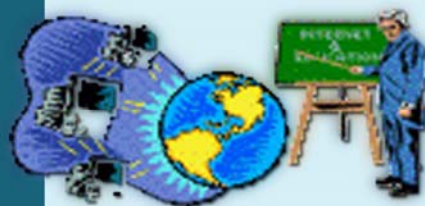


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Aims and Scope

Educational Technology & Society is a quarterly journal published in January, April, July and October. *Educational Technology & Society* seeks academic articles on the issues affecting the developers of educational systems and educators who implement and manage such systems. The articles should discuss the perspectives of both communities and their relation to each other:

- Educators aim to use technology to enhance individual learning as well as to achieve widespread education and expect the technology to blend with their individual approach to instruction. However, most educators are not fully aware of the benefits that may be obtained by proactively harnessing the available technologies and how they might be able to influence further developments through systematic feedback and suggestions.
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The aim of the journal is to help them better understand each other's role in the overall process of education and how they may support each other. The articles should be original, unpublished, and not in consideration for publication elsewhere at the time of submission to *Educational Technology & Society* and three months thereafter.

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Guest Editorial – Innovations in Designing Mobile Learning Applications

Yueh-Min Huang¹, Wu-Yuin Hwang² and Kuo-En Chang³

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This special issue aims at giving readers several innovative ideas of designing mobile learning applications. Recently the rapid growth of mobile technologies has leaded e-learning to a new era. Mobile devices become more powerful, portable and convenient to accompany users anytime anywhere in the daily life, resulting in that the applications for mobile devices have been widely utilized at schools, workplaces and daily life. Innovative design of mobile learning applications can facilitate users not only studying learning contents conveniently but also interacting with others collaboratively anytime and anywhere. With these features, mobile learning application will become indispensable for those learners owning hand-held devices at hand. Furthermore, with the advanced technologies like GPS, RFID or sensors, mobile devices also provide context-related opportunities for users to enjoy their personal moment or explore their surrounding context from wherever they may be.

Review study

Mobile device applications bring a great amount of convenience for not only learners but also educators. Therefore, how to utilize these strengths well become important, and using the appropriate strategies is one of the major issues. The first paper entitled “The Add-on Impact of Mobile Applications in Learning Strategies: A Review Study” written by Yu-Lin Jeng, Ting-Ting Wu, Yueh-Min Huang, Qing Tan and Stephen J.H. Yang investigates the add-on impact of mobile applications in learning strategies and also identify and discuss the significant characteristics of mobile learning.

Mobile learning definition in higher education

Generally, many researchers have defined mobile learning from different dimensions. Mobile learning has one assumption that learners can move continually with mobile devices and possible wireless connection. Mobile devices also could provide meaningful assistance to users’ work, study and entertainment. For education, the context, learning process and the outcomes should be considered with an extension to the outside of the classrooms or lecture halls. The paper “Defining Mobile Learning: Redesign Higher Education Landscape” written by Mohamed Osman M. El-Hussein and Johannes C. Cronje attempted to interpret the meaning of mobile learning in higher education by applying mobile concepts and characteristics as various elements of the mobile learning experience.

Mobile device applications on knowledge management and learning enhancement

Jane Y-K Yau and Mike Joy study the approach of using dairy to record users’ learning contexts in m-learning application; because that learning contexts in dairy are significant and helpful for selecting appropriate learning materials to users in their paper entitled “A mobile context-aware framework for managing learning schedules – data analysis from a diary study”.

Providing the advanced mobile device application on education not only create a better learning environment for students but also enhance their learning motivation. Nevertheless, teachers know more about what students think during their learning process, they can assist more on learners’ difficulties and then to improve their learning. Pi-Hsia Hung, Yu-Fen Lin and Gwo-Jen Hwang proposed a formative assessment design for integrating PDAs into ecological observations. In the study, PDAs were used as a cognitive tool to provide guidance, information and feedback relevant to the outdoor learning tasks.

In the science curriculum, kinematic graphs are vital but challenging. Many misconceptions may occur when students are learning the kinematic graphs. Simon Wood and Pablo Romero in their paper entitled “Learner centered design for a hybrid interaction application”, delineate the design process of Move Grapher, which is a GPS-enabled, mobile learning application to support the teaching and learning of kinematic graphs.

Yu-Ju LAN, Ning-Chun Tan, Yao-Ting Sung, Chiu-Pin Lin, and Kuo-En Chang built an estimation instruction scenario using the mobile technology to facilitate students’ strategies of discussion, cooperation and computational estimation skills in their paper entitled “Mobile-Device-Supported Problem-Based Computational Estimation Instruction for Elementary School Students”.

In the paper entitled “User Acceptance of Mobile Knowledge Management Learning System: Design and Analysis” written by Hong-Ren Chen and Hui-Ling Huang, proposed a mobile knowledge management learning system for learners to acquire, store, share, apply and create knowledge. By integrating mobile knowledge management into practical teaching activities, learners can develop their knowledge management and problem solving abilities.

Mobile computer supported collaborative learning

Jeff J.S. Huang, Stephen J.H. Yang, Yueh-Min Huang and Indy Y.T. Hsiao attempt to propose a collaborative service mechanism and an analysis mechanism to improve mobile collaboration. The aim of this paper, “Social Learning Networks: Build Mobile Learning Networks Based on Collaborative services”, promotes Internet-based informal collaboration over CSCW and MCSCL by exploring the plausibility of providing system-level support and services for forming collaborative groups dynamically.

Mobile device applications on language learning

Shu-Chen Cheng, Wu-Yuin Hwang, Sheng-Yi Wu, Rustam Shadiev and Ching-Hwa Xie in their paper entitled “A Mobile Device and Online System with Contextual Familiarity and its Effect on Campus English Learning” explored how context-familiarity using multimedia and GPS can help students learn campus English as second language and designed a mobile system to facilitate their collaboration of English learning both in class and on campus.

Language learning has always been a trend around the world and people with good language ability may benefit their communication in their study, workplace and daily life. Mobile device application can facilitate learners’ language learning with authentic context support and retrieve digital information in the Internet as well. Tim de Jong, Marcus Specht and Rob Koper explored how mobile media delivery can affect language learning by comparing two context filters and four content selecting methods in their paper entitled “A study of Contextualized Mobile Information Delivery for Language Learning”.

The Add-on Impact of Mobile Applications in Learning Strategies: A Review Study

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ABSTRACT

Mobile devices are more powerful and portable nowadays with plenty of useful tools for assisting people handle daily life. With the advance of mobile technology, the issue of mobile learning has been widely investigated in e-learning research. Many researches consider it is important to integrate pedagogical and technical strengths of mobile technology into learning environments. This review study focuses on the investigation of add-on impact of mobile applications in learning strategies. We surveyed recent researches including context awareness, pedagogical strategy-enhanced learning scenarios, as well as collaborative and socially networked mobile learning. Through this review study, essential characteristics of mobile learning were identified and discussed. With the essential characteristics, we emphasized on the add-on impact of mobile learning and elaborated mobile learning model in learning strategies.

Keywords

Mobile devices, mobile learning, ubiquitous learning, pedagogical strategies

Introduction

The advance of mobile technologies have turned handheld devices a part of people's daily life, such as in communication and entertainment. Meanwhile, educators strive to facilitate learning by applying mobile technology and appropriate learning strategies. Nowadays mobile devices, such as smart phones, have equipped with location information receiver, camera, RFID reader, and other environmental awareness sensors. These can provide rich and interactive multimedia learning content for educational purpose. In addition, appropriate learning strategies can help educators facilitate mobile learning process and achieve their educational goals.

Most of previous work about mobile technologies has been focused varied strength to emphasize the assistance in mobile learning activity. In this review study, we take more practical points of view to describe how mobile technologies facilitate mobile learning activity. The advanced mobile technology provides users with two important features in recent mobile learning research, situated context and ubiquitous mobility. Ubiquitous mobility has been considered and implemented in several researches in recent years (Sharpley Beale, 2003; Joiner et al., 2006; Fallahkhair, 2007). With ubiquitous mobility, students can facilitate learning activity in the outside world and connect to other peers by connecting to network. Mobile technologies offer rich content of mobile learning and deliver information effectively for students during their learning activities. The feature of mobility also makes mobile learning become more and more distributed (Chang et al., 2003; Corlett, et al., 2005; Clough, 2008). Situated learning is one of mobile learning applications (Hall & Bannon, 2006; Morken, et al., 2007; Lai, et al., 2007); it is the learning that takes place in the context corresponding to the learning materials. Situated learning provides learners with authentic learning examples which suit the learner's learning context. With mobile situated learning system, learner can acquire the context-aware learning materials to enhance their learning experience. Table 1 shows the benefits of added equipment on mobile devices. Museum guide system is an extension application of mobile situated learning system. Giuseppe et al. (2009) propose a location-aware, multi-device museum guide system which integrates various types of games and context-dependent information. The proposed system help improve the visitors' experience by extending their interaction with exhibits. This kind of informal learning may draw more attention from mobile learners. Handheld devices have been deployed as learning tools in both formal and informal learning contexts. Clough et al. (2008) investigate how experienced users of mobile devices use their mobile devices to support intentional informal learning. The results show that mobile devices are used extensively in an informal learning context by mobile learners. Also, they use mobile devices in ways that correspond to the collaborative,

contextual and constructivist mobile learning activities. Moreover, the embedded GPS receiver built into the mobile devices brings new applications and opportunities to trigger content or action relevant to the learning context. This feature also causes the improvement in mobile situated learning process.

Table 1. The benefits of added equipment on mobile devices

Added equipment on mobile devices	Description	Objective
Wireless network connection	Provide the connection between mobile devices and Internet.	To communicate with remote application server which can bring the context based learning information for mobile learner in situated learning environment.
Embedded Camera	Enable the capture of current environment in mobile learning activity.	To upload the picture of current environment on the application server. With collaborative effort of mobile learners, the picture can draw discussion and comments which provide situated knowledge.
Embedded GPS receiver	Provide the current coordinate of the mobile device.	To monitor the position of mobile learner and provide location-based authentic learning materials.
Additional RFID reader	Connect to RFID tag and receive the information.	To retrieve the information corresponding to current learning activity and bring benefit in situated learning environment.

From the pedagogical aspects, mobile learning offers context of authentic learning materials in the learning activities. Therefore, the pedagogic strategies can be utilized in mobile learning activities through the advanced mobile technique. Collaborative and cooperative mobile learning activities facilitate mobile technique as the learning tools (Lundin & Magnusson, 2003; Ng, et al., 2005; Järvelä, et al., 2007; Huang, et al., 2008 & 2009). Yang (2006) constructed three systems in the context aware ubiquitous learning environment, which include peer-to-peer content access and adaptation system, personalized annotation management system, and multimedia real-time group discussion system. In that environment, researcher utilized the effective and efficient advantage of ubiquitous learning to design the strategy of peer-to-peer collaborative learning to the learners. The author addresses the newly concept of collaborative activity can fully support the needs of peer-to-peer collaborative learning.

Situated context and ubiquitous mobility are important features when developing the educational mobile activities. The add-on impact of mobile application in learning strategies will also put emphasis on the two features. This study is organized as follows. In literature review, we collect recent researches focusing on technology and pedagogy supported mobile learning examples in facilitating mobile learning process. In the third part of the study, the essential attributes of mobile learning will be summarized to emphasize the add-on impact of mobile technology in learning strategies. We conclude this study by reflecting impact and learning models associated with mobile learning in education.

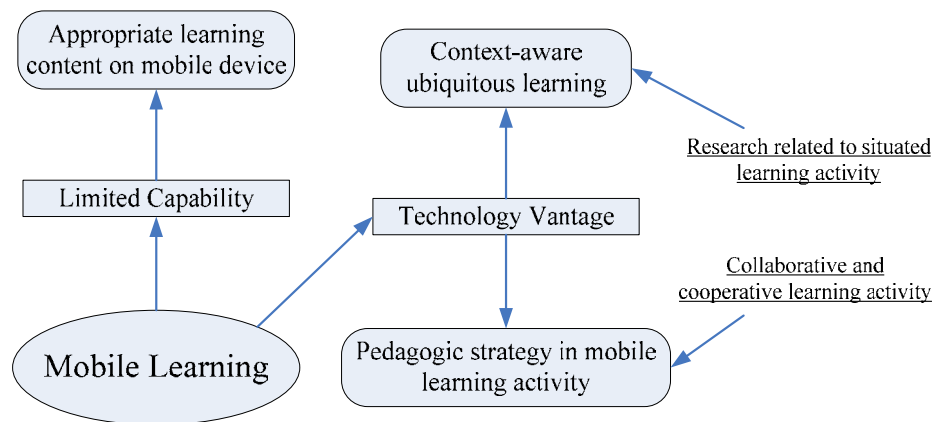


Figure 1. Architecture of the literature review

Literature Review

Figure 1 shows the architecture of this literature review. Firstly, in order to deliver the appropriate learning content on mobile devices, some researches focus on the adaptive content investigation. Moreover, right learning content corresponding to mobile learner's context is more important than a transparent learning content. Then, the pedagogic strategy in mobile learning activity is illustrated and investigated.

The rapid development of wireless network technologies and various mobile products have enabled people to conveniently access the information resources anytime and anywhere without constraints of time or place. The advanced available technologies, such as high bandwidth wireless communication networking infrastructure, wireless technologies, and advanced handheld devices, have extended online learning modes from E-learning to M-learning, in which learning objects have started to extend traditional learning manner towards widely used in daily life for various purposes (Sharples, 2000). However, mobile devices for learning are limited by screen size, computational power, battery capacity, input interface and network bandwidth (Chen, Chang, & Wang, 2008). Thus, how to adapt information for delivery to mobile devices has become a critical issue in mobile learning environment. To address this concern, many researchers have investigated the issue in different ways and have proposed several solutions (Gaedke et al., 1998; Goh, Kinshuk, & Lin, 2003; Huang & Sundaresan, 2000; Lemlouma & Layaïda, 2003). Yang, Chen, & Shao (2004) developed a universal access mechanism which can provide a transparent and seamless browsing experience of adaptive content based on XML/RDF, CC/PP, and UAProf techniques. Besides, content server can create adaptive multimedia content used on Dublin core/MPEG-7 and SMIL for multimedia content description and composition. Lemlouma and Layaïda (2004) proposed the system using the XQuery language and delivering the SOAP services to achieve automatic adaptation of the content based on its semantic and the capabilities of the target device. Zhang (2007) proposed several perspectives to discuss the web content adaptation for mobile devices. Huang, et al. (2008) utilized Fuzzy Weighted Average (FWA) algorithm to design a context-awareness synchronous learning system. The proposed manner provides various content styles to make learning contents appropriate to be displayed on diverse learning devices.

Recently, the concept of context-aware ubiquitous learning has been further proposed to allow students learning with variety of mobile devices and facilitate a seamless ubiquitous learning environment (Chang, Sheu, & Chan, 2003; Sakamura & Koshizuka, 2005; Rogers et al., 2005), which learning situation focuses on emphasis the characteristics of learning at the right time and right place with right resources in the right ways and conducts real-world learning activities with adaptive supports from the learning system (Hwang, Tsai & Yang, 2008; Peng et al., 2009; Yang, 2006). In order to achieve context-aware and seamlessly learning environments, some ubiquitous computing technologies and devices were usually utilized to detect or sense users' context information, such as RFID, GPS, specific sensors, contact-less smart cards, wearable computers, and wireless communications. (El-Bishouty, Ogata & Yano, 2007; Hwang, Tsai & Yang, 2008). The acquired context information was not merely used to identify learners' situations but also utilized to support personalized learning guidance. Through physical integration, students can learn physical materials in the real world and conduct authentic activities based on learner-centered and situated learning pedagogies (El-Bishouty, Ogata, & Yano, 2007; Hwang, Tsai, & Yang, 2008; Shaw, Turvey & Mace, 1982; Young, 1993). For example, Chen, Kao, & Sheu (2003) constructed a mobile scaffolding-aid-based bird watching learning (BWL) system which provides cognitive tools to support outdoor nature and science education afforded by mobile personal digital assistants. Chen, Kao, & Sheu (2005) developed a mobile butterfly watching learning system which supports independent learning and outdoor learning based on a wireless network, data mining technologies and using PDAs. Yang (2006) constructed three systems and utilized the effective and efficient advantage of ubiquitous learning to design the strategy of peer-to-peer learning model to the learners. El-Bishouty, Ogata, & Yano (2007) proposed the Knowledge Awareness Map which provides personalized learning condition to the students according to their current need and location and recommends the best matched materials according to learner's current task and current location. Tan, Liu, & Chang (2007) developed an Environment of Ubiquitous Learning with Educational Resources (EULER), which allow students observing real learning objects and sharing learning experiences to each other. Chen & Hsu (2008) proposed a personalized intelligent mobile learning system which utilized the fuzzy Item Response Theory presenting the appropriately English news articles and suitable vocabularies to the learners. Hwang et al. (2009) developed a context-aware u-learning environment to assist inexperienced researchers in learning single-crystal X-ray diffraction operations, and used the knowledge-based systems developed for instructing the learners based on the contexts sensed in the real learning environment. Peng et al. (2009) proposed a Ubiquitous Performance-Support System which combines digital and physical resources and

the manner of data-driven decision making to assist with administrators and educators for understanding the perceptions of experts and students.

In addition to the integration of suitable software and novel mobile technologies, how to combine appropriate pedagogical strategy for enhanced learning application was another critical important issue in mobile learning environment. Some of the studies proposed the navigation mechanism and intelligent tutoring system supporting suitable tutorial strategies for students increasing learning opportunities (Ghiani et al., 2009; O'Grady, O'Hare, & Sas, 2005; Pianesi et al., 2009; Virvou & Alepis, 2005). Moreover, the high interaction strategy was proposed to use for promoting social interaction and enhancing user experience in several studies (Hourcade & Berkel, 2008; Paterno & Santoro, 2003; Wessels et al., 2007). Collaborative and cooperative learning are generally the first method chosen in mobile learning environment. Collaborative and cooperative learning is based on the constructivist theory which prompts students to learn by doing and construct knowledge for themselves (Schunk, 1996), and that pedagogical strategies have been widely applied in mobile learning activities (Dearman, Hawkey, & Inkpen, 2005; El-Bishouty, Ogata & Yano, 2007; Huang, Huang, & Hsieh, 2008; Huang, Jeng, & Huang, 2009; Lundin & Magnusson, 2003; Patten, Sa'nchez, & Tangney, 2006; Yang, 2006). Besides described above, Peng et al. (2009) proposed the approach of data-driven decision making as a mindtool which should facilitate critical thinking and higher-order learning by adapting to the learners. Zurita & Nussbaum (2004) developed a constructivist learning environment by providing each child with a share of the necessary information to accomplish the educative activity goal. Chen, Kao, & Sheu (2003) utilized the method of scaffolding which can enhance comprehension, improve independent learning and application, and promote knowledge transfer. The main research applications of situated learning and ubiquitous learning have been discussed in this paragraph. The next section will discuss the essential attributes of mobile learning then conclude the researches.

Essential Attributes of Mobile Learning

Learning through mobile devices is the trend of digital learning field. Generally, learning that happens on any pervasive computing devices can be referred to mobile learning. Therefore, mobile learning includes portable technologies and mobile contexts in mobile learning society. This section describes the add-on impact of mobile learning based on four dimensions as shown in Figure 2. The four dimensions are situated learning environment, virtual group awareness/strategies, enhanced pedagogical learning process and mobile learner/coacher.

