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Colloquium

A key step to understanding paradigm shifts in e-learning: towards context-aware ubiquitous learning

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Introduction

Electronic learning (e-learning) has become widely accepted in both entirely online learning environments and in blended learning contexts (Mayadas, Bourne & Bacsich, 2009). In a broad sense, e-learning is used to describe the way people use an electronic device (usually a computer) with learning technology (LT; Rushby & Seabrook, 2008) to develop new knowledge and skills individually or collaboratively. Mobile devices with LT, such as PDAs, smart phones and portable computers, constitute various forms of wireless environments that foster two-way, real-time communications among users, as well as between the user and their context, and can have many functions to promote mobile learning (m-learning; Rushby, 2005). Since the early 2000s, new forms of mobile technology containing additional sensor devices have been providing new directions for technology-assisted learning, and this has led to context-aware ubiquitous learning (u-learning; Hwang, Wu & Chen, 2007; Yang, 2006), which enables users to interact and learn with sensors and radio frequency identification (RFID) embedded objects in their surroundings (Curtin, Kauffman & Riggins, 2007). Context-aware ubiquitous technology is continuing to develop and spread, and its applications have begun to influence learning in various fields and disciplines (de Jong, Specht & Koper, 2008).

Although Taiwan is very competitive with regard to research and development and gaining patents in the ICT (information and communication technology) industry, its achievements are still unsatisfactory when it comes to making good use of such devices in various contexts (Economist Intelligence Unit, 2008). In order to better prepare for the cutting-edge context-aware u-learning that is being developed as part of government-funded, national e-learning research in Taiwan, we first identify the similarities and differences among conventional e-learning, m-learning and context-aware u-learning in terms of theoretical and practical variables. To date, there has been no research published concerning the paradigm shifts in e-learning leading to the development of context-aware u-learning, and thus we propose a set of significant values

based on the relevant literature to guide the development of context-aware u-learning applications. In addition, we present a context-aware u-learning case to demonstrate how it can be used in real-life contexts. Finally, the research agenda along with some concerns are presented, followed by the conclusions to this work.

Paradigm shifts from conventional e-learning to m-learning to context-aware u-learning

When applying a new type of LT, we may need a new paradigm for guiding the use, design, implementation and assessment of the technology (Richey, 1998; Rushby, 2005). e-Learning has become prevalent in all kinds of learning contexts since the mid-1990s, and Yang, Okamoto and Tseng (2008) observe the LT field and indicate that context-aware u-learning is an emerging computer-supported learning paradigm. Based on this trend, we are experiencing a paradigm shift from conventional e-learning to m-learning (Rushby, 2005) and another from m-learning to context-aware u-learning (Hwang, Tsai & Yang, 2008). The theoretical framework given in Figure 1 may help readers identify the important factors constituting a context-aware u-learning environment, and give a clearer picture of these shifts.

To prepare for the latest shift to context-aware u-learning, we first identify the similarities and differences among conventional e-learning, m-learning and context-aware u-learning in terms of the theoretical and practical variables in Table 1.

Values and directions for guiding potential context-aware u-learning for learning, teaching and research purposes

Richey (1998) identifies values as personal interests as well as beliefs and ideals, all of which help the researchers guide the selection of the important components used in this study. Since context-aware u-learning is different from conventional e-learning and m-learning, in order to identify potential ways to realise context-aware u-learning in

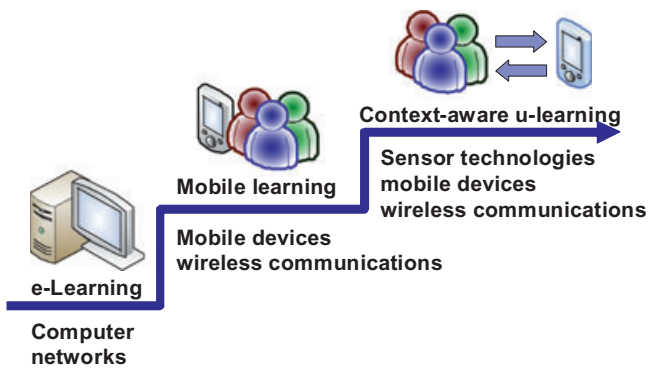

Figure 1: The components of paradigm shifts in e-learning

Table 1: The similarities and differences among e-learning, m-learning, and context-aware u-learning in terms of theoretical and practical variables

