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Hsinyi Peng^a, Yi-Ju Su^a, Chien Chou^a & Chin-Chung Tsai^b

^a Graduate Institute of Education and Center for Teacher Education, National Chiao Tung University, Hsinchu, Taiwan

^b Graduate School of Technological and Vocational Education, National Taiwan University of Science and Technology, Taipei, Taiwan

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Ubiquitous knowledge construction: mobile learning re-defined and a conceptual framework

Hsinyi Peng^{a*}, Yi-Ju Su^a, Chien Chou^a and Chin-Chung Tsai^b

^aGraduate Institute of Education and Center for Teacher Education, National Chiao Tung University, Hsinchu, Taiwan; ^bGraduate School of Technological and Vocational Education, National Taiwan University of Science and Technology, Taipei, Taiwan

Emerging from recent mobile technologies, mobile learning, or m-learning, is beginning to offer ‘stunning new technical capabilities’ in education (DiGiano et al., 2003). This new genre of learning is viewed as a revolutionary stage in educational technology. However, ubiquitous computing technologies have given rise to several issues. This article revisits the relevant definitions and provides a conceptual framework of ubiquitous knowledge construction in light of contemporary research and theory. The framework can be used to assist educators and researchers who are examining the specific implications of mobile learning.

Keywords: mobile learning; m-learning; ubiquitous computing

Introduction

By the end of the decade or sooner, the transition to ubiquitous computing will become a pervasive force that changes the ways of human communication (Gardner, Morrison, Jarman, Reilly, & McNally, 1994; Hill, Reeves, & Heidemeier, 2000; Bull Bull, Garofalo, & Harris, 2002). Emerging from current ubiquitous technologies, mobile learning, or m-learning, is about to offer ‘stunning new technical capabilities’ in education. Ultimately, these increasing computing capabilities will fulfill the goal of equitable access, and therefore enhance the processes of learning and teaching (Kearsley, 2000; DiGiano et al., 2003).

A number of studies have been implemented into various mobile-learning environments worldwide, such as the *MobiLearn* project (Hardless, Lundin, Löff, Nilsson, & Nuldén, 2000), the *Palm Education Pioneers (PEP) Program* (www.palmgrants.sri.com), Microsoft’s *Anytime Anywhere Learning (AAL)* project (<http://www.microsoft.com/education/?ID=aal>), and the *Musex* project (Yatoni, Sugimoto, & Kusunoki, 2004). In Taiwan, several projects developed wireless mobile ad-hoc learning systems to probe the future of classroom learning (e.g., Chen, Kao, & Sheu, 2003; Chen, Kao, Yu, & Sheu, 2004). These projects seem to envision the potential of future learning.

Even given the above premises of mobile learning, researchers have not yet reached a consensus on the definition and the scope of this new genre of learning. The term *m-learning* is defined differently among different studies, an important but not surprising fact that perhaps reflects the novelty of this area and the fact that m-learning

*Corresponding author. Email: sindypeng520@gmail.com

and its applications are still evolving. Furthermore, the distinction between e-learning and m-learning remains unclear among studies. The absence of both an appropriate definition of m-learning and a rigorous understanding of its potential might hinder future research and applications. The development of such a definitional understanding often hinges on a prior exploration of the consequences of the topic at hand.

One consequence of rapid technological development is that the theoretical framework for mobile learning has not yet been clearly established. Thus, a comprehensive framework would be helpful in processes related to design, development, and evaluation, particularly as researchers and practitioners implement technological innovations (Hill, Reeves, & Heidemeier, 2000). As ubiquitous computing appears to represent the future of education technology, it is crucial for educators to be prepared to use such force to enrich teaching and learning in the classroom. Teacher training focusing on mobile vision and competencies is desirable in order to facilitate the transformation of pedagogy. Also, issues and potential problems should be addressed before large-scale projects are executed.

This study attempts to address the following issues: (a) the redefining of mobile learning; and (b) the establishment of a theoretical framework of ubiquitous knowledge construction.

Re-defining mobile learning

From e-learning to m-learning

In predicting the next stage of e-learning, Keegan (2002) asserts that the next task of future educators will be to assemble comparable systems for wireless computing technology, similar to the ones for wired technology. That is, m-learning may be the next stage of e-learning and may become the next milestone of educational technology. Figure 1 presents the developmental stages of educational technologies, which move through the stages of programmed instruction, computer-assisted instruction, Internet-connected e-learning, and even the context of wireless m-learning.