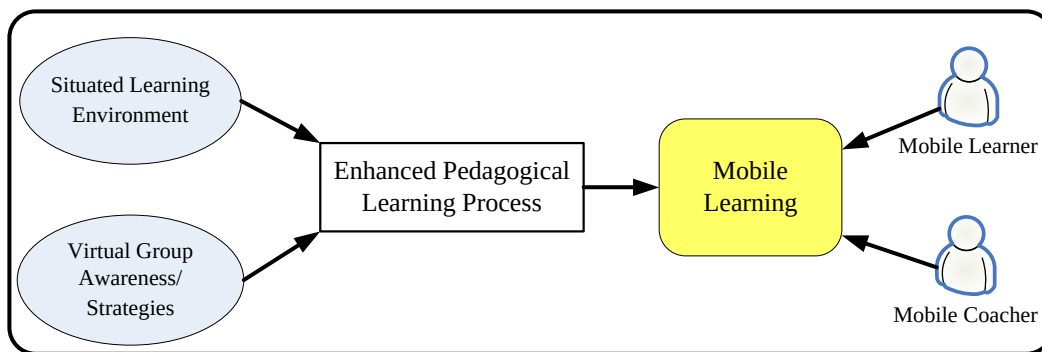


Figure 2. Essential attributes of mobile learning

Mobile learner and coacher

The advance of pervasive technologies brings opportunities for educators to design interactive learning activities. Such environment encourages learners to utilize the learning tools and explore the knowledge (Price, & Rogers, 2004; Monahan, et al., 2008). Learners can learn the knowledge and access the information anytime and anywhere without too much additional efforts. In mobile learning process, learners' learning portfolio will be recorded and the relevant information around learners will be tracked in mobile applications. Accordingly, the authentic learning materials or the appropriate contextual learning content will be provided according to the learner's learning context. The mobile application needs feedback from learner to provide personalized learning suggestions. The mobile

learning system is adaptive to the mobile learners, which can offer right learning content in right places to right learners. The mobile learning scenario to mobile learners should be natural without carrying additional devices.

The mobile coacher could be a mobile application agent or a real lecturer who guide learners to problem solving in mobile learning activities. Mobile learning applications are expected to offer learners the sharing of their learning portfolio, learning context, and learning feedback to their mobile coacher. After receiving the relevant learning information of learners, mobile coacher can provide adaptable personalized learning contents and suggestions. Besides, the mobile coacher scaffolds the learning assists according to learner's ability and learning progress in their learning activities. The mobile coacher is expected to monitor learners' needs and provide them with appropriate aid in the learning activity.

Enhanced pedagogical learning process

Mobile learning is diverse from traditional electronic learning, thus the conventional pedagogical theory should be revised to fit the characteristics of mobile environment. The enhanced pedagogical learning process is utilized to facilitate the learning in mobile learning activities. For example, blog articles were applied to construct a learning map called blog-based dynamic learning map (Wang et al., 2008). It is designed to provide informative and structured blog articles to assist students' learning. Therefore, a collaborative learning process can be facilitated by utilizing a mobile blogging system (Huang et al., 2009). In this mobile collaborative learning process, the blogging system is employed as a data collector and an information sharing platform for mobile learners. A revised pedagogical learning process associated with mobile technology has formed the pedagogical foundations of mobile learning. Chen, et al. (2003; 2008) have designed mobile application system for modeling, coaching and scaffolding the authentic activities and faded the support during the mobile learning process. They facilitate collaboration and support some of the social practices associated with learning. Therefore, the traditional pedagogical theory can take advantage of mobile technology and bring more efficient learning process to mobile learners. The combination of collaborative, contextual, constructionist and constructivist principles should be derived from augmented pedagogical learning process.

Situated learning environment

Mobile technologies gradually facilitate and enhance learners' interaction by means of accessing, discussing and sharing associated information through social networks. A situated learning environment aims to contextualize learning activities by enabling the learners to interact appropriately with their environment (Patten, et al., 2006). The advanced function of mobile devices make it possible for detecting learner's learning environment by embedded mobile sensors. Yang, (2006) proposed a context aware ubiquitous learning environment to provide contextual information and support peer-to-peer collaborative learning. The mobility, communication features and computational capacity of handhelds provide learners with authentic learning activities by simulating a situated learning environment. In cognitive apprenticeship, knowledge is situated within authentic activities and taught through interaction with instructors (Brown et al., 1989). Therefore, a vivid learning interaction with the environment makes the add-on impact of mobile learning in situated learning environment.

Virtual group awareness/strategies

Various studies (Danesh, et al., 2001; Inkpen, 1991; Mandryk, et al., 2001) describe the benefit for bringing mobility, and portability to face-to-face CSCL environments when students are wirelessly interconnected by handheld devices. Zurita, Nussbaum, & Salinas, (2005) proposed dynamic grouping methodology which is like re-composition group members during the collaborative activity. The results let future research understand which group composition should be favored in a given set of circumstances. Therefore, the member of virtual group should be deployed in particular given learning context to facilitate learners engaging in the learning topics. Uzunboyly, et al. (2009) investigated the use of integrating mobile telephones, data services to increase students' use of mobile technologies and develop environmental awareness. The result of grad analysis was found that students had more positive attitudes toward environmental issues. With the development of mobile applications, virtual group

awareness can be emphasized and augmented. This improvement in mobile learning draws more opportunities in utilizing pedagogical learning strategies.

With the integration of the four attributes, a mobile learning activity would be sturdy in perspective of learning model. A mobile learning environment should have learner and coacher combined with enhanced pedagogical learning strategies. To address the mobility in mobile learning, the technologic advantages should be valued. The situated learning environment utilizes the strength of mobility and brings context awareness learning materials for mobile learner and coacher. In this environment, mobile learner can have the awareness of group membership which could increase the learning motive or improve the learning efficiency.

Conclusions and Discussions

This review study focused on pedagogical learning strategies applied in mobile learning environments. Through the survey of recent researches on mobile learning, we investigated the add-on impact of mobile applications in learning strategies and concluded the following observations.

Mobile technology brings the impact of mobile learning on traditional pedagogical learning strategies. The mobile learning model emphasized on mobile users, learning strategies, situated environments, and virtual group awareness. The advance of mobile technology assists the development of “situated classroom” which is an augmented knowledge context environment pertaining to learners’ daily life. The situated classroom is able to convey information between learners and coaches while the learning strategies are deployed. With the enhanced pedagogical learning strategies, learners obtain skill and knowledge in situated classroom. Many currently available mobile learning applications highlight the mobility, ubiquitous computing, and portability features to facilitate learning process by utilizing those features. Nevertheless, a more important issue is to rationalize the customized mobile learning applications in the proposed pedagogical learning strategies. Mobile technology does not aim to complicate learning process but facilitate mobile learners’ learning process. To create new innovative learning opportunities, one needs to take into account the usability and the rationality. We believe that the appropriate application of mobile devices is to be developed in the combination of appropriate use of mobile technology and enhanced educational underpinning.

Future studies with the support of mobile technology could be directed towards the integration of learning strategies and emerging mobile sensor technology. More and more mobile devices in the future will be equipped with sensors and accelerometers which mean the track of mobile learners will be more precise. Combine the personal learning portfolio with physical learning behavior would bring new issues in the field of mobile learning.

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Defining Mobile Learning in the Higher Education Landscape

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ABSTRACT

The article seeks to clarify the meaning of mobile learning by applying its key concepts to learning experiences in post-school education. In other words, it seeks not to discuss one fixed meaning of mobile learning but to disassemble the basic components and provide an interpretation of the model in the context of higher education. The article argues that in order to comprehensively understand and define mobile learning, we should from the outset separate its key components and arrange them under three different concepts. The first concept relates to the mobility of the technology. The second concept hinges on increased learner mobility. The third concept examines the mobility and dynamism of the learning processes and the flow of information. The article concludes that knowledge in the modern world is transformed by the development of revolutionary technologies in society.

Keywords

Mobile learning, Mobility, Mobile technology, Mobile learner, Design, Instruction, Higher education, E-learning

Introduction

The evolution of handheld portable devices and wireless technology has resulted in radical changes in the social and economic lifestyles of modern people. Today, many technological devices are produced in portable form and people have become accustomed to them. These devices are reshaping users daily lives in different ways. But the development of digital technologies has so far been limited to social communication and few people have regarded mobile learning as a core pedagogical activity in higher institutions of learning. Although this model has been used as a minor adjunct to learning activities such as lectures and assignments, it is still not the primary mode of delivery in higher education. Currently, the instructional technology transmitted by means of mobile technology is mainly social and, to a lesser extent, economic.

Advanced mobile devices such as “smart” cellular telephones are very popular among people primarily because they are wireless and portable. These functionalities enable users to communicate while on the move. The popularity of these devices is therefore a consequent of their ability to function at multiple levels. Moreover, the intense commercial competitiveness in the mobile device industry is forcing manufacturers to be very innovative, constantly striving to introduce new features that can give them a competitive edge.

Against this backdrop, visionary educators, designers and developers should begin to consider the implications of these devices for the modern teaching and learning environment. In such an environment, contents and services can be relayed to a university student by personal wireless mobile devices. This will add another layer to the personal computer-based model of teaching and learning. This also means e-learning will take place in conditions that will be radically different from those educators and learners are familiar with. Providing university students with services, content instruction and information outside the traditional learning space is becoming more acceptable among education providers who predicate their services on the routine use of advanced information and communication technologies.

This article seeks to provide a comprehensive definition of mobile learning and attempts to understand why actual learning practices are changing very rapidly while the learning theories that support educational practices are not. To find viable answers, the article will describe the different components of mobile learning that reflect on the increasing mobility of learners, learning and learner technology.

The emergence of revolutionary technologies has had a significant impact on educational technology. It has increased the potential of e-learning as a mode of delivery in education. By definition, mobile learning (or “m-learning”) is learning by means of wireless technological devices that can be pocketed and utilised wherever the learner’s device is able to receive unbroken transmission signals (Attewell & Savill-Smith, 2005). For example,

Laouris and Eteokleous (2005) have reiterated the need for a definition of mobile learning that takes into account all the aspects of the mobile learning process Nyir (2002) has also contributed to a philosophy of mobile learning that relies on Dewey's insights into democracy and education. Nyir and his contemporaries argue that mobile devices are responsible for undermining and, in many cases, eliminating the fixity of traditional classrooms such as lecture halls, laboratories and all the paraphernalia of traditional education. For decades, these traditional spaces have depended on static models of communication and devices for subject delivery. Significantly, mobile devices are revolutionary because they transcend the boundaries of the structural stasis of classrooms and lecture halls and their associated modes of communication – they do not have to be confined to one particular place in order to be effective.

Research method

The purpose of this article is to reflect on and understand the position of mobile learning in higher education. It also hopes to develop a succinct definition applicable in the context of university and college education. The bulk of this article is primarily an analysis of the literature about mobile learning. It sets out to critically examine a selection of documents that relate to mobile learning. These documents consist of conferences proceedings, journal articles, reports, projects and pilot studies of mobile learning projects. Nieuwenhuis (2007, p. 82) shows how such texts can shed some light on the phenomenon under investigation. It was therefore necessary to read and reflect on all these documents, to draw conclusions about issues around mobile learning. This approach allowed the authors to identify relationships and connections between the ideas and information from the literature, and explicate existing relationships between theory and practice in the field of mobile learning.

In order to identify the appropriate body of literature in this field, we conducted an online search of the international journals that are devoted to research on mobile learning. The most important of these resources are described in Table 1.

Table 1: Results of a web search to find the most important resources on mobile learning

Name of resources	Rationale	URL
Journal of educational technology and society	ET & S deals with research on knowledge in the modern world and how it is transformed by the development of revolutionary technologies in society.	http://www.ifets.info/others/
International Journal of Interactive Mobile Technologies (IJIM)	(iJIM) describes the most recent trends and research outcomes and presents the various aspects of interactive mobile technologies.	http://www.online-journals.org/index.php/i-jim
International Journal of Mobile Learning and Organisation (IJMLO)	(IJMLO) is a refereed, multidisciplinary journal which publishes research on the latest changes in mobile learning	http://www.inderscience.com/browse/index.php?journalCODE=ijmlo
International Journal of Mobile Communications (IJMC)	(IJMC) focuses on the international scope of overcoming cultural and national barriers. It also publishes articles on the accelerated rate of technological changes in the global economy.	https://www.inderscience.com/browse/index.php?journalID=40
The Conference Proceedings of MLEARN 2004	The theme of this conference was “Learning anytime everywhere”	http://www.mobilelearn.org/mlearn2004/

Most of the articles in these academic journals and conferences capture research evidence on the practicalities of mobile learning. The papers were selected based on the extent to which they have succeeded in explaining and describing how mobile learning is growing in visibility and how it is acquiring an incremental importance in higher education practice throughout the developed world (Traxler, 2007).

After selecting the appropriate articles, they were analysed by tabulating the various themes and sub-themes as mobile technology, nomadic learner and mobile learning addressed by each article. Common themes were then clustered and these clusters were used as the structuring themes of this article.

A conceptualization of mobile learning

The first step to research edification is to explore the wider context of mobile learning.

Mobile learning as an educational activity makes sense only when the technology in use is fully mobile and when the users of the technology are also mobile while they learn. These observations emphasise the *mobility* of learning and the significance of the term “mobile learning”. Traxler (2007) and other advocates of mobile learning define mobile learning as wireless and digital devices and technologies, generally produced for the public, used by a *learner* as he or she participates in higher education. Others define and conceptualise mobile learning by placing a strong emphasis on the *mobility* of learners and the *mobility* of learning, and the experiences of learners as they learn by means of *mobile* devices.

The two terms under consideration in this article are therefore *mobility* and *learning*. On the one hand “mobility” refers to the capabilities of the technology within the physical contexts and activities of the students as they participate in higher learning’s institutions. On the other hand, it refers to activities of the learning process, the behaviour of the learners as they use the technology to learn. It also refers to the attitudes of students who are themselves highly mobile as they use mobile technology for learning purposes.

Traxler (2007) writes: “so, mobile learning is not about ‘mobile’ or about ‘learning’ as previously understood, but part of a new mobile conception of society”. Research and reflections on mobile learning should stimulate multidisciplinary and interdisciplinary thinking and methods in education. They should facilitate our understanding of outdated concepts and rigid assumptions about learning and what it may be in a society that has changed (at least from a technological point of view) out of all recognition in the past few decades.

In this sense, it is impossible to attribute one fixed meaning to the concepts of mobile learning. To fully understand this concept, it is critical to consider the relationships between each of the words used to describe the phenomenon of mobile learning. The use of this premise to understand mobile learning presents an enormous challenge because there are many words and terms, which have been used to define and explain mobile learning as a phenomenon.

For example, Laouris and Eteokleous (2005), conducted a Google search in January 2005 by using the formula {+ “mobile learning” + definition} – and the search produced 1,240 items. When they repeated the same search at end of June 2005 - only six months later, it produced 22,700 items.

To this end, the way in which the responses of previous search are understood will depend on who is asking a question; why they are asking it and the context in which question is being posed. It also depends how the concepts contribute to the total meaning and understanding of the phenomenon. This means different people mean different things when they use the terms “mobile learning”.

Traxler (2007) notes that there are some definitions and understandings of mobile education, which focus only on the technologies and hardware, whether it is a handheld and mobile device such as personal digital assistants (PDAs), Smartphones or wireless. These definitions undermine a proper understanding of the uses of mobile technology in learning by confining their explanations and descriptions to the actual physical way in which the technology operates. Other definitions place more emphasis on what learners experience when they use mobile technologies in education, while others inquire how mobile learning can be used to make a unique contribution to the advancement of education and other forms of e-learning.

Mobile learning values and defends in its own unique way the introduction of what is radically new in the technological, social and cultural spheres of human life and activity. We argue that human beings are obsessed by the desire to change, to explore, to learn, design and to introduce what is absolutely new into the framework of past conventions and protocols. Mobile learning opens our minds to the possibility of a radically new paradigm and encourages us to abandon the constraints of our habitual ways of thinking, learning, communicating, designing and reacting.

This argument provides a strong theoretical framework for understanding how *mobility* and *learning* are manipulated in design paradigms. However, the pedagogical view of collaborative learning can be regarded as the theoretical fundamental of design perspective and technology also supports the design view of the system. After students

manipulate the mobile blogging system in a learning activity, the use of collaborative and technological perspective should be observed in the experimental process which can further influence the design aspect by evaluating the learning effect of students (Huang, Jeng, & Huang, 2009).

Traxler (2007, 1) again cautions that “the role of theory is, perhaps, a contested topic in a community that encompasses philosophical affiliations from empiricists to post-structuralists, each with different expectations about the scope and legitimacy of a theory in their work”. If we are to place the phenomenon of mobile learning within the context of the theories of instructional design, we need to “break down the walls to open up new spaces” (King, 2006, p. 171). This means examining some of the foundational assumptions and presuppositions on which all previous understandings of the term “higher education”, or post-school education, are constructed. By using mobile communication devices to deliver higher education content, we are likely to reduce the physical walls of the classroom and replace them with other virtual barriers or constraints. However, it would support just in time learning and training in higher education context and “the results showed a significant correlation between planning and model quality, indicating an overall positive effect for the support tool” (Järvelä, Näykki, Laru & Luokkanen, 2007, 73).

While the content of the education may remain the same, it is delivered by means of a radically new technology that combines the advantages of the Internet as a convenience of portability and education “at any time and in any place”. King (2006, p. 171) highlights how radically different the procedures connected with mobile learning are, when he writes: “by breaking down the assumptions and process behind writing and speaking, we can go beyond them and find new ways of thinking about the world”.

The advent of the technology has created new signs, new ways of writing and receiving information, and new ways of transmitting video clips. These activities are rendered new and unique by a similar function: mobility. Mobile technologies permit users to benefit from the changes in language and signs that have entered our language and experience in the wake of these new technologies.

Derrida (2006) proposes that texts consist of “signifiers” (words) and the “signified”. The ways in which mobile technologies are used have produced a whole new lexicography of signs and numbers as well as conventions for ‘deconstructing’ them. One example of this new lexicography is the number “4” (conventionally the signifier for the numerable “four”). But in mobile-jargon, a kind of written patois, for this generation of higher education learners, this numeral signifies the adverb “for”, as in “Just for me”, which in mobile technology text would be written “just 4 me”.

The limitations of mobile technology such as the small screen size of most of the devices, and the exponential increase in the number of messages sent as SMSs (Short Message Services), have resulted in the unforeseen consequence of creating new signs (“signifiers”) for new meanings (the “signified”). While these ways of communications have subverted all the forms and conventions of formal language, they are nevertheless widely accepted and understood and therefore considered to be normal in the context of mobile cellular devices. In fact, one of the limitations of mobile cellular hardware (the very limited size of its screen) provided the impetus to design a personal instruction and learning, and utilise a new format for text communication as well as imbue traditional forms with and different meanings.

