exploring personalized learning in re-constructed contexts that move with the learners. One can hardly know all of the contexts and variables that might contribute to personalized learning. We only strive to provide a body of evidence to support what aspects of personalized learning were fostered in the study. We also admit that the data collection was not always satisfactory due to the complexity and challenges of investigating students' personalized learning, especially those took place in the informal learning settings.

Conclusion

This study explored how students' personalized learning was fostered using goal-based approach to experiential learning and affordances of the MLE system. We presented the evidence of personalized learning in this study.

Personalization has been a well-articulated and well-discussed aspect in mobile learning research. As stated in the literature review section, in the majority of the existing mobile learning studies, personalization is mainly facilitated (and even controlled) by the adaptive technology. It is true that the adaptive technology may provide personalized advices or resources with respect to the system's perpetually identified and updated student learning characteristics and contexts. In the long run, however, we argue that such learning settings may result in the students' over-reliance on the system's recommendations while not being able to pick up the skills of self-identifying learning strategies or filtering of learning resources that are much needed for genuine autonomous learning. Instead, the MLE system premised on the goal-based experiential learning pedagogical design reported in this paper is an investigation on the other direction of the spectrum of solutions, namely, a curricular activity system with components that design explicitly for personalization. Though starting with a relatively structured mobile learning trail in the farm, we subsequently facilitated and even encouraged the students to show their diversity in deciding what to learn and what artifacts to produce (Wong and Looi in-press). Prior studies on mobile learning trails tended to place their emphasis in analyzing what is happening *during* the trail. Instead, we positioned the learning trail as a means of putting the students into the right learning context; while the genuine deep learning took place in the post-learning trail activities. Thus, we designed a cross-context, seamless learning flow that "press the right button" to stimulate students' greater agency in personalized, meaning making mediated by, but not manipulated by, the technology. We argue that students' such conscious personalization is the key to nurture life-long learners who can practice and develop agency to learn their own ways.

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Dr. Yanjie Song is a Research Scientist in the Learning Sciences Lab, National Institute of Education, Singapore. Her research interest lies in theory, practice and methods of mobile technology educational applications.

Dr. Lung-Hsiang Wong is a Research Scientist in the Learning Sciences Lab, National Institute of Education, Singapore. His research interests include mobile seamless learning and technology-enhanced language learning.

Dr. Chee-Kit Looi is a Full Professor in Learning Sciences Lab, Nanyang Technological University. He has published extensively in the fields of mobile learning and computer-supported collaborative learning, and his research has created significant inroads into impacting school practices.