Many studies use the terms *m-learning* and *e-learning* in a complementary way. Hoppe and his colleagues (Hoppe, Joiner, Milrad, & Sharples, 2003) provide a complete explanation of the relationship between these two types of learning. They define *e-learning* as ‘the learning supported by digital electronic tools and media’ and *m-learning* as ‘e-learning using mobile devices and wireless transmission’ (p. 255). We may conclude that the scope of e-learning contains that of m-learning. This may also explain the reason certain researchers consider m-learning to be almost equal to e-learning in many instances. Figure 2 shows the relationship between e-learning and m-learning.

However, two distinct characteristics differentiate m-learning from e-learning: mobility and ubiquity. These two characteristics are, along with m-learning definitions, treated in the following section.

Definitions of m-learning

M-learning has been defined in various ways, each reflecting the interests of the groups using them (refer to Table 1 for the three classifications). As mentioned above, one definition of *m-learning*, which focuses on its functional components and communication style, characterises it as ‘e-learning using mobile devices and wireless transmission’ (Hoppe et al., 2003; Chang, Sheu, & Chan, 2003). This type of definition is

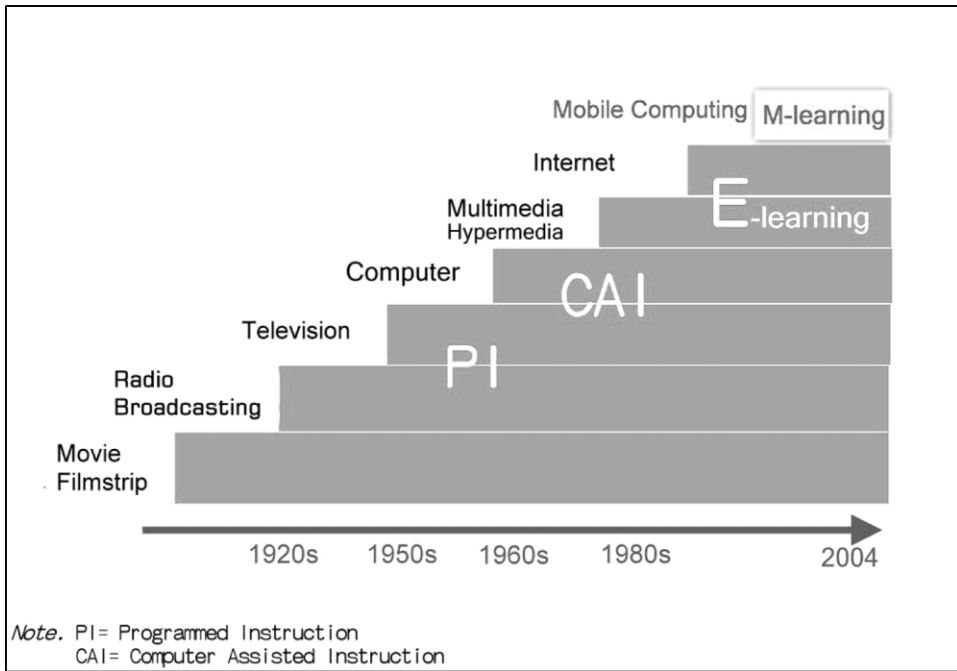


Figure 1. The developmental stages of educational technology.

typically used by computer scientists who are interested in building a functional system connecting devices with wireless networks.

The second type of definition concentrates on its *mobility*. Shepherd (2001) defines m-learning as resting ‘not only on the mobile technologies, but also on the mobility’ (cited from Seppälä & Alamäki, 2003, p. 330). Hummel, Hlavacs, and Weissenböck (2002) suggest that mobility is one of the main differences between m-learning and e-learning, as ‘mobility itself will influence the way of learning, fostering