Mobile devices have therefore encouraged users to redesign old signs of instruction by attributing new meanings to them. They reflect on the processes involved in this activity and point to the fact that: “the danger to meaning [comes] from what is outside the sign {i.e., is neither the acoustic material used as the signifier, nor the signified concept the sign refers to}. In the moment of writing, the sign can always ‘empty’ itself...for here the general conditions for a deconstruction of metaphysics based on the notions of writing and difference, and first arrived at through a reading of how the notion of the sign functions in the phenomenology, are explicitly stated” (Derrida, 2006, pp. xii-xiii).

The purpose of higher education and the relatively new ubiquity of mobile devices in our culture have imbued the mobile device with new meanings. Higher education can now be presented in a more sustained and interactive fashion to empower those who need it. The ontological irony of the situation is that certain unintended developments in the social lifestyles of those who regularly use mobile technologies have opened up new possibilities for mobile interactions that are not confined to social situations. What is being claimed is that new forms of social life and

human interactions owe their origins to technical developments. Interestingly the limitations have compelled users to design new modes of interaction that utilise text rather than face-to face encounters. This implies that “the ontology design enables for a more generic approach – it provides a common formalism for representing context-relevant metadata for content units of diverse levels of granularity” (Jovanović, Gašević, Knight & Richards, 2007, p. 50).

According to (Huang, Huang & Hsieh, 2008, p. 3), the environments in which the study of mobile learning has been conducted have some similar features with in previous studies. These features include:

1. enhancing availability and accessibility of information networks;
2. engaging students in learning-related activities in diverse physical locations;
3. supporting of project-based group work;
4. improving of communication and collaborative learning in the classroom, and;
5. enabling quick content delivery.

However, mobile learning provides the support for learning and training, and “mobile technologies have contributed to the potential to support learners studying a variety of subjects” (Järvelä, Näykki, Laru, & Luokkanen, 2007, p. 71).

Mobile learning in higher education

The most important yet sophisticated concepts for designing instruction in this context are identifying the technology, learner and learning material as well as mobile technology such as portable devices. It also involves identifying learners who are nomadic and able to understand and interpret learning materials. In general, mobile learning – or m-learning- can be viewed as any form of learning that happens when mediated through a mobile devices, and a form of learning that established the legitimacy of ‘nomadic’ learners (Alexander, 2004).

These are the developments that have made mobile devices strategic tools with the capacity to deliver higher education instruction in a way that was never anticipated when the first prototypes of these devices were designed and marketed. Designers can deliver successful higher education products to the present generation of learners, by means of a technology, distinctively adapted for its own personal (mostly social) purposes. This makes technology a particularly potent tool for the delivery and reinforcement of content that would otherwise be identified with the higher education “establishment”. Devices “such as mobile phone and mp3 players have grown to such an extent over recent years and are gradually replacing personal computers in modern professional and social context” (Attewell & Savill-Smith, 2005). Modes of communication that were spontaneously developed by the younger generation have been subverted to serve the purposes of transmitting higher education. Such structural changes in the delivery of higher educational instruction add a powerful tool to the arsenal of available means that educators can use to make delivery more efficient, personal and culturally acceptable to those who pioneered these new modes of text delivery (Fullan, 2007).

These fundamental changes pose new problems to the designers. What new design paradigms and meanings can be attributed to the use of mobile technology? How can we appreciate their full significance within the context of traditional instructional design theory? Before the development of new forms of information and computer technology such as the current mobile “smart” cellular telephones, the design paradigms by means of which the delivery of higher education was understood remained essentially static. The extraordinary potential inherent in mobile devices, anticipate radical changes in the very structure of educational dynamics especially in the way in which people interact with one another in society.

The kind of informal learning through the use of mobile devices makes it an even more potent tool of educational communication than the customary forms and modes of traditional education. These revolutionary changes developed out of the unforeseen significance of human social life generally more “mobile”, creative and opportunistic, than the formal modes of traditional education.

The Definition

The foregoing observations can help designers to understand the position and significance of mobile learning in the context of higher education. It is possible to argue that the portability and mobility of these technological devices

have had strong implications for the meaning of terms that had been extensively defined in existing literature. Using the mobile device as a signifier, the concepts of mobility can be divided into three significant areas: *mobility of technology*, *mobility of learner* and *mobility of learning* especially in higher education landscape.

This tripartite division of mobility is evident in the current literature on the subject and designers who have used mobile technology for educational purposes have confirmed this. Figure 1 is a graphic depiction of the three divisions of mobile devices that can deliver a higher level of educational instruction. In practice, the technology, the learner and the actual learning process operate in an uninterrupted continuum within the social context of education. The subversion of the signifier here (that operates to the advantage of the educator and the educated) is that mobile devices were constructed and marketed as forms of technology, designed solely to enrich and enhance the social and personal lives of users. The successful delivery of higher educational instruction depends on the tripartite significance of the word mobility as it is used in the context of higher education. These three elements are interdependent and are equally important in making mobile devices viable as instruments for the delivery of higher education instructional contents.

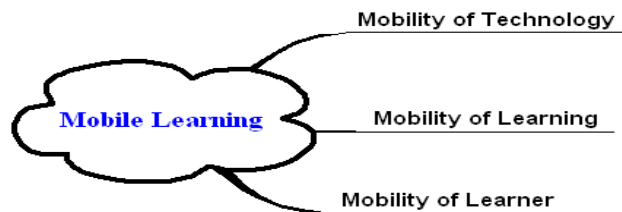


Figure 1: The three concepts of mobile learning

Accordingly, the article's authors define mobile learning as learning environmental based on mobility of technology, mobility of learners and mobility of learning that augments the higher educational landscape.

Mobility of technology

The mobile technology referred to in this article is mainly more advanced cellular telephones. But there are other forms of technology such as "smart" phones, digital cameras, flash-discs, iPods and personal digital assistance devices (PDAs). Mobile devices used to deliver higher education content and instruction can also function as audio-players, media-players and digital cameras. Advanced mobile devices are furnished with Wireless Application Protocol (WAP) and Wireless Fidelity (Wi-Fi) capacities so that a user can connect to the Internet by means of his or her PDA (Trinder, 2005).

The mobile cellular devices mentioned above have the capacity to link to the Internet and deliver content and instruction that can enable learners to learn at anytime and anywhere in a format that is culturally prestigious among people in the same age group. Most of the more advanced models can support a portable, digital and wireless lifestyle and mode of teaching and learning. It is precisely the mobility of these devices that makes them highly prestigious and therefore desirable as instruments of learning among learners in the same age group. In fact they are highly valued by young people in their early twenties because they are visible indicators of wealth, privilege, luxury and modernity. Mobile devices with advanced features like those mentioned above are therefore regarded as more trendy, fashionable and prestigious among these consumers than the standard desktop personal computers that connect to the Internet by means of landlines.

The first designers of this mode of delivery were extremely ingenious in the way in which they exploited the prestige and iconic value of mobile devices among young people in their twenties. Educationists have in effect adroitly utilised one of the most potent symbols of wealth, prestige and fashion among the young. Education by means of mobile devices is therefore nothing if not revolutionary in its design methods, implications and results.

Trinder (2005, pp. 7-8) explains the functionalities of the most popular and expensive mobile phone technologies. These include an organiser, video camera, telephone, GPS and film player. They also include games, e-book, e-mail facility Internet access and musical MP3s. But the most popular functions in all mobile phone remain the short

messaging service (SMS) and the multimedia messaging service (MMS) – frequently used functions in the delivery of higher education instructions. This innovation has been discussed in terms of Trinder’s (2005) classification of PDA functionality.

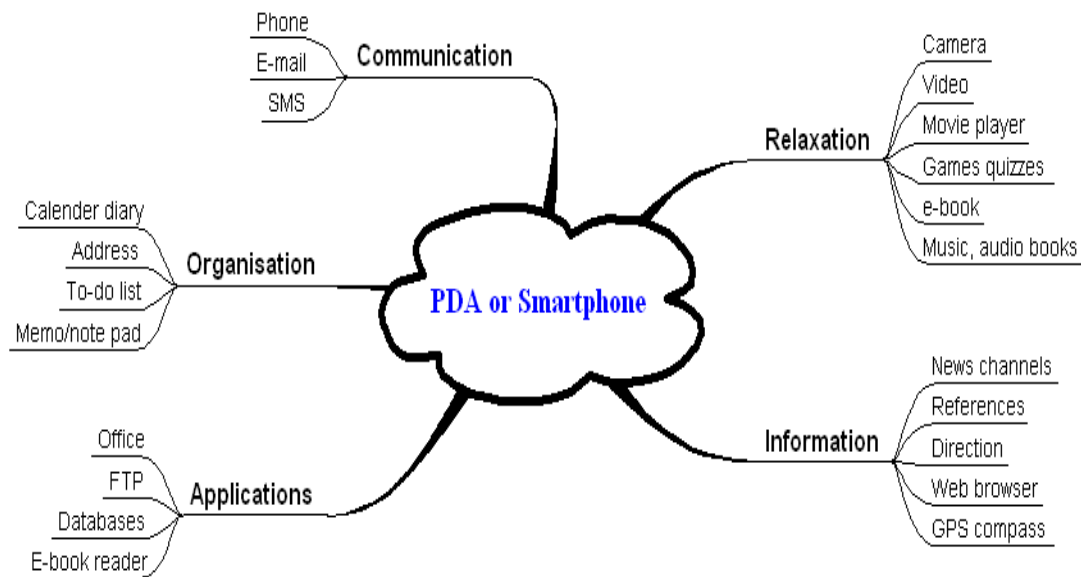


Figure 2: PDA technology (Source: Trinder, 2005, p. 7)

Figure 2 highlights the functions of Personal Digital Assistant (PDA). This device connects easily with the Internet, and enabling it to perform many different functions. (Kukulska-Hulme & Traxler, 2005, p. 2): Also “when combined with wireless connectivity, learning activities can be monitored and coordinated between locations. However, the task of designing such activities and appropriate learner support is complex and challenging. The impacts of new mobile technologies need to be appraised and evaluated” (Kukulska-Hulme & Traxler, 2005, p. 2). This is because of the challenges that still have to be overcome before this mode of educational delivery becomes as widely accepted as e-learning. However, Motiwalla (2007) states that although it is inevitable that m-learning will soon become an essential extension of e-learning, this transition will not happen overnight. Instant access to learning at any time and in many places will obviously be very useful to learners, but only to a privileged few until wireless technology becomes more efficient and widely available. It also depends on designers’ ability to apply the appropriate forms of instruction that will make this mode of learning an essential tool in the delivery of higher education.

From a technological point of view, mobile devices are becoming more and more capable of performing all the functions necessary in learning design. Since affordability and sophistication of mobile device technology have increased its popularity within the educational context and, educationalists should determine whether current theories of psychological, educational learning and instructional design are adequate to describe the processes and meet the challenges posed by this new mode of delivery. Traxler (2007) writes: “[designers have] not explored the actual technologies or pedagogies in any detail and [have] sought to define questions for discussion rather than provide answers for what might in fact be premature or inappropriate questions”.

Mobility of learners

E-learning mediated by personal computers is mostly bound by location and time (availability) because of the configuration of a personal computer. The computer has no wireless learning tool linked to the Internet, which means that one must always work in one place at a particular time determined by availability and connectivity. But with mobile learning, learning can occur at any place and at any time. The ordinary (non-mobile) personal computer with landline connections to the Internet is constrained by the places in which they are located and their availability. Non-portable personal computers are too heavy to move easily and so learners are compelled to work in the same place and during the time slots allocated to them by university authorities. By contrast, learning with mobile is a learner-

centric activity because it is both mobile and nomadic, and not pedagogically teacher-centric as in the case of traditional lectures and hardware installed in one particular location under the aegis of the university's authorities.

Ting (2005) makes the following remarks about the advantages of mobile learning: "The overall advantages provided by the mobile learning are [that it is characterised by] more flexible, accessible and personalised learning activities. Such advantages [...] keep the learners engaged in the ongoing learning activities and enhance their productivity and effectiveness". Furthermore, Guralnich (2008) suggests that the designer would be better served if he/she considered the entire context in which learners will use particular m-learning programme. However, today's designers often tend to borrow design ideas from their e-learning experience.

Mobile learning devices also have the capacity to enhance a learner's sense of individuality and community as well as his or her motivation to learn through participation in collaborative learning. These devices stimulate a learner's sense of ownership of the content as he/she participates actively in a variety of social, collaborative and cooperative activities - all of which are centred on the mobile learning device.

Educators and designers should address the needs of learners in this age of wireless communication and connectedness. Slogans such as "walk and use", "walk and talk", "just for me" and "just in time" usher in the new phrases in education like "You ring, we bring" ushered in previous developments in society. Instructional theory in this mobile age should be learner-centric rather than technology- or teacher-centric. This is because, as Uden (2007) observes: "Mobile technologies offer new opportunities for students' educational activities in that they can be used across different locations and times". Students using mobile technologies are not only remote from their instructors; they also fully control the access of information on their mobile devices. In this light, one of the main advantages of mobile learning is that it allows this generation of learners to enjoy a certain amount of freedom and independence.

Mobility of learning

Researchers and practitioners of mobile learning are engaged in pioneering experiments for transmitting the full content of higher learning to students by means of mobile cellular devices. Walker (2007) points out that the advantages of mobile learning are not dependent solely upon the ability to use a portable and wireless communication device successfully. He argues that the kind of learning experienced by mobile owners is unique because it is received and processed within the context in which the learner is situated. The context is utterly individual – completely different from the rigid outlay of the traditional classroom or lecture room, and the computer laboratory.

The international conference on mobile learning entitled *MLearn 2004* adopted as its guiding statement the desire to provide "learning anytime and everywhere", Attewell & Savill-Smith (2005)'s paper and those of other contributions were designed to indicate how such a vision could be fulfilled. Most of the papers presented at this conference focused on the description and development of theories that would support the practice of mobile learning and the design production of mobile learning materials and systems.

Mobile learning devices have also enriched the theory and practice of e-learning. Contemporary consumers of higher education in developing countries almost always use mobile learning devices as adjuncts to e-learning in higher education. Sophisticated mobile devices are currently capable of delivering a comprehensive range of e-learning materials by means of web connections, infrared and bluetooth transmissions. For Ally (2005) "mobile learning [is at the] intersection of mobile computing and e-learning; [it provides] accessible resources wherever you are, strong search capabilities, rich interaction, powerful support for effective learning and performance-based assessment".

There are two well-publicised convergences that are effected by mobile technology:

- Firstly, a convergence between mobile technologies as learning and instructional design, and the marketing of mobile computer-communicators are combined into a single device. This device is able to access the Internet, function as a telephone, camera, video and audio player and perform wireless computing tasks.
- Secondly, and equally importantly, a "convergence is occurring between the new personal and mobile technologies and the new conceptions of learning as a personally-managed lifelong activity" (Sharples, Taylor & Vavoula, 2007).

Table 2: Convergence between learning and technology (Sharples, Taylor & Vavoula, 2007, p. 4)

New Learning	New Technology
Personalised	Personal
Learner-centred	User-centred
Situated	Mobile
Collaborative	Networked
Ubiquitous	Ubiquitous
Lifelong	Durable

Table 2 encourages the designers to ask the following questions as they reflect on these new modes of educational delivery: “What does this new mobile technology bring to learning?” One of the most significant answers to this question is: “New technologies allow us to develop full digital records of our lives and experiences” Beale (2007). Laouris and Eteokleous (2005) highlight the changes that one can expect to occur in consumers of higher education when “tomorrow's learners will have access to a dynamically changing repertoire of devices and services that will differ in speed, processing power, monitoring (and other outputs) characteristics. As our engagement with technology changes with time, mobile learning becomes a function not only of time, but also of the momentarily available and dynamically changing technology” Laouris and Eteokleous (2005).

For Banks (2008): “further studies are painting a picture of today’s youth becoming increasingly comfortable and accepting of their new digital lifestyles, powered by technology such as mobile phones. These phones are, enriched by portable entertainment devices such as iPods, digital cameras, Sony PSPs, and Nintendo’s Gameboy. Friendships are made, maintained and lost online often in virtual worlds and on social networking sites such as MySpace and Facebook. Much of what we are seeing today—generally out of the classroom but increasingly in it—is technology-driven, but this technology is not universally accessible to all” (Banks, 2008, p. 53). If Banks’s vision is correct, then more and more institutions of higher learning will embrace the potential inherent in emerging wireless and mobile technologies for the purposes of higher education. Despite the importance of mobile wireless technological devices as the sole provider or as an adjunct provider of higher education in the not-too-far future, there are still those who refuse to recognise the potential of this emerging form of educational delivery.

Conclusions

In conclusion, the authors define mobile learning as “any type of learning that takes place in learning environments and spaces that take account of the mobility of technology, mobility of learners and mobility of learning”.

Since mobile learning is spreading rapidly and likely to become one of the most efficient ways of delivering higher education instruction in the future, it has become necessary to examine its implication for the design of teaching and learning. The uses and applications of mobile learning have multiplied in different contexts even though the eventual consequences of the proliferation of this medium are not yet entirely clear, either to designers and practitioners themselves or to researchers. .

It is necessary for research on the effects and modes of mobile learning to investigate and explore the practice of this particular medium in terms of the instructional design theories of the past, and to adapt such theories so that they can account for the extraordinary number of changes that have taken place not only in education, but in society at large.

Designers and practitioners of education are therefore responsible to produce coherent and reliable accounts of the likely consequences of the proliferation of mobile devices in the higher education landscape. The proper design of the technologies leads to greater effectiveness of mobile learning. Such accounts should consider the multiplicity of meanings that are implied by the mobility of educational delivery and the mobility of learners. It is also necessary to describe in detail the various advantages and disadvantages of mobile instructional devices as tools for the delivery of higher education. Philosophers of education should explain the philosophical and theoretical assumptions of mobile learning in higher education. They should also clarify the design paradigm shifts that this mode of delivering higher education has introduced into the world of practice.

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A Mobile Context-aware Framework for Managing Learning Schedules – Data Analysis from a Diary Study

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ABSTRACT

We report the results of a diary study to determine whether a diary approach could be used as a successful way of retrieving a) the user's learning contexts, b) which learning contexts are significant for consideration within an m-learning application, and c) which learning materials are appropriate for which learning situation. Analyses of data provided by 32 participants have helped us to establish the applicability of using a learning schedule for retrieving a learner's location and available time contexts. This understanding was required in order to determine the realistic usability and potential deployment of our mobile context-aware learning schedule (mCALS) framework, which uses a learner's schedule (i.e. electronic organizer) to retrieve their location and available time contexts. The purpose of this framework is to suggest appropriate learning materials to students based on the values of the proposed contexts (including learning styles, knowledge level, concentration level and frequency of interruption, at the point of usage). The study suggests that the framework should include verification methods to counter against the possibility of students not adhering precisely to their planned learning schedules. Motivation was established as a crucial learning context which should be incorporated into adaptive mobile learning applications.

Keywords

Context-aware, diary study, mobile learning

Introduction

Context-aware mobile learning (hereafter, abbreviated as m-learning) applications emphasize the use of learning contexts and the automatic retrieval of these using context-aware technologies such as location-tracking devices. Advantages include improving the learning situation and providing convenience to learners (Yau and Joy, 2009a). Learning contexts are defined by the student's situation and are used in applications in order to match, adapt or select appropriate learning content suitable for their situation and/or environment. These contexts can include the student's internal characteristics, the activities being undertaken, their location, their available time, and types of mobile device being used (Wang, 2004). Three perspectives should be considered for evaluating these applications. These are 1) *pedagogical* - how materials should be designed to enhance the learning experiences and to meet the learning requirements of students; 2) *usability* - how the user interfaces of applications on mobile devices should be designed to enhance human-computer interaction; and 3) *technological* - the physical layout of learning materials and how they can adapt to different sizes of mobile device screens (Yau and Joy, 2010).