Theoretical and practical variables		*Conventional networked e-learning*	*m-learning*	*Context-aware u-learning*
Distinct features of learning		Distance free, holistic learning, synchronous and asynchronous access	Distance free, holistic learning, synchronous and asynchronous access, situated in authentic environment, timely access to learning information	Distance free, holistic learning, synchronous and asynchronous access, situated in authentic environment, timely access to learning information, adaptive and active learning support
Major LT tools		PC, notebook computer, and Internet-supported devices	Mobile devices (eg, PDA, cell phone, portable computer) with wireless communications	Sensor technologies (eg, RFID readers and tags, GPS) with mobile devices and wireless communications
Locus of control	Internal, based on learner perspective	Self-directed user	Active user	Active user or sensor-motivated user
	External, based on tool application	Guidance based on online behaviours	Guidance based on wireless, networked learning behaviours	Guidance based on online and authentic learning behaviours
Major sources of information		Wired servers	Wireless servers and authentic objects	Wireless servers and authentic objects with embedded sensors
Applicable academic and industrial fields		Almost every field and discipline	Learning declarative knowledge, such as the observations and classification of a set of target objects	Learning procedural knowledge, such as learning to complete a complex experiment
Instructional modes		One-to-one, one-to-group or group-to-group learning activities	One-to-one, one-to-group or group-to-group learning activities with authentic context information for declarative knowledge, such as observation and classification of real-world learning targets.	One-to-one, one-to-group or group-to-group learning activities with authentic context information for procedural knowledge, such as the skills or ability to complete a complex experiment with several items of equipment
Assessment modes		Value-based, synchronous or asynchronous judgment from self, peers or instructors, or artificial grading from the learning system	Value-based, live judgment from self, peers, instructors, or artificial grading from the learning system	Value-based, live judgment from self, peers, instructors, or artificial grading from the learning system, especially suitable for evaluating real world learning activities
Learning Scenarios		Passive online learning context	Real world and passive online learning context	Real world and more active online learning context
Related pedagogical theories or tutoring strategies		Almost all kinds of pedagogical theories or tutoring strategies	Almost all kinds of pedagogical theories or tutoring strategies, especially project-based learning, authentic learning, scaffolding	Almost all kinds of pedagogical theories or tutoring strategies, especially project-based learning, authentic learning, scaffolding, cognitive apprenticeship

LT, learning technology; RFID, radio frequency identification; GPS, Global Positioning System.

the research, we review the literature and provide a summary of the recognised values associated with this technology with regard to learning, teaching and research in Table 2.

All attributes concerning teaching and learning are worth researching, including materials, resources, users, contexts, meta-cognition and the ways users develop the knowledge and skills. In addition, Yang *et al* (2008) identify eight major characteristics of context-aware u-learning, namely mobility, location, interoperability, seamlessness, situation awareness, social awareness, adaptability and pervasiveness. These features deserve closer observation to further identify strengths and weaknesses when engaging students in this kind of e-learning.

An example of context-aware u-learning

For the purpose of evaluating the effectiveness of this contextualised media for learning and the possible problems that may arise (de Jong *et al*, 2008), we design a case to explore the learning conditions and all possible factors. Figure 2 shows the arrangement of the context-aware u-learning environment, which is a butterfly garden with each host plant labeled with an RFID tag. Moreover, each student has a handheld mobile device equipped with an RFID reader. In the learning area, wireless communication is provided, so that the mobile device can communicate with a computer server. As a student moves around the learning area, the system can detect their location by reading and analysing the data from the nearest RFID tag. Consequently, assessment can be conducted to evaluate the learning performance of the student in the real world.

Figure 3 shows the user interface for conducting the assessment process in an authentic environment, which is an ecology garden consisting of tens of plants for raising butterflies. With the help of mobile devices, wireless networks and RFID sensors, the