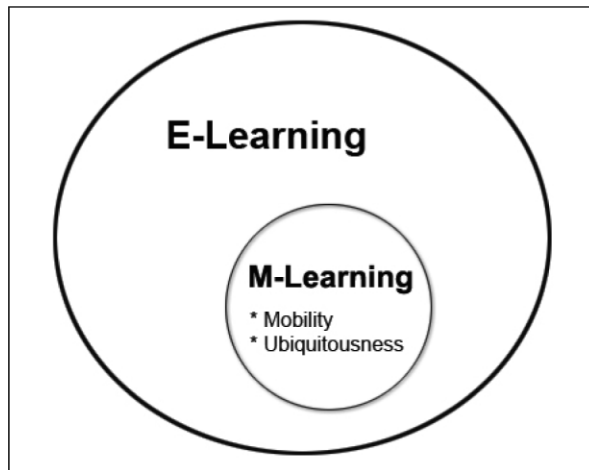


Figure 2. The relationship between e-learning and m-learning.

the utilisation of small free time slices for learning and attending lectures' (p. 5). Such statements correspond to the proposal made by Kynäslähti (2003), according to which *mobility* refers to 'convenience, expediency, and immediacy which are valuable to teachers and students as they are teaching and learning' (cited from Seppälä & Alamäki, 2003, p. 330). Apparently, mobility has added a brand new dimension to learning technology.

The main idea of the third definition resides in the word *ubiquity*. The term *ubiquitous computing* means on-demand computing power with which users can access computing technologies whenever and wherever they are needed. Kearsley (2000) describes ubiquitous computing as 'one of the future directions of on-line education', which allows learners to engage in 'processing data for personal preferences, security/safety, or networking' (p. 165). Hummel and Hlavacs (2003) define *ubiquitous computing* from the learner's point of view as:

a situation in which a multitude of connected and embedded systems and devices work together to build an ambient computing environment... allowing [users] to access learning content from anywhere at anytime, and to communicate with colleagues or lecturers synchronously and asynchronously much more frequently. (p. 6)

In contrast to studies embracing the merits of m-learning, a few have started to address the possible limitations of 'anytime anywhere' learning. Fischer (2002) argues that, when positioned in an information-rich environment, users must cope with the

Table 1. Three classifications of m-learning definitions.

Classifications	Year	Authors	Definition of M-Learning
Functional Components and Communication Style	2000	Quinn*	'Mobile learning is learning through mobile computational devices.'
	2003	Hoppe, Joiner, Milrad, and Sharples	'E-learning [uses] mobile devices and wireless transmission.'
	2003	Chang, Sheu, and Chan	'Mobile learning has three essential elements: the mobile learning device, the communication infrastructure and a learning activity model.'
Mobility	2001	Shepherd	'M-learning is not just electronic, it's mobile.'
	2003	Kynäslähti	'... three different elements for mobility and all of these are valuable to teachers and students whilst they are teaching and learning: convenience, expediency and immediacy.'
Ubiquity	2003	Hummel and Hlavacs	'A situation in which a multitude of connected and embedded systems and devices work together to build an ambient computing environment ... allows [people] both to access learning content from anywhere at anytime, and to communicate with colleagues or lecturers synchronously and asynchronously much more frequently.'

Note: *cited from Seppälä & Alamäki (2003).

critical challenges of, first, having to concentrate on tasks and, second, having to say the ‘right thing’ at the ‘right time’ in the ‘right way’ (p. 5). Hill and her colleagues (2000) have refined the definition of *ubiquitous computing*, characterising it as ‘... the widespread availability of portable, networked technologies which offers an enhanced model of access to computing technologies to provide just-in-time, when-needed computing’ (p. 4). From the aforementioned statements, it can be concluded with rigor that the meaning behind the word *ubiquity* refers not to the idea of ‘anytime, anywhere’ but to ‘widespread’, ‘just-in-time’, and ‘when-needed’ computing power for learners.

To summarise, considering aspects of technologies, functionality, and constraints of anytime anywhere learning, this article proposes an alternative definition of *mobile learning*: ‘In order to benefit from convenience, expediency, and immediacy, mobile learners use ubiquitous computing technologies to learn the right thing at the right time at the right place’.

A conceptual framework of ubiquitous knowledge construction

When reviewing current m-learning studies, researchers have noted that a number of studies treat the issues of the technical design and the development of mobile technologies. Seldom do any of these studies elaborate on learning theories to support m-learning. Hoppe and his associates (2003) state that the simplistic view (of m-learning), which ignores recent conceptions of education and pedagogy, might narrow the focus on learners and become a mechanism directed solely at content delivery. In this case, the letter *m* in the term *m-learning* would no longer refer to the adjective *mobile*, but to *mechanical*. A theory-based framework may provide functional guidelines according to which researchers could carry out initiatives. Also, practitioners may be better informed about the decision-making processes, the problems, and the results to be expected.