Our mobile context-aware learning schedule (mCALS) suggestion mechanism was initially proposed as a theoretical framework in Yau and Joy (2008). The two main aspects of mCALS are 1) the context-aware suggestion mechanism, and 2) the learning schedule approach. A *context-aware suggestion mechanism* is potentially desirable for a student because the system is able to find out automatically their current learning contexts and suggest only appropriate materials to them for that situation. The intention is to create and maximize learning opportunities for learners in different m-learning situations. Other suggestion mechanisms have been proposed by Cui and Bull (2005) and Martin and Carro (2009), however, these applications require users to enter contexts information directly onto the mobile device and are not context-aware.

Our framework's *learning schedule approach* can be deployed by using electronic organizers integrated in mobile devices. This approach uses the student's study schedule (timetable) information entered in advance, to retrieve their location and available time information at moments when they may wish to study. This approach is proactive (as opposed to interactive) because it does not request users to enter information at the time of usage. The learning schedule approach removes the burden for users having to enter their location and available time information onto the device directly; and we wanted to investigate an alternative simple and effective method of retrieving contexts automatically. We also proposed this approach in order to eliminate the need for context-aware sensor technologies because these would not be necessary if learners adhered to their schedule and had kept it up-to-date (in order to

retrieve location and available time information accurately). Finally, data analyses of our interview study have shown that the act of pre-planning scheduled events can be motivating for some students to carry out their studies. Therefore, this learning schedule approach can potentially provide a motivational strategy for self-regulated students (Yau and Joy, 2009a).

Five learning contexts – learning styles, knowledge level, concentration level, frequency of interruption and available time – were identified as important contexts to be considered and have been incorporated into our framework (Yau and Joy, 2009a). The framework consists of a suggestion mechanism, which selects appropriate materials (from a learning object repository) to students based on the values of the proposed contexts, at the time of usage. A learning object repository such as www.codewitz.org can be used for retrieving Java learning materials.

The methodology used to design our framework consists of three stages: 1) theoretical design development, 2) pedagogical, usability and technical feasibility studies, and 3) framework validation. The rationale for proposing this framework includes that students may want to make use of their idle time and/or whatever available time they have for learning/studying (Yau and Joy, 2009a; Martin and Carro, 2009). Our purpose is to support these students by providing them with appropriate study materials for the circumstances that they are situated in. In the *theoretical design development* of our framework, we incorporated self-regulated learning theory and proposed that the learning schedule approach can be a successful time-management technique and an effective self-regulated learning approach for motivated students. Results of an interview study supported this claim (Yau and Joy, 2009a). We conducted *feasibility studies* in terms of three different perspectives – *pedagogical, usability and technical* i.e. interview study, diary study and technological framework design, respectively. 37 volunteers participated in our interview study and we were able to provide an insight into the learning requirements of intended users and whether our framework can be potentially used by them. Detailed results of this study are in Yau and Joy (2009a). The *usability* diary study forms the focus of this paper. The *technological* feasibility study was conducted to determine the feasibility of implementing our framework at present with current technologies, and this forms the focus of a future paper.

This paper is structured as follows – a literature review is provided in section 2; the ‘diary: diary-questionnaire’ methodology we used for data collection is presented in section 3; the data analysis of our diary study is described in section 4, and finally, in section 5, we present our conclusions and future work.

Literature Review

A literature review on some of the evaluation methods deployed from the *pedagogical, usability and technological* perspectives are provided below.

Pedagogical Methods

Typical methods used for evaluating m-learning outcomes include interviews, questionnaires and diary studies; all of which require learners to give their own retrospective accounts of their learning. Limitations of these methods include (a) there may be inaccuracies in students' recall and rationalization of information, and (b) some learners may not possess the meta-cognitive skills necessary to reflect on their own accounts of learning experiences and be able to convey this information accurately (Vavoula *et al.*, 2007).

Usability Methods

A usability inspection may consist of a number of data collection and analysis methods. Its aim is to (a) identify usability problems in order to incorporate suitable usability application functions into the design of the user interface, and (b) to specify and fulfill system requirements of potential users. A *user-centered system design* usually begins with an extensive analysis of potential users, tasks and environment, where potential users are involved in the process of system design from the beginning of system development and are consulted at each incremental stage of the development and evaluations. It is completed when the system usability criteria are satisfied (Petrelli and Not, 2005).

Technological Methods

An implementation (or a prototype) of the application is usually required for a technological evaluation. The evaluation process typically involves (a) an *evaluator* who plans and conducts the evaluation, and (b) a *volunteer* who tests the implemented application on a mobile device. Depending on the nature of the evaluation, the volunteer is asked to provide information about their usage of the application before, during and/or after the hands-on experience with the device. The technological evaluation of an application can take place in either the authentic context in which it is intended to be used, known as a *real* evaluation, or in a virtual or replicated context (a *simulated* evaluation).

Research Methodology

A ‘*diary: diary-questionnaire*’ study was chosen as the feasibility methodology for determining the usability of our mCALS framework prior to its implementation. The diary study, its advantages, reasons for deploying it, alternative usability methods, data sample and preliminary data analysis, were presented in Yau and Joy (2009b). This study offered the following advantages: (a) a more straight-forward approach for both the researcher and volunteers to conduct the study; (b) an increase in the number of potential participants; (c) simplicity for volunteers to capture their daily activities for the 2 days required for our study on paper; (d) ease of data collection; and (e) no additional necessary training time and financial resources (such as the use of mobile devices for recording data logs for students to use for two days). Such a method is especially beneficial for obtaining real-time information without the implementation of data logs to record usage of mobile devices to obtain the same information from learners (Wild *et al.*, 2005).

The reason that GPS technologies are not deployed as an alternative to the diary study is that we wish to determine whether learners’ location and available times can be retrieved accurately using their schedule information. Observation studies would not have been feasible in place of the diary study because learners would need to be tracked for the duration of two days, and learners may not have been comfortable being tracked, and this would affect the validity of the results (Vavoula *et al.*, 2007). There would also be limitations imposed by alternative technological methods, if these were to replace the diary study. Such limitations include the amount of time necessary to implement and debug a system which would not crash for the duration of two days which students are required to use, the current inability of GPS to work effectively indoors, and resource constraints affecting the availability of sufficient suitable equipment to support the participating students. Problems experienced by students using such systems to perform evaluations have been reported, and these have deterred students from further conducting the experiments (Corlett *et al.*, 2005).

This usability feasibility methodology was critical to our research because of the nature of the framework which deployed a learning schedule. In order to be able to retrieve the location and available time contexts accurately, users must be able to plan their schedule in advance, conform to it and keep it up-to-date. The interview data analysis showed that many participants did make use of a diary and that they followed their events closely (Yau and Joy, 2009a). However, there may be discrepancies between what participants said they did, and what they actually did do. Therefore, this phase was important for determining (a) whether a diary approach could be used as a successful way of retrieving users’ location and available time contexts, by investigating the degree of accuracy that students were able to keep to their diary, and (b) the important learning contexts that should be considered as the basis for recommending appropriate learning materials to students. A further reason that GPS (or similar) technologies were not deployed as an alternative to the diary study was that we wanted to determine whether learners’ location and available time can be retrieved accurately using their schedule information alone. The study was not a burden on the participants, since they were only required to fill in their timetable at the beginning of each day, a brief ‘diary-entry’ form (with mainly multiple-choice questions) after each learning session, and a short ‘diary-questionnaire’ at the end of the study. The whole experiment should not have taken much of the learner’s time.

Three parts of the ‘pen and paper’ diary study were specifically designed, as follows.

- Part 1 required volunteers to use ‘*diary schedule*’ sheets to keep a chronological record of their study-related and -unrelated events for 2 days and to provide information such as location, nature of event, time (to and from), whether these were completed/attended, and a reference number of the event.

- Part 2 required volunteers to use ‘*diary entry*’ sheets to fill out information relating to their completed study-related events including the reference numbers of the event (for cross-referencing), actual start and finish time of events (to the nearest five minutes), the location of the event, their choice for studying in that location, information about the noisiness, busyness, and temperature of the environment, how frequently they were interrupted, how motivated they were, how urgent the task was, how well they concentrated throughout the session, and if they concentrated better or worse at the beginning and end of the session. (identical sheets were given to each volunteer – one for each event – and the maximum number of recorded study-related events by any one student was 13).
- Part 3 required volunteers to fill out ‘*diary-questionnaires*’ to provide additional information relating to diary planning, effects of different learning contexts towards their concentration level, whether they can usually concentrate at the same level throughout a learning session, whether they plan a certain activity to be completed at a certain location, and which activities they would carry out when they had different amounts of time available to them.

Volunteers were given instructions to complete each of two ‘*diary schedule*’ sheets at the beginning of each of the two days they had chosen to carry out the diary study. They were given the flexibility to choose two days (consecutive or otherwise) where they had a sufficient number of tasks or activities. They were asked to fill out a ‘*diary entry*’ sheet immediately after each completed study-related event to reduce the disadvantages of the ‘recall’ effect (Wild *et al.*, 2005) i.e. students may not remember the exact settings and information that they were required to provide after some time had elapsed. Volunteers were asked to complete the ‘*diary-questionnaire*’ sheet at the end of the diary study. An instruction sheet and a consent form for conducting the diary study accompanied the diary study sheets.

32 volunteers participated in our study and each filled in a diary for two days. This formed a total of 64 days of diary for analysis, 157 ‘*diary entry*’ sheets were completed, and 31 (out of 32) ‘*diary-questionnaire*’ sheets were completed. A pilot study was first carried out to ensure that (a) all parts of the study were clear, and (b) to provide an opportunity for reflection of the diary structure and the questions in light of responses from volunteers. Thereafter, 13 students participated in our main study – these students were enrolled on computer science (9), German-language students (2), law (1) and engineering (1). The data from these 13 students and the three pilot students are named *batch 1*. We also obtained 16 volunteers from the PA College in Cyprus, enrolled on Business Administration (7), Business Computing (4), Accounting (3) and Marketing (2); the data from these students are named *batch 2*. The age range of the participants was 18-30 and they were in various years of study.

Data Analysis

In this section, we present the data analysis together with the following four research questions:

- Can a diary approach be used to retrieve the *location* context?
- Can a diary approach be used to retrieve the *available time* context?
- Which learning contexts should be used for recommendation?
- Which type(s) of learning materials are appropriate for which circumstances?

Our analyses for the first two and the last (sections 4.1, 4.2 and 4.4) are necessarily descriptive, whereas we are able to apply a quantitative analysis to the third (section 4.3).

Can a diary approach be used to retrieve the location context?

All 32 of the participants were able to plan their study-related events ahead for the 2 days required. All of batch 1 participants noted both study-related and -unrelated events, whereas, the batch 2 participants only noted down their study-related events. A possible explanation of this was that the diary study coincided with the onset of their exam period, hence they were very busy attending revision lectures and self studies, and omitted other events which they may have felt to be less important to them at that point in time.

275 events were recorded from these students, 181 were study-related and 94 were study-unrelated. 251 of the 275 events (91%) recorded by participants went as anticipated i.e. the event was completed or appropriately attended to, $\chi^2(1, N=274) = 189.7, p < .001$. 23 events (19 study-related and 4 study-unrelated) were indicated *not* to have gone as anticipated by 8 participants from batch 1, an average of 2.875 events by the 8 participants. Only one event was indicated by a batch 2 participant as not to have gone as anticipated and this was due to "boredom". Explanations for the events not having gone as anticipated were provided, as follows:

- Reasons concerning the study-related events included (a) their planned tasks required a longer time for completion, (b) they were interrupted often, sick, tired or had low levels of productivity and decided to either not commence or discontinue with the activity, (c) their scheduled events were cancelled, delayed, rescheduled or exceeded the scheduled time, and (d) there were transportation delays.
- Reasons concerning the study-unrelated events included (a) they changed their minds regarding their planned activities that they had wished to carry out, (b) the location of a meeting place with friends was changed, and (c) there was a lack of time.

Via the 'diary-questionnaire', we obtained additional information regarding the diary planning of participants. 12 out of the 16 participants from batch 1 (and 2 out of 16 from batch 2) indicated that they normally kept a diary, of whom one noted that they only kept the important events in their diaries. All of the 32 participants indicated that they did not have any problems keeping and updating the diary for the two days for our diary study.

Our diary study results showed that in general students did not have any problems planning, keeping and updating their planned events, at least for the duration of two days. This was supported by our interview study results where 27 out of 37 participants (i.e. 73%) (Yau and Joy, 2009a) who had informed us of their regular paper-based or electronic-based diary usage. Of the 275 scheduled events, only 9% had not gone as anticipated, and these were affected by unforeseen circumstances. This is a clear and statistically significant difference in the frequency of which events went as anticipated compared to those which did not. That only 9% of events were not anticipated is a relatively small percentage considering the large number of events that were recorded by a total of 32 participants. Thus we conclude that our learning schedule approach for retrieving the location context can be used as a preliminary proactive source of retrieving the location, whilst noting that additional methods could be employed to verify their actual location, such as the use of GPS and WLAN technologies.

Can a diary approach be used to retrieve the available time context?

The times and locations of participants' scheduled study-related events for the two days noted in part 1 of the study were checked against the times and locations indicated on the corresponding 'diary entry' sheets in part 2. 'Diary entry' sheets were only necessary to be completed for each study-related event and not for study-unrelated events. Participants were asked to round their start and finish times to the nearest five minutes. 91% of participants' events went as anticipated (see 6.1); however, there were some discrepancies between the planned and actual start and finish times of the events, described below. For the events which went as anticipated, the actual and planned locations were consistent. Out of the total of 157 completed diary entry forms, 109 were from participants of batch 1 and 48 were from participants of batch 2.

The planned and actual start and finish times of 52 out of the 109 study-related events (47%) from batch 1 were matched. There were discrepancies between the actual and planned start and finish times of the remaining 57 events, and these events were recorded from 12 out of the 16 participants. These 57 events are classified into the following two categories of events.

1. 20 events were *scheduled classes or meetings*. These often started and finished 5 or 10 minutes earlier or later, exceptionally finishing 35 minutes earlier. Participants often rounded the start and finish times of lectures to the hour on their 'diary schedules' sheets, when in fact, lectures at our university started at five minutes past the hour and finished at five minutes to the hour.
2. 37 events were *self-studies*. Due to the nature of these events, it was assumed that participants gave themselves the flexibility of starting and finishing at an earlier or later time, when it was convenient for them. The actual start and finish times ranged from a start of 20 minutes earlier to 95 minutes later and from a finish of 105 minutes earlier to 115 minutes later (depicted in Figures 1 and 2).

As a result, the discrepancies between the actual and planned amount of time spent on their self-study events ranged from -110 to +110 minutes, for the participants in batch 1 (depicted in Figure 3).

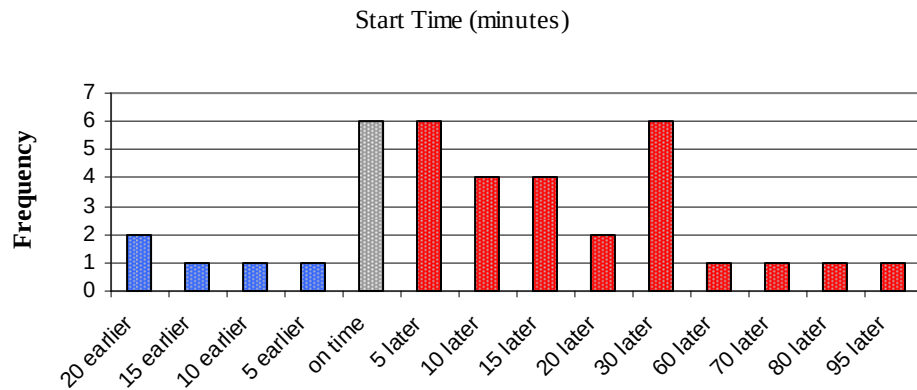


Figure 1: Actual start times of self-study events

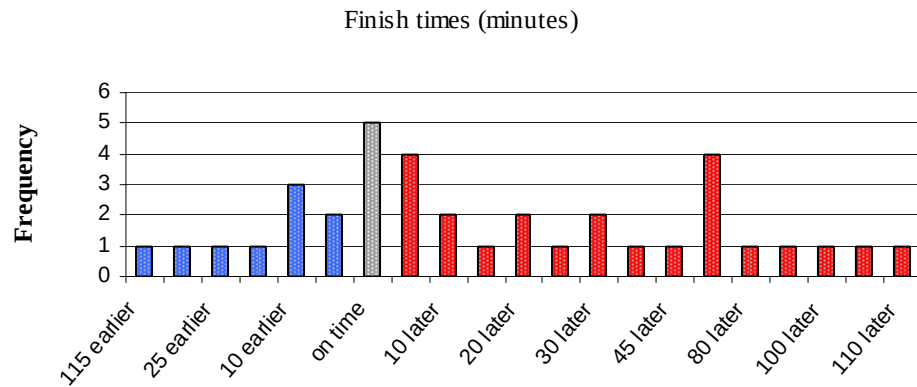


Figure 2: Actual finish times of self-study events

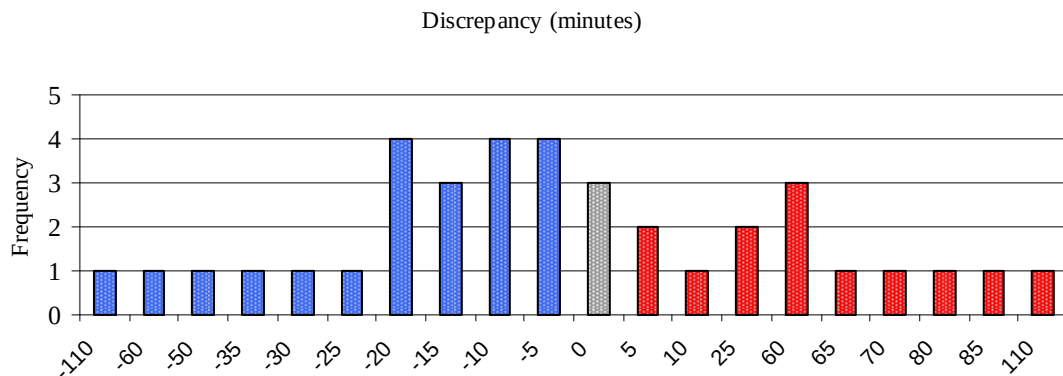


Figure 3: Discrepancies between the actual and planned amount of time for self-study (batch 1)

Regarding the data from batch 2, the actual and planned start and finish times of 44 out of 48 study-related events were matched and were recorded by 9 participants; whereas the remaining 4 study-related events were not. One of the four events that were not matched was a scheduled class and the remaining 3 events were self-study events; these were recorded by 2 participants from the batch. 5 participants did not note down the actual start and finish times of

their events on the diary entry forms; however common amongst the batch 2 participants were 2 daily laboratory revision exercises classes, in preparation for their exams. We presumed that due to the importance and urgency of these events, these participants had attended these events from start to finish.