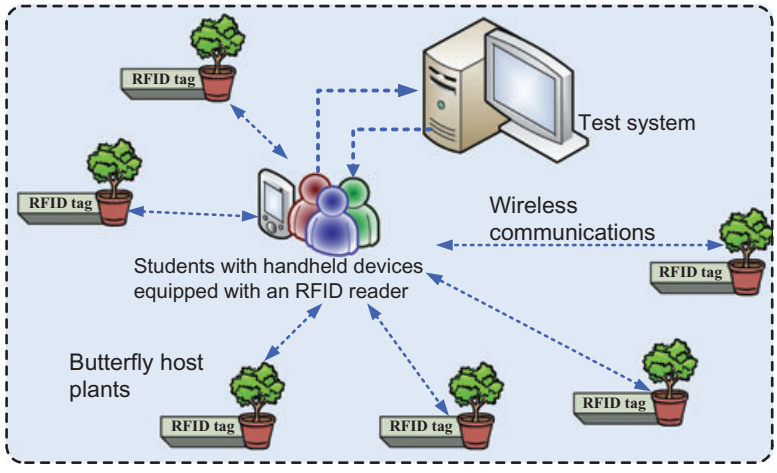

Figure 2: System architecture of the context-aware u-learning environment

Table 2: Guiding values and directions for context-aware u-learning

Guiding values for context-aware u-learning	*Benefits for stakeholders*	*Directions for learning and teaching*	*Examples of possible research topics*
Immediacy (Yang, 2006)	Answering questions and solving problems without hesitation or delay; learning effectiveness and efficiency	'Providing intuitive ways for identifying right learning contents and right learning services in the right place at the right time' (Yang, 2006, p. 188)	Gifted student education (Luor, Johanson, Lu & Wu, 2008), handicapped student education, CMC with language learning (Liu & Chen, 2007), applying u-learning to various disciplines and industries, meta-cognition
Inquiry learning (de Jong, 2006)	Constructing knowledge and skills by interacting with people, objects and contexts; exploring different learning styles and strategies	Exploring the real world; developing personalised learning strategies and styles	Home-schooling and non-school education (Luor *et al*, 2008), CALL with language learning (de Jong *et al*, 2008; Liu & Chen, 2007), a specific instructional design model/theory and a taxonomy for each academic discipline, study area or industry (Liu, 2008)
Collaborative learning (de Jong, 2006)	Forming teamwork-based competition and support	Enhancing the success rate of meeting learning goals with peer support	Applying u-learning to various disciplines and industries, CMC with language learning, elderly education, handicapped student education
Guided learning with practices (de Jong, 2006)	Exploring various types of u-learning and their efficacy	Scaffolding the learning process with realisable methods (Chu, Hwang, Huang & Wu, 2008)	Handicapped student education, CALL with language learning, applying u-learning to various disciplines and industries, meta-cognition
Assessment by sensors with RFID technology (Curtin *et al*, 2007)	Exploring resource-based learning (Kim *et al*, 2008)	Identifying effective and efficient tools with realisable methods or techniques	Home-schooling and non-school education, handicapped student education, elderly education, applying u-learning to various disciplines and industries
Facilitating learning skills (Hartley, 2007)	Investigating various skills to promoting the best learning outcomes with the right application	Eliciting better learning performance; enhancing learning transfer; promoting critical thinking	Handicapped student education, elderly education, applying u-learning to various disciplines and industries
Facilitating social skills (Hartley, 2007)	Investigating beliefs, attitudes, preferences or problems about u-learning with peer support or contextualised media for learning	Enhancing the affective relationships and strengthening the interactions among peers and between students and teachers	CMC with language learning, handicapped student education, elderly education, home-schooling and non-school education

CMC, computer mediated communication; CALL, computer-assisted language learning; RFID, radio frequency identification.

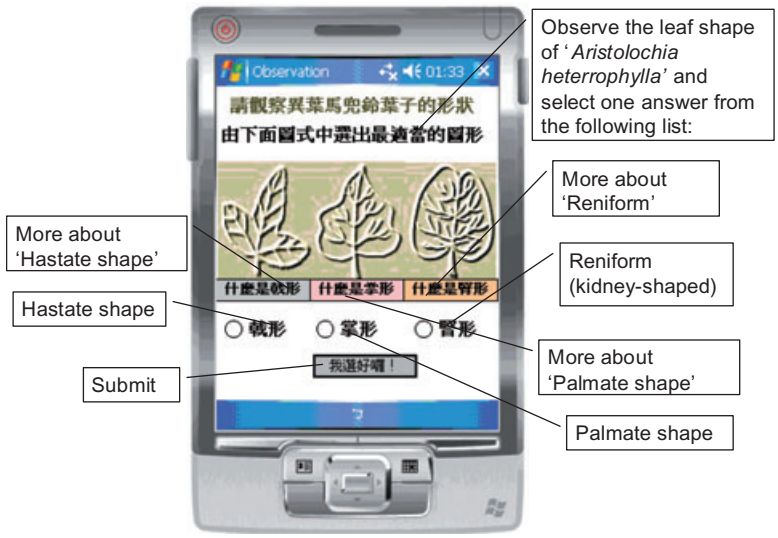

Figure 3: Assessment interface for the target plant

learning system can detect the learning behaviours of the students and interact with them, including guiding them to observe target areas, presenting supplemental materials, and asking some questions to evaluate their performance as they are engaged in the activity. In this illustrative example, the test system guides the student to a target plant and asks him/her to identify it. If the student fails to correctly identify some feature of the plant, eg, the student decides that the leaves are 'Palmate shaped' while the correct answer is 'Hastate shaped', the test system will guide the student to find a plant with 'Palmate shaped' leaves. After comparing the correct leaf shape with the misidentified one, the student is asked to answer the question again.