This study provides a framework of ubiquitous knowledge construction. As depicted in Figure 3, the components of this framework are organised in a hierarchical fashion starting from the m-learning infrastructure on the bottom (learners and tools),

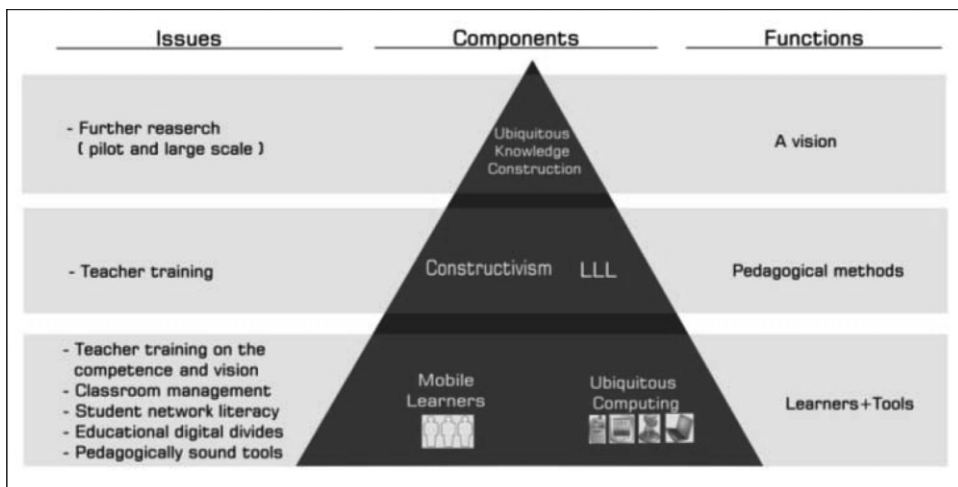


Figure 3. The conceptual framework of ubiquitous knowledge construction.

moving to pedagogical methods (constructivism and lifelong learning theories, or LLL for short), and ending with the vision on the top (ubiquitous knowledge construction). The following section illustrates these components and issues in this framework.

Infrastructure: learners and tools

Learners: the mobile learner

The idea of a *mobile learner* is derived from the term *mobile people* (Hardless et al., 2000). Hardless and his colleagues first use *mobile people* to refer to a condition that characterises people ‘who are either locally mobile, i.e., in an office building and spending most of their working day away from their room, or those people who are truly mobile by not spending more than few moments at anything similar to an office. Their work is distributed in both time and place’ (2000, p. 3). Similarly, Ljungberg and Kristoffersen (2000) state that mobile people are engaged in three typical instances of mobility, including traveling, visiting, and wandering (Ljungberg & Kristoffersen, 2000). That is, mobile people do not participate in traditional ‘competence development activities’. Rather they need alternative forms of competence development in which they can participate in collaborative activities at ‘the time and place of convenience’ (p. 3). Considering the context of educational settings, where learners play a crucial part in learning, this article proposes the term *mobile learner*.

Tools: ubiquitous computing

The co-founder of Intel, Gordon Moore (1965) studied the history of computing technologies and, in 1965, announced a trend line known as Moore’s Law. Moore asserts that computing power doubles every 18 to 24 months, and as a result, the cost of computing is fundamentally halved. Based on such a line of development, Bull and his colleagues (2002) contend with reasonable confidence that the majority of students in public schools (in the United States) will have a portable wireless device (PWD) by the end of the decade or sooner.

Ubiquitous computing consists of wireless networks and mobile devices. While mobile devices are necessary for mobile learning, wireless network technologies, such as wireless LAN (Local Area Network), Bluetooth technologies, GSM (Global System for Mobile Communications), and GPRS (General Packet Radio Service) work together with mobile devices to form the infrastructure of mobile learning. Sharples (2000) has identified the important aspects of mobile learning, including personal mobile technology, software and hardware organisation, and interfaces. Adapting the findings outlined in Sharples’ study, this article reorganises these three important aspects along slightly different lines, thus arriving at the following three aspects: mobile computational hardware, mobile software, and mobile interface.