Results from the ‘*diary-questionnaire*’ showed that 10 out of 15 participants from batch 1 indicated that they had always carried out the activities that they had planned at the specified location. One participant indicated that they usually did, and another participant indicated they sometimes did and the remaining 3 indicated that they did not always carry out the activities that they had planned at the location. Most of the batch 1 participants indicated that they were always in the location that they had planned, except for two participants who noted that they occasionally would complete their previous studying activities together with their current one in the same location. 11 participants from batch 2 noted that they had always carried out the activities that they had planned at the specified location, one noted that they had sometimes done so, and 4 that they did not carry out the activities that they had planned at the location. Out of the batch 2 participants, 8, 2 and 5 indicated that they were *always*, *sometimes* and *not* in the location that they had planned respectively.

The results showed that the actual locations of participants were consistent with their planned locations of events. In the case of the actual start and finish times of scheduled classes events in comparison with the planned times, there were small discrepancies of 5 or 10 minutes earlier or later than planned, with occasionally a larger discrepancy. For self-study events, participants were also in the same locations as planned, however there were more and larger discrepancies between the planned and actual start and finish times. Our conclusion is that the retrieved available time of a learner from the learner schedule can be used as the default values of their available time at a certain point in time. An additional user verification method may be required to enable users to verify the amount of available time retrieved, and change this, as necessary.

Which learning contexts should be used for recommendation?

In this section, we present a quantitative analysis of the learning contexts and identify correlations with the other factors we have measured which affect a student's study activity.

Correlations between the attributes and the learners' level of concentration

The qualitative data analysis from our interview study has demonstrated relationships, either positive or negative, between *busyness of environment*, *noise*, *temperature*, *motivation*, *frequency of task*, *frequency of interruption* and the concentration level of a learner (Yau and Joy, 2009a). Therefore, we require further quantitative analyses to establish the relationships between these attributes and the concentration level of a learner. 157 completed ‘*diary entry*’ sheets were obtained, and each recorded a learner's levels of concentration and the values of the various attributes in each learning session. We make the assumption that each set of responses obtained from the ‘*diary-entry*’ sheets, with attributes coded on a parametric scale of 1 through 5, is normally distributed, each having a mean and a standard deviation (N=157) as follows:

- *Noise* – mean = 2.16, SD = 1.03
- *Busyness of environment* – mean = 2.2, SD = 1.07
- *Temperature* – mean = 3.0, SD = 0.50
- *Frequency of interruption* – mean = 2.13, SD = 1.05
- *Motivation* – mean = 3.56, SD = 0.94
- *Urgency of task* – mean = 3.29, SD = 1.03
- *Concentration level* – mean = 3.44, SD = 0.94

Table 1 shows the correlation matrix where correlations between each of the attributes and participants' concentration level throughout a session were calculated. We calculated the zero-order correlations and subsequently the partial correlations, where other factors were controlled to ensure that the other attributes in the observations were not affecting the outcomes of the correlations. The significances of the normal and partial correlations of each factor are also displayed in this table.

Table 1: Normal and partial correlations between concentration level and factors

	Factors	Normal*	Partial*
1	Noise	-.271	-.310
	Significance (2-tailed)	.001	.000
2	Busyness of environment	-.029	.183
	Significance (2-tailed)	.721	.024
3	Temperature	-.020	-.064
	Significance (2-tailed)	.806	.434
4	Frequency of Interruption	-.205	-.051
	Significance (2-tailed)	.010	.535
5	Motivation	.445	.425
	Significance (2-tailed)	.000	.000
6	Urgency of Task	.101	-.063
	Significance (2-tailed)	.208	.441

*Note: The number of degrees of freedom is 155 for zero-order correlations and 150 for partial correlations.

When we correlated the noise level normally with the concentration level, the result was a statistically significant negative correlation ($r = -.271$, $p < .001$), suggesting that the higher the participants had found the noise level to be, the lower their average concentration level. The partial correlation between noise level and concentration level was even higher than the zero-order correlation ($r = -.310$), and the correlations became stronger after controlling for the other factors.

Negative zero-order correlations were found between the *busyness of environment*, *temperature* and *the frequency of interruption* in relation to the concentration level. Of these, the zero-order correlation between the frequency of interruption and the concentration level was statistically significant ($r = -.205$, $p = .010$), indicating that the higher frequencies of interruption coincided with lower levels of concentration. However, after controlling for the other factors, this correlation was no longer significant (partial $r = -.051$, $p = .535$).

Positive correlations were found between the *motivation* and *urgency of task* (zero-order only) in relation to the concentration level, of which the correlation between motivation and concentration level was significant ($r = .445$, $p < .001$). The results showed that the most significant factors affecting participants' concentration levels positively and negatively were *motivation* and *noise* respectively.

Regression analysis, t-test and analysis of variance

A regression analysis was performed to show the correlation between the concentration level and all the other attributes in order to predict changes in the concentration level. The regression model significantly predicted changes in concentration level, $F(6, 150) = 10.889$, $p < .001$, adjusted $R^2 = .276$. This revealed that the motivation was the most important factor in determining participants' concentration levels, such that higher motivation led to higher concentration levels after controlling for the effects of all other variables. Moreover, *noise* also independently predicted changes in concentration level, such that more *noise* decreased concentration level.

Two statistical tests were employed to investigate whether there were any consistencies in the levels of concentration of participants throughout a learning session. On the 'diary-entry' sheets, participants selected what they regarded as their concentration (a) *throughout the session*, (b) *at the start of the session*, and (c) *at the end of the session*.

1. A t-test was applied to compare the means of two values – the concentration level at the start and end of the session. The mean of the end concentration levels was 3.08, which was lower than the start concentration 3.44. To test that this lower level at the end of the session was not due to chance, the observed difference ($3.4 - 3.1 = 0.3$) was tested against an underlying distribution based on the degrees of freedom (df), which was 159. We obtained $t(159) = 3.579$ and $p < 0.001$, showing that the difference in concentration level from start to finish decreased significantly.
2. An analysis of variance for comparing the means of three concentration values mentioned above. Our results showed that concentration peaked during a learning session and then fell steadily towards the end. Concentration

level depended significantly on the time it was measured (Start vs. Throughout vs. Finish), $F(2, 316) = 10.58$, $p < .001$, $\eta^2 = .063$. Polynomial contrasts were run to explore how concentration level decreased over time. Results showed a significant linear trend, $F(1,158) = 12.066$, $p = .001$, $\eta^2 = .071$, in addition to a significant quadratic trend, $F(1,158) = 8.130$, $p = .005$, $\eta^2 = .049$. These linear and quadratic trends suggested that while concentration level decreased over time, it actually peaked during the study session.

Results from the 'diary-questionnaire'

Results from the 'diary-questionnaire' relate to the effects of the various factors on the 31 learners' concentration for studying:

- *Noise* had an effect on 25 participants, but for 19 participants this was a lesser effect when they were completing an urgent task and 12 participants noted that there are not usually any times when noises did not affect them.
- *Busyness of an environment* had an effect on 21 participants.
- *Temperature* had an effect on 18 participants and not on the remaining 13 participants.
- *Motivation* had an effect on 27 participants. The effect was significant (a) on 24 participants in determining whether they would study at a particular location, and (b) on 26 participants in determining whether they would study a particular topic.
- *Internal distractions* had an occasional effect on 25 participants.
- *Urgency of task* had a significant effect of eliminating (a) general distractions for 19 participants, and b) noise distractions for 20 participants.
- 23 participants had *discontinued with their studies* due to distractions (such as noises, heat, phone ringing, fire alarm, busyness of environment, tiredness, motivation, mood, hunger, and talked to others instead). The 8 participants who not discontinued with their studies despite distraction gave as the main reason determination to finish their study activities.

Results from the 'diary-questionnaire' also show that 15 participants from batch 1 had the opinion that there were normally changes in their concentration level within a learning session. Reasons included (a) becoming tired or bored, (b) the difficulty of the work was, (c) potentially better motivation or mood at the start of the session, (d) interruptions/distractions, and (e) how well their work was going. 13 out of the 16 participants from batch 2 indicated that there were usually changes in their concentration level within a session, whereas 3 indicated that they could concentrate at the same level throughout a session.

Discussion

A participant's high level of motivation during a learning session was shown to have a positive impact on how well they could concentrate throughout that session. Similarly, a high noise level in an environment had a negative impact on student concentration. Statistically insignificant negative correlations between the *busyness of environment*, *temperature* and *frequency of interruption* were found in relation with the concentration level of a student, and a statistically insignificant positive correlation was found between the *urgency of task* factor and the concentration level of a student. We conclude that the two variables – *motivation of a learner* and *noise in the environment* – are two necessary variables that should be taken into consideration in the selection of appropriate learning materials for students in different situations.

Which type(s) of learning materials are appropriate for which circumstances?

Via the completed 'data-entry' sheets, reasons for participants' chosen types of locations for performing their study activities were obtained, as follows:

- Coursework assignments (as well as writing/updating reports, making notes, and reading) were completed in *department office*, *library*, *home (bedroom, dining room, study)*, *train and student union building*. The main reasons given for studying in these locations included that the location was quiet or relaxing, it being their preferred study location, the availability of academic help and resources, as well as the urgency of the task. The main reasons for studying in the two latter locations included maximizing productivity and not wasting idle time whilst travelling or waiting.

- Hands-on programming (as well as learning how to program and programming exercises and projects) was completed in *computer laboratory, library and home (bedroom)*. The main reasons were the same as the ones stated above.
- Making a presentation was completed at home (kitchen).
- Lectures and classes were completed in lecture theatres or classrooms due to the scheduled locations.

14 participants indicated that they did normally plan a certain study activity to be completed at a particular location. Reasons for this included that some places were better for them to concentrate and they had a higher level of productivity there as well as due to the requirement to use certain resources (such as books or computers). The remaining 17 participants indicated that they did not plan a certain study activity to be completed at a particular location because they were able to perform them in any location.

In the ‘*diary-questionnaire*’, participants were asked to name the study activities that they would perform when they had a) *less than 15 minutes*, b) *15-30 minutes*, c) *30 minutes to an hour*, and d) *over an hour*, respectively. The results revealed that participants would choose shorter and easier learning/studying activities such as *planning, brainstorming, reading*, or none at all (because the time available was too short), when they had a shorter time for example 15 minutes or less. When they had more time available for example half an hour or more, they would carry out more difficult tasks requiring more concentration such as *writing coursework assignments*, and *programming* etc. This suggests that there is a relationship between the time available to a student and their motivation for carrying out a particular learning/studying task.

General suggestion rules can be formed considering the motivation level of the learner and the types of materials suitable for different values of these. We established the following suggestion rules for students to perform their self-study events. Note that the difficult, medium and easy levels of tasks are in terms of cognition:

- If motivation = high and available time > 30 mins then difficult tasks are selected.
- If motivation = medium and available time > 30 mins then medium tasks are selected.
- If motivation = low and available time > 30 mins then easy tasks are selected.
- If available time < 30 then easy tasks are selected.

For the selection of Java materials to students, we used a simplified version of Cui and Bull’s (2005) suggestion rules for recommendation, and the choice of time durations is also consistent with theirs. Instead of considering the student’s concentration level and frequency of interruption, the student’s motivation level and their available time is to be considered. The full set of modified suggestion rules can be found in (Yau and Joy, 2010). An example is given, as follows.

1. Tutorials, exercises and revision materials are selected
 - o If motivation = any level and available time > 30 mins.

Lastly, the learner’s learning styles and knowledge level were also to be considered. This can be done by matching the learner’s learning styles and knowledge level with the learning object metadata containing information relating to these attributes.

Conclusions and Future Work

In this paper, we have described our diary study for data collection and analysis in relation to our mCALS framework which uses a learning schedule as a proactive approach in retrieving the learner’s location and available time contexts. Data analysis shows that the planned and actual locations of learners were entirely adhered to, and 47% of the planned and actual start and finish times were precisely matched. Although, evidence suggests that the planned location of a learner can be relied upon as the actual location, there may always be unforeseen circumstances when the learner is not adhering to their schedule. We propose that our learning schedule approach can be used as a default method of retrieving the learner’s location and their available time. Thereafter, verification methods are to be put in place to verify the location, using GPS technologies outdoors and wireless LAN indoors, together with a user interactive method to request users to confirm their available time. Four learning contexts –learning styles, knowledge level, motivation, and available time – are to be incorporated into our framework for the suggestion of

Java learning objects to students. Motivation and available time are considered when selecting students' own learning/studying materials to them in different situations. Future work includes a technical implementation of our framework on a mobile device with a built-in learning schedule and context-aware technologies.

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Formative Assessment Design for PDA Integrated Ecology Observation

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ABSTRACT

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

Keywords

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

Background and Motivation

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

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

In the past few years, several studies concerning the use of PDAs and wireless communication networks in outdoor teaching have demonstrated the benefits of such an approach. For example, Chu, Hwang, Huang and Wu (2008)

reported the use of mobile and wireless communication technologies in the butterfly ecology garden for an outdoor activity of a Natural Science course in an elementary school. Hwang, Kuo, Yin and Chuang (in press) indicated that well designed learning paths are necessary for situating the students in a quality mobile learning environment. Researchers further showed that the development of Mindtools is helpful to students in improving their learning achievements in such mobile or ubiquitous learning environments (Chu, Hwang & Tsai, in press; Peng et al., 2009).

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

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

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

Rationale for worksheet design

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

Intrinsic Cognitive Load Instructional Design

Intrinsic cognitive load is associated with the interaction between the nature of the materials being learned and the proficiency level of the students (Sweller et al., 1998; Paas et al., 2003). Hence, the prerequisite knowledge needed to be learned, or the wide open ecology environment, could be sources of intrinsic cognitive load. In other words, the intrinsic cognitive load depends on the inherent difficulty of the learning material, for example, how many elements there are and how they interact with each other. The materials used in this study were three process worksheets with learning guidelines that students needed to know about the three field trips to different wetland ecological systems of

mangroves. The use of the process worksheets helped break the learning activities into smaller learning tasks of different natures. The worksheets indicated the upcoming events as well as the order and the nature of the activities. The first process worksheet guided students to observe and describe the mangrove wetland ecological system they saw. The second phase was to instruct students to use the database to support what they had observed. The final worksheet guided students to compare and contrast the things they had seen. In short, each process worksheet guided students' attention to different target tasks related to exploring the mangrove wetland ecological system.

Extraneous Cognitive Load Instructional Design

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

Germane Cognitive Load Instructional Design

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

The three-layer framework of observation worksheet design

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

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

working on his e-diary with a computer. In this extended learning activity, the students were guided to search for information in the e-library when they did not get the correct or sufficiently detailed answers.

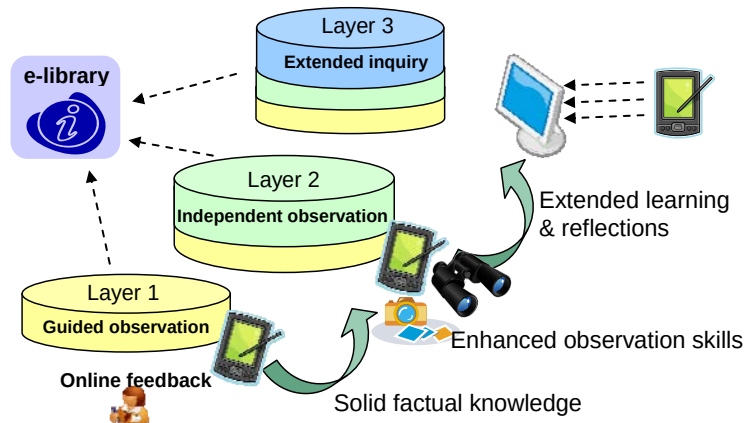


Figure 1. The three-layer observation worksheet design

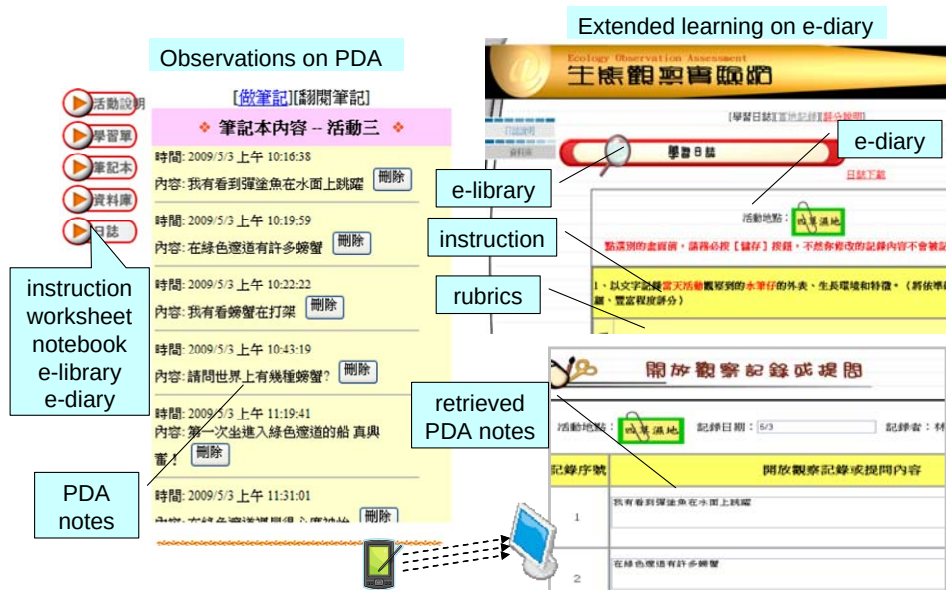


Figure 2. Snapshots of PDA notes and e-diaries



Figure 3. Snapshots of the e-library

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

Formative assessment and data collection designs

Participants and procedures

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

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

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



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

Table 1 shows the descriptions of the three outdoor activities of the PDA integrated ecology observations. For the first activity, the participants listened to a 40-minute lecture on mangrove forests and then started their observation journey. The observation targets were mainly guided by the worksheets. Both multiple-choice and short-answer questions were presented sequentially on the PDAs. Online feedback of the correctness of students' responses to the multiple-choice questions was provided. For the second and third activities, the students visited different sites for an extended learning experience. True-false questions were included in the second worksheet to facilitate students' elaborated observation skills. Moreover, the feedbacks (such as the correctness of the observations, factual information, adaptive supports, and score of each response) were provided for the short-answer items for the 2nd and 3rd worksheets. It was also suggested that the students search for detailed information in the e-library if they did not

get the right answers. For each outdoor activity, the students were required to finish their e-diary within a week. Figure 4 provides some snapshots of the activities. The upper section of Figure 4 shows the ways that students used the PDAs and telescope when they were working on their worksheets. The lower section of Figure 4 shows examples of target observation objects (black faced spoon bill, crab, and mangrove plant). The richness of the ecology system was very appealing but distracting for most of the participants. The PDA provides well-structured scaffolding for students' observation learning. The online feedback helped the students clarify their knowledge, elaborate their descriptions and extend their inquiries sequentially.