Figure 3 shows the user interface for conducting the assessment process. The test system will guide the student to a plant and will ask the student to identify it.

If the student fails to correctly answer the question for the second time, the u-learning system will show the correct answer and the detailed information of the plant to the student, as shown in Figure 4.

The research agenda and research questions, with some concerns

The 14-professor research team is developing LT mobile devices and working with a group of elementary school students and teachers who are studying natural science. Later, we will keep exploring context-aware u-learning with various groups of students and instructors in high schools and at universities, gradually including more disciplines in the material (eg, environmental science and language learning). We are exploring the new values of context-aware u-learning with the following research questions:

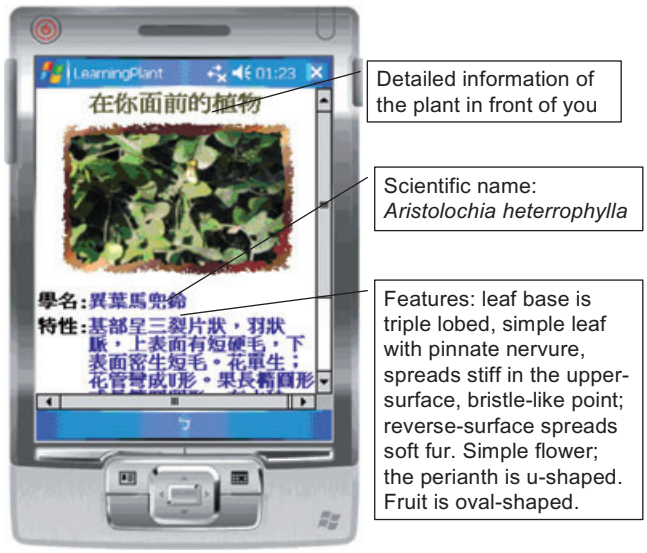

Figure 4: The test system shows the answer and detailed information

- What is the best practice with this kind of context-aware u-learning?
- What are the most appropriate roles of the instructors and students?
- Are there any obstacles when students engage in context-aware u-learning? If so, how can we overcome these?
- Do the instructors enjoy this new type of context-aware u-learning? And what are the reasons for their responses?
- Do students perform better with context-aware u-learning than they did with conventional e-learning or m-learning?
- What are the best functions for sensor/RFID embedded objects in the surroundings, and how do we select the best locations for them?

Moreover, we are concerned with the following problems when designing the study:

- How much collaboration among the students and how much support from the instructors is needed, since the sensor/RFID embedded objects in the surroundings have already provided all the necessary information to the users?
- In order to realise the authentic values of context-aware u-learning, should we provide strict, principled guidance for the instructors and students (guided learning with practice) or should we let them follow their interests from the beginning to the end (inquiry learning)? Or should a mixed method be used?
- How can we effectively assess the learning outcomes for this kind of context-aware u-learning with the cooperation of students in an open context?
- What is the return on investment (Njenga & Fourie, in press) for LT tools and other context-aware u-learning equipment in terms of costs and benefits, even when it is hard to measure such things?

Conclusions

We are using a mixed form of qualitative and quantitative research methodologies in conducting the study to address the questions outlined above. The research results will be used to identify authentic, effective applications of context-aware u-learning, as well as solutions to any problems that arise and new research topics that should be pursued (Hwang *et al*, 2008). With more new values being identified in LT (Liu, 2008; Rushby & Seabrook, 2008), interested researchers may better explore formal and informal complex learning with mobile LT (de Jong *et al*, 2008; Kim, Lee, Merrill, Spector & Merrienboer, 2008) and context-aware u-learning with RFID technology (Curtin *et al*, 2007). In addition, related applications of Global Positioning System are also worth investigating, if the research can be expanded in this direction. We sincerely hope this work will help interested stakeholders better understand and even contribute to the paradigm shifts in e-learning, and also shed more light on the growing field of context-aware u-learning.

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