Mobile hardware. Sharples and Beale (2003) have conducted a technical review of mobile computational hardware. There are six general categories consisting of wrist-worn devices, mobile phones, handheld computers, web PADs, laptop computers, and pen tablet computers.

Mobile software. Pea et al. (1999) and Fischer (2002) provide some insights into both the content and the design of software. Pea and his colleagues ascertained that the

establishing of pedagogically sound software is critical for future ubiquitous learning environments. Pedagogically sound software should include both computer software and learning software that comprise the relevant content, tools, and activities. Referring to the challenges of software technology, Fischer (2002) predicts that, in addition to considering the needs of end-users, we should also 'place the evaluation in the hands of users'. Meanwhile, because humans naturally work in learning and knowledge-building communities, the development of imminent mobile software should encourage the transition from 'reusable to collaborative knowledge construction' in order to make 'sustained knowledge creation' not just possible but likely (p. 5).

Mobile interface. Several articles address principles governing the design of appropriate human-computer interactions for mobile learning. For example, what kinds of hotkeys or reading environments will meet the special needs of learners who are moving? In their analysis of the behaviours of mobile learners, Hummel and Hlavacs (2003) point out the implications of m-learning interface design: '... mobile learning sessions are characterised by short interactions (e.g., asking a question in a chat room), quick information retrieval (e.g., looking up the next meeting date in a physical or virtual class), and working off-line connecting just for uploads from time to time' (p. 7). The design of mobile interface should be intuitive enough so that mobile learners can interact with it in a short period of time.

Relevant issues

A number of issues are associated with mobile learners and the upcoming wave of ubiquitous computing in education, which are educational digital divides, classroom-management issues, issues of network literacy, and the need of building partnership for pedagogically sound educational tools.

Educational digital divides. The digital divide separates those students who are in the wealthier schools from those who are from the poorer ones. However, the hardware digital divide is a temporary phenomenon. As the cost of portable wireless access to the Internet becomes affordable for everyone, the concern will be about the educational digital divide that separates those students who are taught by technology-savvy teachers from those who are not. The development of these ubiquitous computing environments for students presents exciting challenges for teacher education programmes. It seems reasonable to provide programmes or training that focuses on both competencies and visions for both pre-service and in-service teachers. As mentioned by Bull et al. (2002) in their recent study, a substantial challenge facing the entire educational community hinges on the urgent demand that '... educational and development communities should begin planning now for the best uses of ubiquitous computing' (p. 7).

Classroom-management issues. The ubiquitous computing will be a disruptive cultural force that has great potential for good or ill (van Hover, Berson, Bolick, & Swan, 2004). The widespread and applicative character of computing technologies may result in problems for teachers and students. Many problems are essentially related to a lack of student knowledge and skill in the management of computers, as well as to a lack of teacher experience in classroom management. For example, instead of focusing on learning activities, teachers might need to handle frequent

interruptions that are due to students' difficulties with software use or with technical problems in the hardware (Gardner et al., 1994). Moreover, certain problems stem from unreliable mobile communication, such as a loss of connection, different bandwidth variability, heterogeneous systems and devices, possible security risks, lower power supplies, the small storage capacities of portable devices, and so forth (Hummel & Hlavacs, 2003).

Meanwhile, it might be difficult for teachers to monitor the current learning status of each student. With the wireless environment, students might be easily distracted by off-task behaviours. Researchers have found that students browse irrelevant online resources in class, exchange instant messages with others, or play illegal computer games installed in the mobile devices (Newhouse & Rennie, 2001).

The issues of network literacy. As the Internet becomes a primary source of information in mobile learning settings, an increased number of activities are taking place online. The Internet itself is a neutral resource originally designed to facilitate communication. However, the growing obsession with the Internet has also triggered certain negative effects on education. Recently, researchers, school teachers, and parents have become aware that these effects are taking place in high school settings. Issues of network literacy will need to become a priority across disciplines, and educators will need to promote appropriate and safer use of the Internet (Johnson, 2001; Schwartau, 2001).

The need of building partnership for pedagogically sound educational tools. Educators should take a proactive stance towards emerging technology and become integrally involved in the development, as well as the evaluation, of pedagogically sound educational tools. A partnership should be established among schools, corporations, universities, and professional organisations. By becoming involved early in the process, there is a greater chance that hardware and software may meaningfully improve teaching and learning.