Online feedback

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

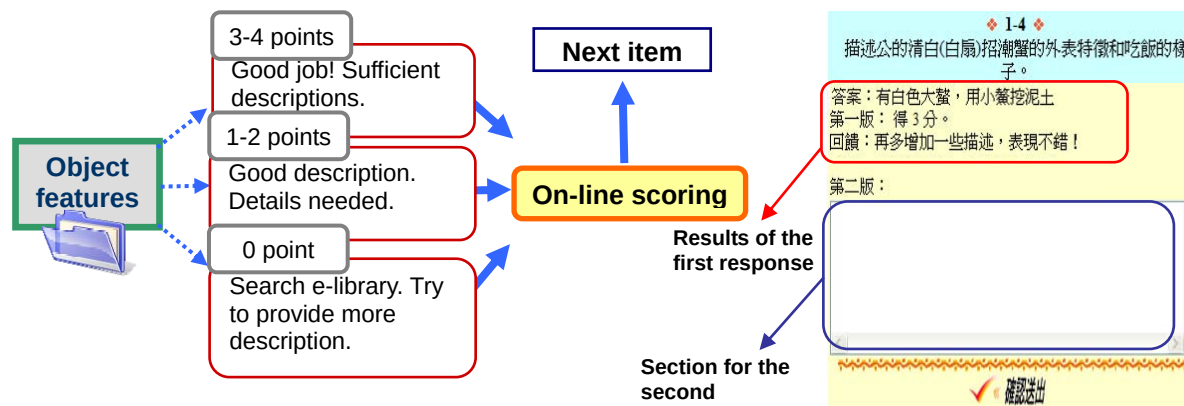


Figure 5. The feedback system for the learning tasks on the PDAs

Scoring for constructed responses

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

Findings and Discussion

Students' performance on the PDA integrated observation activities

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

demonstrated better persistence in pursuing their own questions. Some students became very capable of using the online search tools for their extended inquiries.

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

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

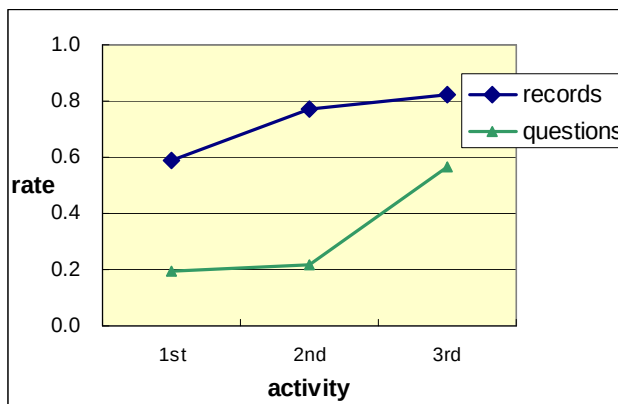


Figure 6. Students' performance profiles on observation records and questions on PDAs

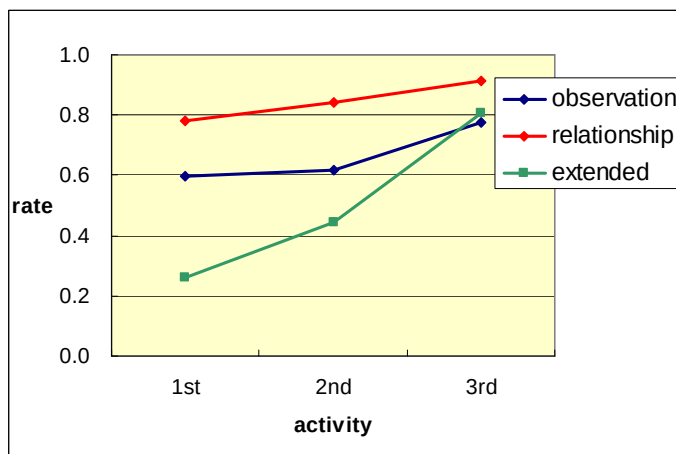


Figure 7. Students' progress profiles on extended learning in e-diaries

Contrasts of different learning profiles

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

ecology related (e.g. Why use a PDA instead of a PC?), or were similar to the questions on the worksheet (e.g. What are the features of the fiddler crab?). To sum up, the students in the great progress group raised relatively more relevant questions and were persistent in successfully solving these questions.

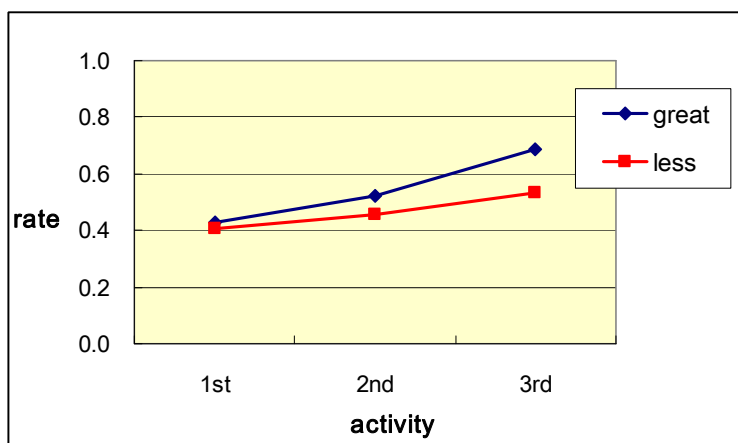


Figure 8. The contrast of different progress profiles of PDA integrated learning

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

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

Conclusion

Outdoor activities are very exciting for most elementary school students. However, the unlimited learning space could also be very confusing or result in cognitive overload for novice learners. In this study, a formative assessment

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

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

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

Acknowledgments

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Learner Centred Design for a Hybrid Interaction Application

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ABSTRACT

Learner centred design methods highlight the importance of involving the stakeholders of the learning process (learners, teachers, educational researchers) at all stages of the design of educational applications and of refining the design through an iterative prototyping process. These methods have been used successfully when designing systems employing innovative concepts or technologies. In this paper we describe the design process of Move Grapher, a GPS-enabled, mobile learning application to support the teaching and learning of kinematic graphs in schools and colleges to children aged 15 – 17. Move Grapher implements a hybrid mode of interaction; besides implementing a graphical user interface, it enables learners to employ an embodied type of interaction as a way of supporting them in generating learning insights. Involving stakeholders and iterative prototyping were important methods in the design process, however, the innovative nature of the technologies employed and the embodied element of the interface had a decisive influence in determining the roles the stakeholders played as well as the nature of the deployed prototypes.

Keywords

Learner centred design, mobile learning, location awareness, embodied interaction, kinematic graphs

Introduction

Students of mathematics and physics need to understand how to construct and interpret kinematic graphs which plot distance or speed against time (see figure 1). They need to do this with fluency and accuracy, recognising the meaning and significance of the variable, slope, area under the graph and intersections with the axes. However, students are susceptible to a number of misconceptions such as viewing the graph as a picture or confusing the gradient and height (McDermott, Rosenquist & van Zee, 1987; Beichner 1990, 1994; Beichner & Robert, 1994; Janvier, 2004). These are related with associating the symbols and representations in these graphs with the concrete movement of an object. For example, in the graph-as-picture error, students might think the graph is an illustration of the travelled terrain mistaking an increase in velocity with travelling up a hill.

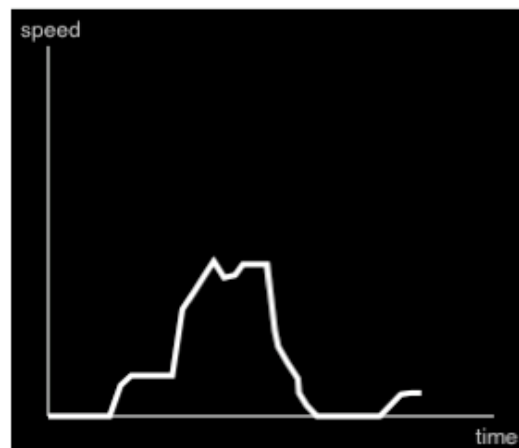


Figure 1. A Speed Time Graph

Two successful ways of learning about kinematic graphs are hands-on approaches and using tools and instruments. The idea behind hands-on approaches is that a powerful paradigm in learning is activity followed by reflection (Harel and Papert, 1991; Ackermann, 2001; Simpson & Noss, 2006) while using tools and instruments allows students to view in real time the effect of the movement of concrete objects on a graph (Mokros & Tinker, 1987; Thornton &

Sokoloff, 1990). In the study reported here, we went beyond just combining these two approaches, we enabled students themselves to be the moving objects so that in this way we could exploit their kinesthetic functions to support effective mappings between movement and its graph representation. In order to implement such an approach, we employed innovative technologies such as location awareness and large screen capabilities of modern mobile phones. Developing learning applications using innovative technologies can however add an element of uncertainty and complexity to the design. In order to meet these potential challenges we employed a learner centred design (LCD) methodology, an approach that has been proven successful in these cases (Good & Robertson, 2006; Goolnik, Robertson & Good 2006).

This paper describes the learner centred approach that was employed to design activities and representations that would effectively exploit the learner's kinesthetic functions when learning about kinematic graphs. The next section talks about the teaching and learning of kinematic graphs and about approaches that have employed similar technologies. The following section talks about the use of LCD for innovative systems. The section "The design process of Move Grapher" summarises the work done in terms of the LCD process followed. The section "Establishing the requirements" describes two initial studies aimed at clarifying the requirements of the design. The following section, "Paper prototyping", describes two studies intended to refine early versions of the prototype. The section "High fidelity prototyping" describes the iterative refinement of the computerised prototypes that implement the approach. The paper finishes with a discussion of lessons learned and relevant conclusions.

Innovative approaches for the learning of kinematic graphs.

Kinematic graphs are an important part of the language of physics and being able to construct and interpret them correctly is essential to understanding and communicating mechanical concepts effectively. However, in using kinematics graphs for mathematics and science, students are susceptible to a number of important misconceptions (Beichner 1990, 1994). These include: viewing the graph as a picture, confusing the gradient and height, confusing variables (mistaking acceleration for velocity, for example), assuming (for the purpose of calculation) that the line representing the movement passes through the graph's origin, and confusions involving areas (misunderstanding the area, or calculating area instead of the gradient and visa versa). The first two errors are the most common (Beichner 1994).

Because of the importance of kinematic graphs for the science curriculum, a wide variety of instructional approaches have been implemented to address the difficulties described above. From those, two have been particularly successful: hands-on approaches and using tools and instruments. In the latter, students are allowed to engage in learning activities that have the concrete output of building or modifying something, while in the former a variety of tools are used to produce real-time graphs of the movement of concrete objects. Zollman (1994), for example, uses a hands-on approach as he enables students to perform low-tech, manual editing of motion videos. Students place acetate transparencies on video screens to mark the changing positions of key objects. This enables them to answer their own inquiries at their own pace (Zollman, 1994). Beichner (1996) uses similar techniques to provide a more direct validation of the approach. He employs video motion analysis software in a variety of situations ranging from teacher-led demonstrations to allowing students to edit and analyse the videos by themselves. The greatest learning gains were associated with the hands-on approach. Hoyles and Noss (2006) enabled students to produce motion animations using a programming environment. Students engaged in a range of activities: exploring motion and plotting graphs, predicting graphs after observing motion, "guess my graph" (trying to reconstruct motion based on a graph) and matching descriptions of motion. Each of these activities reflects the importance of the students constructing their own graphs.

Probably the most well-known programme of research associated with the use of tools and instruments to learn kinematic graphs has been the micro-computer based laboratory (MBL) tools (Mokros & Tinker, 1987; Thornton & Sokoloff, 1990). MBL tools link sensor equipment to computer software to allow the real-time generation of graphs from the movement of concrete objects. The idea behind this approach is that observing the changes in position, speed and acceleration of concrete objects can achieve a deeper appreciation of the relationships between movement and the corresponding graph. More recent studies (Nerimovsky, Tierney and Wright, 1998; Arzarello & Robutti, 2004) have adapted the sensor equipment to detect the student's movement, either producing real-time graphs on the desktop screen or storing the data for later display. They justify their approach in terms of an embodiment perspective (Johnson, 1987; Lakoff, 1987), the notion that thinking is an activity that involves the whole of the

human body and not just the brain. Arzarello & Robutti (2004) in particular, argue that the interpretation of movement graphs can be supported by the direct experience of generating them and that that embodied interaction combined with collaboration can support the transition from perceptual facts to symbolic representations. Beichner (1990) argues that the ability to view results in real time is as important as the kinesthetic elements. The study reported here follows a similar approach, however instead of using bespoke sensor equipment and desktop computers, we have employed the location awareness and relatively large screen of Apple's iPhone for both detecting the student's movement and displaying the corresponding movement graphs. In order to design a learning application with this innovative technology we employed a learner centred methodology. Before describing the design process that we followed the following section talks briefly about learner centred design.

Learner centred design

Move Grapher is an application that employs innovative technologies and whose activities and representations will be unfamiliar to learners. Therefore, to minimise the risk of producing software that would be difficult to understand and use it was important to employ an approach that has proven successful for designing innovative learning applications. LCD advocates the involvement of stakeholders (teachers, learners, education policy makers, educational researchers, etc.) at all stages of the design process as well as the use of iterative prototyping to refine the design of learning applications (Good & Robertson, 2006; Goolnik, Robertson & Good 2006). Similarly to Participatory Design (Muller & Kuhn, 1993), LCD is in favour of stakeholders partnering with designers as a way of producing more useful technology. However there are differences between these two approaches stemming mainly from the fact that in LCD the main users are young people. This fact raises issues related with the responsibilities young people should have if they are part of the design team and in general with the role and involvement that learners should have in the design process.

According to Druin (2002), the four roles that children can play in the design of new technology, from least to most involvement, are: user, tester, informant, and design partner. A user role assumes that children's interactions with technology would be observed to assess the impact it has on their learning. Traditionally, this happens once there is a finished system and the feedback obtained could be used to improve future technologies. In the tester role, besides observing their interactions with technology, researchers could ask children for their comments and opinions regarding their experiences from those interactions. Also as testers, children interact with prototypes, versions of the system that have not yet been released, and their feedback can be used to refine those prototypes. As informants, children can participate in the design process at various stages, from giving their opinions about early paper sketches or storyboards of intended ways to use technology to interacting with prototypes or with the finished system. Finally being a design partner implies an equal opportunity of contribution throughout all stages of the design process.

There have been different views as to what is a suitable level of involvement for children when designing innovative technology. Until recently, it was assumed that the most appropriate role was as user (see for example Conlon & Pain, 1996) but lately higher levels of involvement have been considered as desirable. Scaife & Rogers (1999), however, question the wisdom of involving children as design partners given that frequently they know little about the domain and the way it should be taught. They suggest that in some contexts it would be more appropriate for children to be considered as testers rather than as design partners. A design partner role is sometimes challenging even for teachers as they might know about difficulties children encounter when learning with traditional materials but not about what might be effective with innovative technology. Druin (2002) points out that this is not necessarily a problem as every stakeholder will have areas of expertise and areas they might not know much about. While children cannot do everything adults can do, they might have special experiences and view points that can enrich the design process.

Regarding the types of prototypes that could be employed, there is a continuum on the level of fidelity, how much resemblance with the final product there is, that the prototype can embody. At one end of the continuum there are low fidelity prototypes. These are prototypes produced in a medium different from the final product, for example paper sketches or storyboards illustrating intended uses of the technology. Next are mid-fidelity prototypes, possibly computerised versions but with very limited functionality. High fidelity prototypes are typically similar to the final product although they might only implement a subset of the functionality and might not be very robust (Rogers, Preece & Sharp, 2002).

Typically, low fidelity prototypes are employed early in the design process, to design the conceptual model (the high-level conceptualisation of the structure of the system), to explore alternative designs quickly and cheaply or to understand and model workflow, for example. High fidelity prototypes, on the other hand, tend to be used later in the process and mainly to evaluate interaction (Rudd, Stern & Isensee, 1996). Usually there is a smooth progression as prototypes evolve from low to mid and high fidelity. Low fidelity prototyping has been used successfully in supporting the design of the representations employed or in evaluating aspects related with the interface for learning applications, (Goolnik, Robertson & Good 2006), in mobile learning (Parsons, Ryu, Lal & Ford, 2005) as well as for systems implementing an embodied form of interaction (Fernaes and Tholander, 2006).

The design process of Move Grapher

Move Grapher was designed as an application to allow users to generate and display, immediately, distance and speed time graphs of their own motion whilst walking and running. So that learners could focus on the concepts taught rather than the working of the interface, the application needed to be quickly learnable by students and teachers. The application was designed to help identify misconceptions and gaps in knowledge while reinforcing and consolidating understanding, two of the purposes of academic games identified by Gredler (1996). Teachers involved in establishing the requirements (as described in the next section) also emphasized the importance of competitive and collaborative elements.

The iPhone has many advantages as a platform for developing an application of this nature. With GPS it is capable of detecting movement, and its 85mm screen with a resolution of 480 x 320 pixels is ideal for displaying graphs generated, allowing individual students to view their own graphs immediately. The iPhone software development kit includes frameworks for capturing and retrieving location data. The nature and popularity of the device might also prove a motivating factor for students using it.

Using GPS entails a requirement to use the device outdoors which has both costs and benefits: logistical issues arise (supervision, constraints of poor weather) but learners are freed from the space constraints of the classroom allowing them to generate graphs with a wider range of movements over a longer time period. Although the iPhone also includes an accelerometer from which movement data could be captured for the purpose of generating kinematic graphs (Anastopoulou, 2004), unfortunately the accuracy appears to be insufficient to be useful in this context. Using the accelerometer to capture motion over these distances would also require the user to maintain consistent orientation of the device, but if future iPhone revisions improve the accuracy of accelerometer data, an option could be provided to use it in this way in place of GPS with very little impact on the user interface.

Move Grapher was designed in a Learner Centred fashion and the main stakeholders (teachers, educational researchers, learners with and without any knowledge of the subject matter) participated at different moments of the design process. This process comprised an initial stage devoted to establishing the requirements of the application, a subsequent phase of generating and refining a conceptual model and its associated interface and a final stage of refining and evaluating a computerised prototype of the application. The following sections describe each of these phases.

Establishing the requirements

In determining how the application would support the teaching and learning of the concepts underlying distance and speed time graphs, nine mathematics teachers were involved in a series of interviews to establish how the application should address concepts and misperceptions, how it might be used, and what they saw as its essential requirements. Each of the teachers participating in the study was involved in delivering to students of 16-17 years of age topics in mechanics in which the understanding and application of the knowledge of distance and speed time graphs constituted a key component. The participant teachers had experience in the delivery of these topics ranging from three to over thirty years teaching.

The teachers were interviewed individually. Interviews combined closed and open questions. Each interview comprised discussions of three key aspects that would inform the development of the prototype. These were: the conceptual difficulties that their students had encountered and particularly struggled with, how the application might

be used and integrated into learning activities, and the requirements it would be essential that the application should fulfill. In establishing and prioritising these requirements, a mixture of proposed requirements and those generated by the teachers was selected by them and ranked in order of importance.

From the responses given by the teachers, it was established that the application should allow both teachers and students to create and send a graph to other users (promoting collaborative learning), that students should be able to try to match a graph displayed on screen by recreating the movement described, that students should have a high level of control in starting and stopping the recording and graphing of their movements and that an element of competition should be incorporated into the activities that application supported. Additionally, some of the teachers considered it important to distinguish between graphing distance and speed (ignoring direction) and graphing their vector counterparts (accounting for direction in how the graph is constructed); but on the means necessary to do this, perhaps by requiring users to walk in a straight line or by resolving components of the motion, there was no consensus. The action of sending graphs between users was identified in three contexts: teachers sending graphs to students; students sending graphs to their peers; and students sending graphs to teachers. The first context would allow teachers to provide students with graphs appropriate to particular (possibly differentiated) learning outcomes, the second would promote independent and group learning and the third would allow teachers to assess and provide feedback on the product of the students' work.

Paper prototyping

The paper prototyping studies can be divided into two, the first to support the generation and refinement of the conceptual model with educational technology researchers as participants and the second to refine the graphical interface with students as participants.

Generating the conceptual model

The concrete aim of this part of the study was to choose a model to ask student participants to evaluate, identify potential issues that students might have with the initial interface designs presented, and to generate ideas as to how the affordances of the iPhone might support the aims of the application.

Two storyboards were prepared based on alternate conceptual models. The first was closely based on a constructionist approach (Papert and Harel, 1991) in which the graphs themselves are learning objects to be generated, shared and discussed by students (Simpson, Hoyles and Noss, 2006). The other placed greater emphasis on creating graphs as part of an academic game (Gredler, 2006), in which key concepts required for creating and interpreting kinematic graphs were implicit rather than explicit, but in which knowledge gaps are identified and understanding is consolidated and reinforced. In each case collaboration was central to the design. Each cell in the storyboards showed a screen in a particular state, marked with indications as to what would appear when any given control was touched.

The educational technology researchers comprised six members of the University of Sussex Interactive Digital Educational Applications, some of whom also had recent involvement in the teaching and learning of kinematics. They were asked to conduct a cognitive walkthrough using two tasks for each prototype, taking on roles as students and considering whether the user would understand the action required, see what was needed to complete it and interpret the response at each stage. The object-based prototype was evaluated by walking through the process of creating a distance time graph (by moving around) over a specific period to send to a fellow student, then as that student receiving the graph and creating (again through movement) a graph to match it as closely as possible, and reading of the accuracy score representing how close they came. For the purpose of evaluating the level based prototype, the researchers considered two tasks: beginning and playing the game by moving around; and viewing and helping another user by calling directions.

The findings showed that the object-based prototype was easier to understand than the level-based prototype, although it was felt that the latter might make a better game. An advantage offered by the object-based prototype was the depth of understanding that explicitly connecting with and reinforcing graphing concepts would offer. Based on

this feedback, the object-based prototype was developed for evaluating with students, incorporating a number of minor changes to the graphical user interface to improve navigation within the application.

Refining the graphical interface

Learners were involved in evaluating the paper prototype that was developed from the storyboards incorporating refinements from the educational technology researchers. The purpose of this study was to inform refinements to the graphical interface by eliciting feedback from students drawn from the target user group, and to identify any other barriers or obstacles in the completion of tasks typical of those that might form part of a lesson on kinematics. The paper prototypes constituted pen and paper sketches of the application screens, with controls and other dynamic elements of the graphical interface represented by sticky notes as illustrated in Figure 2. The tester manipulated these elements, and drew graphs where appropriate, in response to the learners' actions. This allowed users to dynamically interact with the graphical interface, seeing the effect of their interactions represented immediately. Because of the nature of the prototype, learners remained static whilst using the application and where user movement formed an inherent part of the task they described in their own words how they would move.



Figure 2. First paper prototype

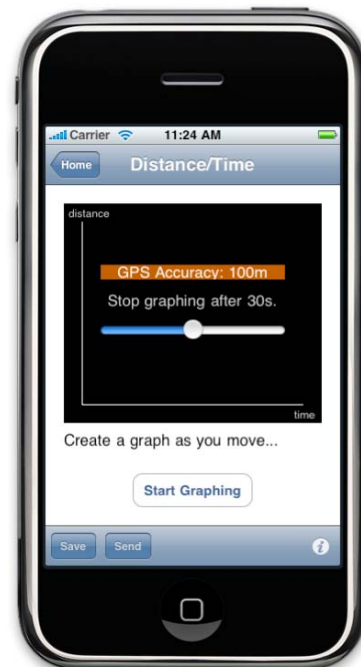


Figure 3. New graph screen, first high fidelity prototype

Students taking part in the evaluation had already studied kinematics, some at advanced level, and were therefore capable of critically reflecting on the application and its relation to their previously acquired knowledge of the relevant concepts. The decision to involve students with a previous knowledge of kinematics was taken given that, according to Scaiffe & Rogers (1999), children cannot discuss knowledge they have not yet acquired. These students were all advanced level mathematics students of between sixteen and seventeen years of age. They could be considered proxy users because of their prior learning: the effect of the study on their own learning was not a part of the evaluation (although the application is also designed as a tool for revision and consolidation for which this would be a target user group).

The paper prototype was developed through two iterations, each being evaluated with four or five learners. Different students were used in each case so all participants were equally unfamiliar with the application. Each learner individually completed a set of tasks by touching the paper prototype and, where appropriate, describing how they would move with the device. Although learners carried out these tasks individually, they included sending, receiving and interacting with graphs as if collaborating with classmates. Feedback was gathered through a short sequence of

questions both before and after the tasks were completed, and from during the task using the “think aloud” protocol. Video of the paper prototype was recorded along with the learner’s commentary so that their progress through the application could be reviewed along with their words.

Several of the learners commented on the overall ease of use and simplicity of the interface. However the most important finding from the study arose when it became clear that users could complete an entire task without realising that they were creating a distance time graph rather than a speed time graph. The interface was redesigned to force users to make an explicit choice. In several cases, the learners also did not see how to start and stop the application from recording and graphing their movement, one of the requirements highlighted as a priority by the teachers. Improvements to the interface rationalised how these settings were presented. Besides these critical changes, the results of the evaluation also highlighted aspects of the interface where the symbols or terminology used was not fully understood by the learners allowing these to be made more appropriate to the target audience.

High fidelity prototyping

The aim of the previous evaluations had been to use information from the learners to improve the graphical user interface. With a hybrid mode of interaction inherent in the design, however, it was important to evaluate the interactivity, particularly its embodied element. Progressing to the development of a high fidelity prototype at this stage made it possible to conduct further studies, both to assess the usability of both forms of interaction and to conduct a preliminary evaluation of the effectiveness of the application for supporting the learning of movement graphs. To determine how the response of the application compared to user expectations, both from usability and educational perspectives, it was essential to implement a prototype that actually employed GPS to allow user interaction in the physical domain. This interaction could have been simulated to build a medium fidelity prototype by having the iPhone view a web-based version of the interface, and having the users movements entered by a researcher, however the complexity involved in implementing such a prototype would be similar to that of the high fidelity prototype. Therefore to benefit from having users interact with GPS a high fidelity prototype was implemented next.



Figure 4. The start menu



Figure 5. The graph received alert

The high-fidelity prototype was developed on the iPhone based on the final paper prototype (see Figure 3). It was implemented in Objective-C using the following tools and libraries from the iPhone Development Kit: X-Code 3, Interface Builder and the Cocoa Touch application-programming interface. In particular, GPS locations were accessed using the Core Location framework, and graphs displayed using functions from Core Graphics. The

prototype version also used the Bonjour Service Discovery Protocol for discovering and connecting with other devices running the application for the purpose of sending graphs; the next revision will use the Bluetooth peer to peer networking in the Game Kit framework to offer this functionality without any Wi-Fi network being necessary. The current version of the prototype comprises approximately 3,700 lines of code in twenty custom classes.

The prototype offers the functionality to create distance and speed time graphs from movement; save, send and receive these graphs; to browse through an illustrated table of saved and received graphs stored on the device; and match a received graph or guess (by tracing on the screen) the shape of a hidden graph. For matched or guessed graphs, the application also calculates a measure of closeness between the learner's version and the original. Figures 4 and 5 illustrate the application's options to activate some of these functions.

Evaluating the usability of the interaction

The prototype was refined iteratively through evaluations with users. This study shared with the previous one the focus on the usability of the interface, and again proxy learners with a well-developed understanding of the mathematical concepts were employed in the studies. Once again an evaluation was conducted with five learners, the results of which informed refinements to the prototype, and a further evaluation involving five learners provided feedback both on these refinements and any other aspects the changes brought to light. Similarly to the paper prototype evaluations, different students were used in each case so all participants were equally unfamiliar with the application.

Whilst the structure of the process for each learner followed a similar pattern, the high fidelity prototype was tested out of doors where a good GPS signal could be obtained. Testing the application in this context made it possible to evaluate its performance in a range of conditions, for example with bright sun on the screen which proved not to cause any problems. Similarly to the paper prototype evaluations, feedback was gathered through a short sequence of questions both before and after the tasks were completed, during the task using the "think aloud" protocol and from the recorded video. However difficulties were encountered with capturing usable video, and better results might be obtained by building a mechanism for screen and audio capture into the application itself. As before, the tasks included simulated collaborative interaction: sending, receiving and interacting with graphs as if working with classmates.

The results of the evaluation included highlighting the usability of the application, specifically the simplicity and intuitiveness of the user interface, which as with the low fidelity prototype several users explicitly mentioned. Users described the application as fun as well as useful. Over the two iterations, a number of improvements were suggested and implemented to address issues where users failed to find settings or cleared their graph unintentionally: From the first test it became clear that a lag (of approximately 5 seconds with a good GPS signal) was confusing users. The lag may be due to the hardware (the GPS chip, antennae or processor speed) or Apple's implementation of the Core Location framework. Future firmware or hardware versions of the iPhone should see this delay reduced, but an indicator showing where the graph would be drawn was found to be useful by users in the second round of testing. It also became apparent that learners with prior experience using an iPhone or iPod touch recognised where to look for controls positioned consistently with the iPhone human interface guidelines, whilst other learners took one or two attempts to locate these.

Preliminary educational evaluation

To test the effectiveness of the application, we intend to test the application as a learning resource with several groups of learners collaborating on activities in the context of a pre-university course. This evaluation has yet to take place, however in a preliminary small-scale study to investigate the effect on learning of the application prototype, three learners at the lower end of the target age range were asked to use the final prototype in a number of activities reflecting the way the teachers had originally suggested the application might be used. The users were selected to include one learner who had yet to be taught kinematics, one user who had begun to learn the topic, and one user who had studied the topic over two years (aged 13, 14 and 15 respectively).

To assist in clarifying how the students' knowledge developed, the students were asked to complete a set of multiple-choice questions before using the application, and a similar (but different) set afterwards. These questions were based on those developed by Beichner (1994) and Simpson, Hoyles and Noss (2006).

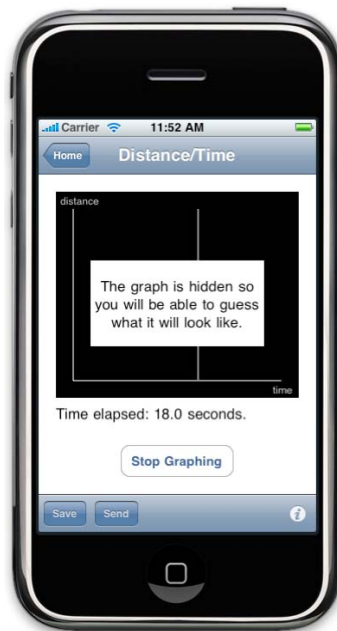


Figure 6. Graph Guessing mode

After completing the first set of questions, the students were shown how to create distance/time and speed/time graphs using the application and asked to spend five minutes exploring these and to explain what they thought the differences were. They were asked to save a graph of each type and talk through what they considered the important points. The students were then given two exercises to complete. In the first they were then given a graph of each type (similar to the one shown in Figure 1) to try to match by moving, and asked to comment on which aspects they found easy and which they found difficult in accomplishing this. In the second, the students were asked to create a graph of each type with the guessing mode on, and to try and predict what it would look like (see Figure 6). Again, they were asked to say what they found more or less challenging.

The student who was unfamiliar with kinematics was unsure at first whether to wave the phone around to create a graph, or to move around herself; experimenting she discovered that walking produced a response on screen. However, her confusion at exactly how the graph related to movement continued; she persistently confused distance and speed time graphs during the activity and when she got counter-intuitive results she would switch both the type of graph on the phone and her mental model, recreating the mismatch. She was able to identify on the graphs where her motion changed (especially in terms of changes in speed) but was not always confident in predicting how this would affect the graph drawn on the iPhone if required to sketch it. She gave her most accurate answers when discussing matching a speed time graph, immediately identifying how to modify her motion to obtain a closer match on the screen. The next youngest learner was familiar with calculating speed but not acceleration. The learners with some familiarity with distance and speed time graphs also initially confused distance and speed, but were quicker to recognise the connection between these concepts and the graphs displayed on the iPhone. They both made similar mistakes initially, but the eldest learner became fluent in identifying the correct type of motion to employ most quickly, and responded accurately to questions as to where the greatest and least speeds were drawn on each type of graph.

Discussion

Overall, the LCD approach proved very useful in producing an application that can exploit students' kinesthetic functions to support effective mappings between movement and its graph representation. In particular, involving

stakeholders in all phases of the design process and the use of iterative prototyping were of central importance to identify a suitable conceptual model and to validate and refine the design. However some characteristics of the application and the modes of interaction influenced the roles some stakeholders could play in evaluating the prototypes, and the complexity of simulating location awareness relative to implementing a GPS aware high-fidelity prototype affected the choice of prototype deployed.

Move Grapher enables students to create movement graphs while moving, and to observe these graphs outdoors, where they have been generated, using a combination of innovative technologies and concepts: mobile phones with location awareness and relatively large screens as well as an embodied type of interaction. All these innovations are central in supporting the learning activity. Without location awareness it would not be possible to create real time graphs and without embodied interaction graph generation usually requires students to make use of advanced computing or programming skills (Simpson, Hoyles & Noss, 2006). This could divert their attention from the main learning task.

Students were involved in low fidelity prototype evaluation, however these were students already with a basic knowledge of movement graphs who could discuss the application in the context of this knowledge and focus on any confusions arising from the interface (rather than from the concepts). Given that they already knew about the principles of movement graphs, they could be considered as proxy learners; although interaction with the application would be a way to consolidate their knowledge and highlight misconceptions in its application. In terms of Druin's (2002) classification, students in this case could be considered as falling into a type between testers and informants. They were involved relatively early in the design process and voiced their opinions about low fidelity prototypes, however their participation in those cases was limited to evaluating the user interface and they did not participate in generating or refining the conceptual model. Other stakeholders, teachers and educational technology researchers, were involved at early stages of the design to support the generation of a suitable conceptual model and the refinement and validation of the initial paper prototypes.

A related issue is the fact that the design went from paper prototypes to high fidelity prototypes implementing most of the functionality. Frequently this transition is smoother but in this case there was not much point in generating prototypes that would only simulate location awareness or would not run on a handheld device given that the complexity involved in implementing them would have been similar as that of generating the high fidelity prototype.

Other important issues stemming from the study are the suitability of GPS technology to produce real time graphs, the appeal and motivation of the learning tasks, and the preliminary conclusions that can be drawn regarding the educational potential of the application.

The Move Grapher application graphs distance or speed against time with a good GPS signal, and accuracy is sufficient to display movement and walking pace meaningfully. However, the limitations due to the technology are significant: firstly the delay between a movement being made and the production of the graph is approximately of five seconds, so that the graph being viewed is not presented in real time. While this is still reasonably fast (compared to the 20 second delay discussed by Beichner, 1990), users found the delay in the first version of the high fidelity prototype confusing. It has been possible to find a suitable workaround to help users predict where the graph will be drawn, and users in the subsequent test responded positively to this. However true real-time graphing would eliminate this issue entirely. Secondly, the inaccuracies are still such that it has been necessary to use a moving average to "smooth" the results that are displayed, introducing a "softening" of sudden movements, so that graphs may not accurately reflect user expectation causing confusion for the learner who may attribute an unexpected result their own misconceptions when in fact the graph should have confirmed their understanding. The nature of the application makes it difficult to write an algorithm to filter or extrapolate from the results using intelligent guesswork and prediction, since if it is used as intended there should be no "typical" movement to base any such algorithm upon.

Collaboration and competition are key aspects of the application. Simply creating a graph from movements is a useful exercise but of limited appeal. The facilities to share graphs to other users, to try to match graphs or to predict how graphs will look are all essential to the learning process: the user is engaged in interpreting movement as a graph or visa versa. The scoring of closeness introduces a game element that can motivate an individual (trying to improve on previous scores) or groups (trying to get the highest score, trying to create a graph that will be difficult to match). Further ideas for introducing game elements, like those developed at the early stages of the design process, may increase the intrinsic appeal of the application. For example the notion of levels could stage progression to

support the development of the learner's skills and designing them would be an opportunity for learners to exercise their own creativity. The process of constructing a level rather than a graph would stretch the user to develop their abstract conceptual understanding even further.

The evaluation of high fidelity prototypes included an element which could be considered as a preliminary educational evaluation. This evaluation has shown that the application can be effective in drawing users' attention to their misconceptions where an understanding of kinematics is already developed. However, it may be that for users trying to develop this understanding persisting confusion acted as a barrier to engagement. By providing a more accessible primary goal ("winning" a level) while reinforcing the underlying concepts as a secondary effect, a more game-like virtual environment might engage beginners for longer and so support conceptual development more effectively. However these conclusions have to be considered as preliminary given the small numbers of participants involved in that part of the evaluation, and as hypotheses they will be tested in the full scale educational evaluation that has yet to be carried out.

Conclusion

The paper has described the design of Move Grapher, an application that employs innovative functionality of modern mobile phones such as location awareness and relatively large screens and that aims to support the learning of movement graphs for pre-university students. The development of the application followed a Learner Centred Design process; stakeholders were involved at every stage of the process and the design was refined through iterative prototyping. The final version produced met the initial requirements: it enables both teachers and students to create graphs by moving, to send those graphs to other users and allows students to match a graph displayed on screen by recreating the movement described. Users have a high degree of control in generating, sending and receiving graphs of their movements. The application has a good usability and a preliminary learning evaluation suggests that the tool has plenty of scope in reinforcing the learning of movement graphs and addressing students' misconceptions in this area. Learner Centred Design proved very useful when designing learning applications for which innovative concepts and technologies play a crucial role. In this design approach iterative prototyping is encouraged and frequently medium-fidelity prototypes that simulate some part of the functionality are created. However in this case it was found that the complexity of implementing this type of prototype would be similar to that of the high fidelity prototype and therefore a high fidelity version was directly implemented. Two important drawbacks from the particular location aware technology used are a five second delay between the movement being made and the graph being generated and an insufficient accuracy to produce a smooth graph. The application addresses these limitations by using a workaround (asking students to predict the shape of the graph) and by "softening" very sudden changes in the reported position.

Although the technologies employed and in particular the developed prototype have shown strong potential to support the learning of kinematic graphs, the reported study represents an initial step in our research agenda. Move Grapher needs to be evaluated to investigate its educational merits. The evaluation should take place within the context of kinematics pre-university courses that employ the tool as a learning resource, involving using the tool collaboratively in group work and ideally investigating its effectiveness for students with different levels of kinematics knowledge. Further work should also include the implementation of game-like elements in the application to increase its appeal.