Pedagogical methods: constructivism and lifelong learning (LLL)

Not until the last four years have some explorative studies set out to investigate pedagogies for mobile learning. Hardless et al. (2000) employ social constructivism and cognitive apprenticeship to support their ideas on collaborative learning and education for mobile people. Hill et al. (2000) utilise constructivism as a pedagogical model for their ubiquitous computing theory. Similarly, grounded on the idea that human learning is highly situated, Sharples (2000) suggests that the convergence of personal technology and lifelong learning (LLL) may 'empower people to manage their own learning in a variety of contexts throughout their lifetimes' (p. 178). It seems warranted that further investigation of the constructivism and the LLL theories may provide educators with important information about curricula development in relation to mobile learning.

Mobile learning based on constructivism

How do learners construct their knowledge? What knowledge do learners construct? How can technology facilitate knowledge construction? And how can learning be supported by ubiquitous computing?

These questions are often raised in the educational context. The basic tenet of radical constructivism emphasises that the process of knowledge construction is highly individualised, meaning that each learner constructs his or her own representations or models based on his or her prior experiences. Second, constructive learning requires learners to be active and responsible for their learning. Learners need to apply self-regulatory strategies to their learning: they must articulate the goals that they intend to achieve, the decisions that they make, the strategies that they use, and the answers that they find. Third, constructivists believe that a learner tends to internalise outer experience in the form of inner personal meaning. This is the process of knowledge elaboration that requires the reflective and critical thinking skills of learners. Another line of constructivism, social constructivists believe that learning takes place through both collaboration and meaning negotiation in the learning community, sometimes takes the form of conversation among learners.

Jonassen, Peck, and Wilson (1999) argue that ‘meaning making is at the heart of a philosophy of learning called constructivism’ (p. 2). The process of meaning making is also the process of constructing knowledge, either individually or collaboratively. They contend that technology is an intellectual partner, or mindtool, with which to engage and facilitate learners’ thinking and learners’ knowledge construction. Learners should learn ‘with’ technology and use technology as a mindtool that supports active, constructive, cooperative, authentic, and intentional learning.

This study integrates the ideas of mindtool and ‘learning with technology’ into the m-learning context. The characteristics of m-learning seem to correspond with the counterparts of constructivism. For example, the learner-centered approach and the skills required for knowledge construction enable learners to regulate learning and determine useful resources for the elaborating process in their daily lives. Through the Internet, technology can support the conversational process by connecting learners to other learners, whether they are in the same classroom, different cities, or around the world. Therefore, ubiquitous computing technology can be seen as an on-demand learning partner and provide when-needed assistance in the sharing of learners’ cognitive responsibilities.

Mobile learning towards lifelong learning

Several researchers have tried to define *lifelong learning*. Fischer (2001b) states that *LLL* is a learning condition that encompasses ‘more than training’ (p. 3). The broad scope of this definition is rooted in Fischer’s assertion that such learning requires more active participation, more non-mechanisation, more elaboration, and more reflection than learning that is limited to training does. Fischer (2001a) further explains the difference between *LLL* and adult education, pointing out that ‘... lifelong learning is more than adult education or training—it is a mindset and a habit for people to acquire’ (p. 8836). An alternative definition of *LLL* is provided by Thorpe (2000): ‘... its literal meaning suggests it should include the whole of education and training ... and informal as well as formal and non-formal learning’, and thus ‘[*LLL*] is very ubiquitous’ (p. 2). Therefore, *LLL* can be seen as a mindset of learning in a natural, adaptive human process in the course of life.

Waycott (2001) tries to explain how mobile technology can be a useful tool in support of learning and workplace activities. Because of its rather easy methods of communication and of accessing information, together with its lighter and smaller

portable size, Waycott states that the potential uses of mobile technologies render these technologies lifelong learning tools.

Similarly, Sharples (2000) argues that there are similarities between LLL and personal technology, including technology that is individualised, learner-centered, situated, collaborative, ubiquitous, and durable. Fischer (2001a) provides five reasons why LLL requires new technologies and media: (a) the production of pieces of information relevant to the task at hand; (b) the automatic or semi-automatic maintenance of consistency between different representations; (c) the dynamic generation of different external views from one complex internal structure; (d) the creation of links between static descriptions and dynamic behaviour; and (e) the linking of action to reflection spaces. Armed with these five reasons, Fischer suggests that researchers and developers need to create innovative new media and technology to let people experience knowledge in new ways. From both Fischer and Sharples, we can realise the convergent trend of personal mobile technology and LLL.

Mobile learning, constructivism, and LLL

As they were presented in the previous sections, the characteristics of constructivism, lifelong learning, and mobile learning are interrelated. First, Sharples' (2000) study reveals the connections among m-learning, constructivism and LLL. Sharples sets out a theory for 'technology-mediated lifelong learning' that draws from social constructivism. Sharples' ideas support the convergence of constructivism with lifelong learning theories in this ubiquitous knowledge construction framework.

Second, Fischer (2001b) addresses four challenges that confront lifelong learning, such as self-directed learning, learning on demand, informational learning, and organisational learning. The first two concerns are close to those found in radical constructivism, whereas the latter two confirm the principles of social constructivism. Therefore, this study suggests taking constructivism as the theoretical basis for attempts to solve the challenges of LLL.

The vision: ubiquitous knowledge construction

Ubiquitous knowledge construction is a vision for future learning. Mobile learners are the center of knowledge construction. Ubiquitous computing technologies, including mobile devices, wireless networks, and other advanced technologies, are tools with which to erect the infrastructure of ubiquitous computing. By studying theories of constructivism and LLL, educators can better appreciate useful methods that can facilitate learning at the right time at the right place. Constructivism expands the width of ubiquity by taking into account learners' motivation, articulation, collaboration, and reflection in the context of meaningful learning (Jonassen, Howland, Moore, & Marra, 2003). In the meantime, LLL theory increases the depth of ubiquity, which transforms segmental and inactive learning styles into one that, being continuous and relatively coherent, parallels a person's lifespan.

Relevant issues

The grand challenge facing America's schools is 'the empowerment of all children to function effectively in their future, a future marked increasingly with change, information growth, and evolving technologies' (International Society for Technology in

Education, 2002, p. xi). Cutting-edge ubiquitous technology seems to be a powerful tool that can offer learning opportunities to all children so that they can better survive in the twenty-first century – in terms not just of work, communications, and learning, but of life, as well. Before the full-scale implementation of ubiquitous computing takes place in schools, it is vital for teachers, technology planners, teacher preparation programmes, and educational decision-makers to develop a vision that rests on support and proactive leadership. Researchers need to conduct research on the effects of ubiquitous computing in the classroom in order to provide practitioners with informed advice. Further studies are needed to evaluate the potential and the pitfalls of ubiquitous computing in the classroom. The best practices based on this framework may provide guidelines for implementation and evaluation techniques.

Conclusion

Underlying this study has been our intention to redefine *m-learning* in terms of mechanism, learning theories, and the constraints of ‘anytime anywhere’ learning. By connecting m-learning with e-learning, one can see that two main characteristics stand out: mobility and ubiquity. Ubiquitous knowledge construction is a vision for future learning that can be implemented through the essential elements of ubiquitous computing and instructional theories. Several issues associated with m-learning are mentioned along with each component.

It is our intention that this construction framework, first, provide fellow researchers with an important lens that illuminates both the pronounced shapes and the subtle contours of mobile learning. Second, we hope that this framework assists researchers who are examining the specific implications of associated issues in education. Future studies based on this study may develop curricula in accordance with ubiquitous knowledge construction theories, together with concrete implementation and evaluation guidelines.

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Notes on contributors

Hsinyi Peng is a research fellow of the Institute of Education at the National Chiao Tung University in Taiwan. Her research interests centre around the design and development of online learning environment for meaningful technology integration into various educational settings, particularly in the teacher-education context.

Yi-Ju Su is the chief of information technology and a teacher of Hsinchu Zhun Guang Junior High School in Taiwan. Her research interests include Internet ethics and mobile learning.

Chien Chou is a professor of the Institute of Education at National Chiao Tung University in Taiwan. Her research interests include information literacy, ethics, and characteristics of net generations in e-learning contexts.

Chin-Chung Tsai is currently a chair professor at National Taiwan University of Science and Technology, Taiwan. His research interests deal largely with constructivism, epistemological beliefs, Internet-based instruction, and human behaviour in Internet environments.

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