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Mobile-Device-Supported Problem-Based Computational Estimation Instruction for Elementary School Students

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ABSTRACT

This study implemented a three-stage problem-based estimation instruction scenario and combined it with mobile technology to provide elementary teachers with an effective e-tool for observing student estimation and leading effective class or group discussions on the selection and assessment of appropriate strategies for solving daily estimation problems. Twenty-eight fourth graders were randomly sampled and assigned to two groups: the experimental group (problem-based estimation instruction using mobile devices) and the control group (problem-based estimation instruction without mobile devices). The analytical results demonstrated that problem-based estimation instruction could effectively help students learn computational estimation skills. Moreover, using mobile devices for problem-based computational estimation instruction appeared to help students discuss and cooperate with others, and moreover the mobile-device-supported problem-based estimation scenario helped students develop metacognition knowledge of estimation strategies.

Keywords

Computational Estimation, Number Sense, Mobile Learning, Problem-Based Learning

Introduction

Computational estimation refers to attempts to make reasonable guesses of approximate answers to arithmetic problems, either without performing actual calculations or before performing them (Dowker, 1992). Computational estimation is a complex skill involving many of the same subtleties and complexities as problem solving. A good estimator can select a strategy appropriate to the problem, including the specific numbers and operations involved (Reys, 1986). Abilities such as flexible thinking, decision-making, answer adjustment, and filtering out of non-sensible answers are crucial to cultivating good estimation skills (Trafton, 1988) and good estimation skills can in turn enhance applied mathematical skills (Coburn & Shulte, 1986).

Computational estimation is one of the most powerful and useful aspects of estimation, and becomes easier to use in daily life, where an estimate is often the only alternative to solving a problem (for example, rapidly selecting the best bargain in a time-limited anniversary sale). The most widely used computational estimation strategies are rounding (up or down), compatible numbers, front-end, and clustering. The rounding strategy is a powerful and efficient method of estimating the sum of several numbers or the product of two multi-digit factors. The rounding strategy can round numbers to the closet larger decade (rounding-up) (e.g. calculating $90 \times 80 = 7200$ to estimate $87 \times 79 = 6873$) or the closet smaller decade (rounding-down) (e.g. doing $400 + 200 = 600$ to estimate $412 + 243 = 655$). If a set of numbers can be easily “fitted together” the compatible number strategy is a good estimation option. When using this strategy, it is best to view all numbers involved in a problem and find those that can form pairs, such as a hundred. For example, one can pair 26 and 81, 56 and 48, and 33 and 75 to form three hundreds to estimate the sum of the six numbers ($26 + 56 + 33 + 81 + 48 + 75 = 319$). This strategy essentially involves combining flexible rounding with experience. The front-end strategy focuses on the “front end”, or left-most digit, of a number, and is particularly useful in estimating solutions to addition problems. An example of using this strategy is calculating $1 + 5 + 3 + 4 = 13$ to estimate the sum of 1.02, 5.53, 3.14, and 4.33 (the sum is 14.02). The clustering strategy can be employed when a group of numbers “cluster around” a common value, such as when 68 and 72 cluster around the

number “70”. For example, to estimate the sum of the five numbers, 78123, 80258, 80301, 79887, and 81926, one can observe that all these numbers are “about” 80000, and then simply multiply this figure by five, yielding a figure of 400000, which is very close to the actual solution of 399865.

Goodman (1991) proposed explicitly teaching estimation skills and strategies to students, and stressing mathematical concepts and properties related to computational estimation. However, those estimation skills and strategies are difficult to address in daily math lessons. Unfortunately, the failure of schools to properly teach these skills (Threadgill-Sowder, 1984) has led to students having poor estimation skills (Case & Threadgill-Sowder, 1990; Dowker, 2003; National Council of Teachers of Mathematics, 2000). Elementary mathematics education in Taiwan also suffers from this problem. According to the General Guidelines for the Grades 1-9 Mathematics Curriculum for Elementary and Junior High School Education (Ministry of Education, 2006), estimation is introduced from grade 3 onwards in elementary education in Taiwan. Estimation is included in the curriculum to help students develop estimation skills they can apply in problem solving. However, a lack of clear guidelines means teachers easily misunderstand the real objectives of estimation instruction and have their students learn estimation by operating calculator (Ong, 2005). Furthermore, teachers teach their students a simple rounding strategy rather than providing them with a complete introduction to and training in various estimation strategies. The instruction situation thus reflects the observation of Reys and Bestgen (1981) and Golden (1998), that estimation lessons typically teach rounding. In Taiwan, students are asked to provide a “unique” estimate by following specific directions, including “round up the answer to hundreds place” or “round down the product to the hundredths place”. The lack of practice in essential estimation skills (e.g. flexible thinking, decision-making, answer adjustment, and filtering out of non-sensible answers) has led to failure to develop student sensitivity and flexibility, both of which are crucial to effective estimation. Consequently, students tend to calculate the exact answer first and then “estimate” based on that answer, confusing them regarding the point of learning “estimation”.

According to the estimation process, a better way to help students develop estimation skills would be to view estimation abilities as a thread to be woven into instruction on estimation, computation, and problem solving. Reys (1986) proposed that the optimal method of developing estimation skills should combine three phases, namely instruction, practice, and testing (making it necessary assess the appropriateness of the selected strategies and the estimation results), which like problem-solving techniques are developed by careful instruction, discussion, and strategy use. Trafton (1988) also proposed that teachers should carefully motivate students, monitor student thinking, clarify study objectives, and be sensitive to the pace of instruction and estimation precision. Trafton (1988), van de Walle (2005), and Case and Threadgill-Sowder (1990) noted that teachers should employ appropriate examples to help students learn different estimation strategies and then employ problems to stimulate students to select an appropriate problem solving strategy via group discussion and reciprocal learning. Trafton (1988), van de Walle (2005), and Case and Threadgill-Sowder (1990) describe this approach to instruction as a problem-based learning (PBL) approach.

In PBL, students work in small collaborative groups and learn the knowledge required for problem solving. The teacher thus becomes a facilitator to guide student learning rather than a repository of knowledge (Hmelo-Silver, 2004). Based on the survey of Norman and Schmidt (1992) and the research of Hmelo-Silver (2004), PBL is identified as offering several potential advantages for student learning: (1) learning in PBL format may initially reduce levels of learning but over periods of up to several years may foster increased knowledge retention; (2) PBL curricula helps students develop flexible knowledge and effective problem-solving skills and enhances the transfer of both concepts and knowledge to new problems; (3) PBL achieves a sustained improvement in self-directed learning (SDL) skills; (4) PBL increases intrinsic interest in the subject matter being taught; and (5) PBL helps students develop effective collaboration skills. Although plenty of evidence exists supporting PBL in students learning, much of the research on PBL has been limited to higher education, mainly in medical schools. Few studies on PBL have considered K-12 education (Hmelo-Silver, 2004). Moreover, the majority of the research on PBL focuses on knowledge construction, problem solving, and SDL, and few works have focused on motivation and collaboration. Hmelo-Silver (2004) argues that PBL should be modified to support PBL for younger learners, particularly the SDL process, which may prove particularly difficult for those who tend to have difficulty applying metacognitive strategies.

The requirement of tailored PBL argued by Hmelo-Silver resembles the claim of Goodman regarding the design of teaching scenario of computational estimation. Goodman (1991) stated that further research on estimation should focus on the estimation instruction scenario, and moreover should clarify when specific estimation strategies should

introduced, as well as what activities, materials, and teaching strategies are best suited to helping students acquire estimation skills. Although the importance of acquiring skills in computational estimation is widely recognized, few works have examined how to implement a problem-based instruction scenario to provide instruction in estimation skills. Furthermore, most research on computational estimation has focused on four topics: relationships between estimation abilities and other abilities (Goodman, 1991; Levine, 1982); identification of estimation strategies (Lemaire & Lecacheur, 2002; Threadgill-Sowder, 1984); error patterns (Reys, 1984); and development of numerical estimation (Case & Threadgill-Sowder, 1990; Siegler & Booth, 2004; Booth & Siegler, 2006). Few studies have applied collaborative learning to PBL to help students develop essential computational estimation skills. This situation may result from the difficulty of effectively implementing group discussion or reciprocal learning in traditional elementary classes. According to Lan, Sung, and Chang (2007; 2009), owing to the lack of target abilities, discussions (among the whole class or in small groups) tend to be dominated by students with stronger target abilities. To deal with the above problems associated with traditional cooperative learning activities, numerous researchers (such as, Lan et al., 2007; 2009; Huang, Kuo, Lin, & Cheng, 2008; Hwang, Yang, Tsai, & Yang, 2009) argued that mobile technology is not only a feasible means of resolving the above obstacles to effective group discussion and reciprocal learning, but can also help teachers observe and track student thinking because of its unique characteristics, including portability, social interactivity, connectivity, individuality, and immediacy.

Considering the limited number of investigations applying cooperative PBL to train elementary students in computational skills, and the very limited number of studies examining the effects of using mobile technology in such training settings, this study implemented a problem-based estimation instruction scenario and assessed effects on training student estimation skills, both with and without mobile technology involvement.

Method

Participants

Because of the limited quantity of mobile devices available (14 Tablet PCs), the study sample comprised just 28 fourth graders randomly sampled from two classes (each containing 26 students) that were stratified sampled from an elementary school in Taipei. All participants were randomly assigned to two groups: the experimental group (problem-based estimation instruction with mobile devices) and the control group (problem-based estimation instruction without mobile devices), each of which thus contained 14 students. The students were then grouped into several small estimation groups, each comprising three or four students. Consequently, each group comprised four small estimation groups, two of three students and two of four students. According to the General Guidelines of the Grades 1-9 Mathematics Curriculum for Elementary and Junior High School Education (Ministry of Education of the Republic of China, 2006), estimation is included in daily math classes, being introduced from grade 3 at the elementary level. Therefore, at least according to the curriculum, all participants had three semesters of exposure to estimation skills via their math class.

Design

This study adopted a mixed research approach, simultaneously gathering both qualitative and quantitative data. In terms of qualitative data, two observers recorded the treatment activities using two digital video cameras (each camera focused on one of the small estimating groups). After completing each unit, the two observers compared their observation results. Furthermore, following treatment the observers reviewed the videotapes of the group estimating process, focusing their observations on the following: (a) individual estimation, (b) self-reflection regarding their estimations, and (c) group cooperation to solve real world estimation problems.

For quantitative data, this study adopted an experimental design. Twenty-eight students were randomly assigned to two groups as detailed above (Participants section). All participants were administered a computational estimation test before and soon after treatment. Student test scores were gathered and analyzed to check whether the two groups performed or progressed differently in terms of computational estimation skills. Furthermore, to understand whether students selected appropriate estimation strategies or problem solving; following the post-test all the students were asked to write down the strategies they used to solve a real world problem which is described in the section on the assessment instruments.

Instruments

Estimation instruction materials

The estimation instruction materials included four units teaching the following estimation strategies: front-end, clustering, rounding, compatible numbers, special numbers, and initial estimate adjustment and refinement. Each teaching unit includes three stages: strategy introduction, individual practice, and group cooperation. Additionally, each strategy was introduced via examples and real world problems. Furthermore, the strategies were delivered via discussion (whole class and small group) and problem-solving activities, as detailed in the section on procedure. Appendix A presents an example of a teaching unit. The corresponding learning activities are detailed in the “Learning scenario” section. Additionally, each teaching unit was taught via two 40-minute periods each week, meaning the four units were taught over 4 weeks.

Assessment instruments

Assessment of the Computational Estimation Abilities of Elementary School Students (CEA Assessment). The CEA assessment was developed by Liu and Lin (1995), and is standardized and specifically designed for Taiwanese elementary school students. The instrument includes a three part computational estimation, involving a total of 36 items, including: order of magnitude estimation, reference number estimation, and open ended estimation. The measurement instrument used in this study comprised the first 24 items of the CEA assessment, *i.e.* 12 items involving order of magnitude estimation (e.g. identifying which option is closest to the answer of $9678-325$: 80, 800, 8000, or 80000) and 12 items involving reference number estimation (e.g. estimating whether the result of 47×32 is bigger than 2000, bigger than 1200, smaller than 1000, or smaller than 800). To prevent students from performing actual calculations, each item was presented for only 15 seconds, after which students were asked to write down their estimates on a small answer sheet, as shown in Figure 1. The scoring mechanism gave each student one point for each correct estimation.



Figure 1. The answer sheet used in the CEA assessment

Assessment of applying estimation strategies (AES assessment). This test assessed student metacognition knowledge regarding selecting and using appropriate estimating strategies to solve a real world problem. The students were shown the item for only 15 seconds and were then asked to write down their estimation strategies. The problem is detailed below.

Some guests are visiting your house this Saturday. Mom has gone to the supermarket to shop for the guests, and is now waiting at the check out, with just one other shopper ahead of her in the queue. At this point she suddenly realizes that she has only 600 NT dollars, and worse still has forgotten her credit cards. She must quickly decide whether she has enough money to pay for her shopping. The prices for the individual items are as follows: 39, 23, 151, 48, 62, and 82 (NTD)

Learning Environment

The Group Scribbles platform. Group Scribbles (GS), developed by SRI international (SRI International, 2007), enables collaborative generation, collection and aggregation of ideas via a shared space based on individual effort and social sharing of notes in graphics and text form. GS supports the coordination of different processors and operates on various client computing devices, including laptops, Tablet PCs, and PDAs. In this study, each student in experimental group was provided a TravelMate C110 Convertible Tablet PC to write down their estimation results. The main GS operation interface takes the form of a three-paned window, as illustrated in Figure 2. Meanwhile, the lower pane is the user's personal work area, or "private area", which contains a virtual pad of fresh "e-sticky notes" on which the student can record their estimate. The "tool bar," shown to the right of the private area, enables users to select the note color and choose whether to input data by drawing or typing. An e-sticky note can be made visible to others by dragging it into the "public area" in the middle upper pane, which is synchronized across all devices. Executing a reverse drag makes the item private again. Users may interact with public e-sticky notes in various ways, including browsing, repositioning them, or moving them from the public area and into their private space. The right upper pane is used for group work, which supports student idea sharing in small groups. An e-sticky note can be invisible to others but group members can see it by dragging it into the group area work. Additionally, the left side of Figure 2 contains a frame called the "control area", which is only visible to the teacher, and which lists all the student numbers and helps the teacher to group students into small cooperative groups.

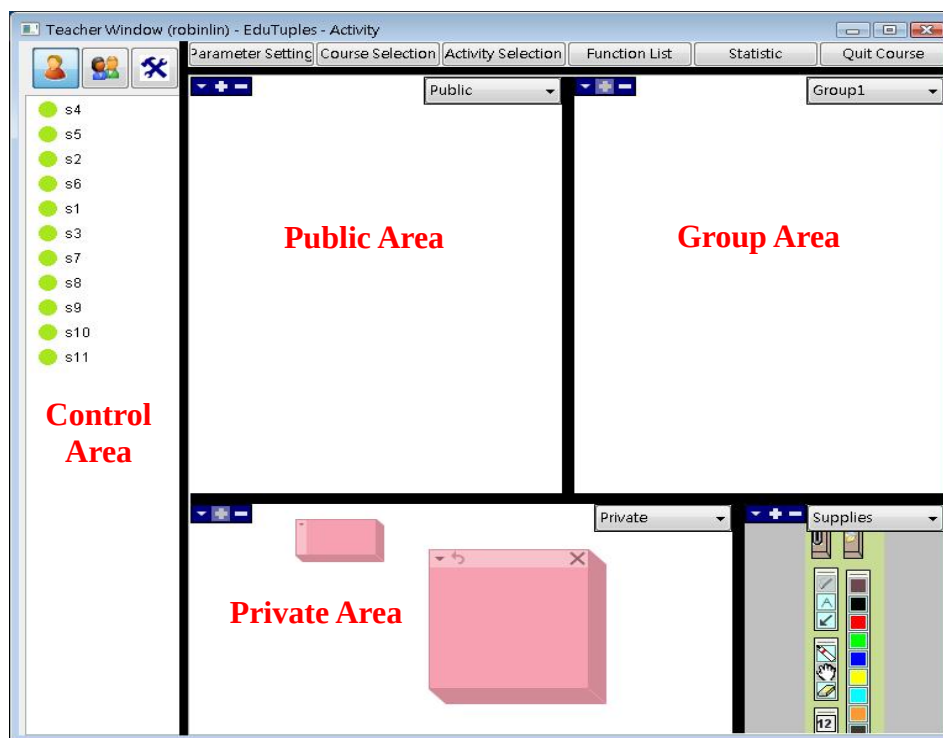


Figure 2. GS operation interface

Learning scenario. To facilitate individual and cooperative learning in PBL for elementary students and cultivate their computational estimation skills, the learning scenario for each teaching unit involves three stages: strategy introduction, individual practice, and group cooperation. During the first stage, strategy introduction, a power-point file presenting a problem-based story is projected onto the screen accompanied by several embedded problems to train students in essential computational estimation skills. The learning activities during this stage focus on class discussion, and the teacher leads the class in identifying the problem and devising the most appropriate estimation strategy. Appendix A. (a) illustrates a fragment of a story line used to introduce and teach students the compatible number and rounding strategies. During this stage, the teacher encourages each student to write down their estimates and drag the e-sticky note into the public area for sharing with the whole class, as illustrated in Figure 3. Changes in the estimation result are permitted within the time limit. Therefore, each student can change their mind if they think someone else has a better answer than theirs. Additionally, to confirm that students understand why and how to

choose an appropriate strategy, the teacher asks students why they selected their preferred strategies and how they obtained their estimates.

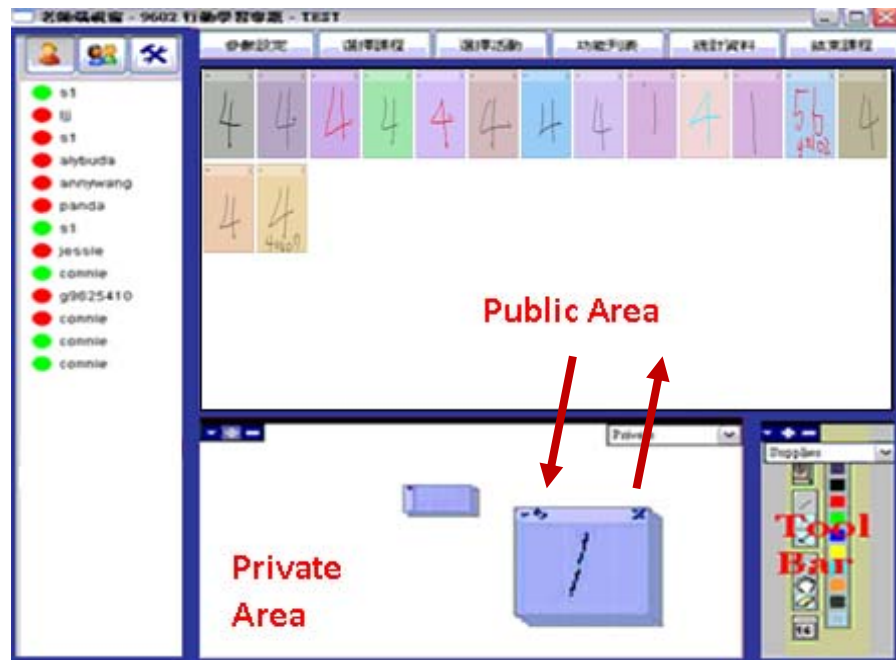


Figure 3. Example of individual estimation results from the strategy introduction stage presented for discussion by the whole class

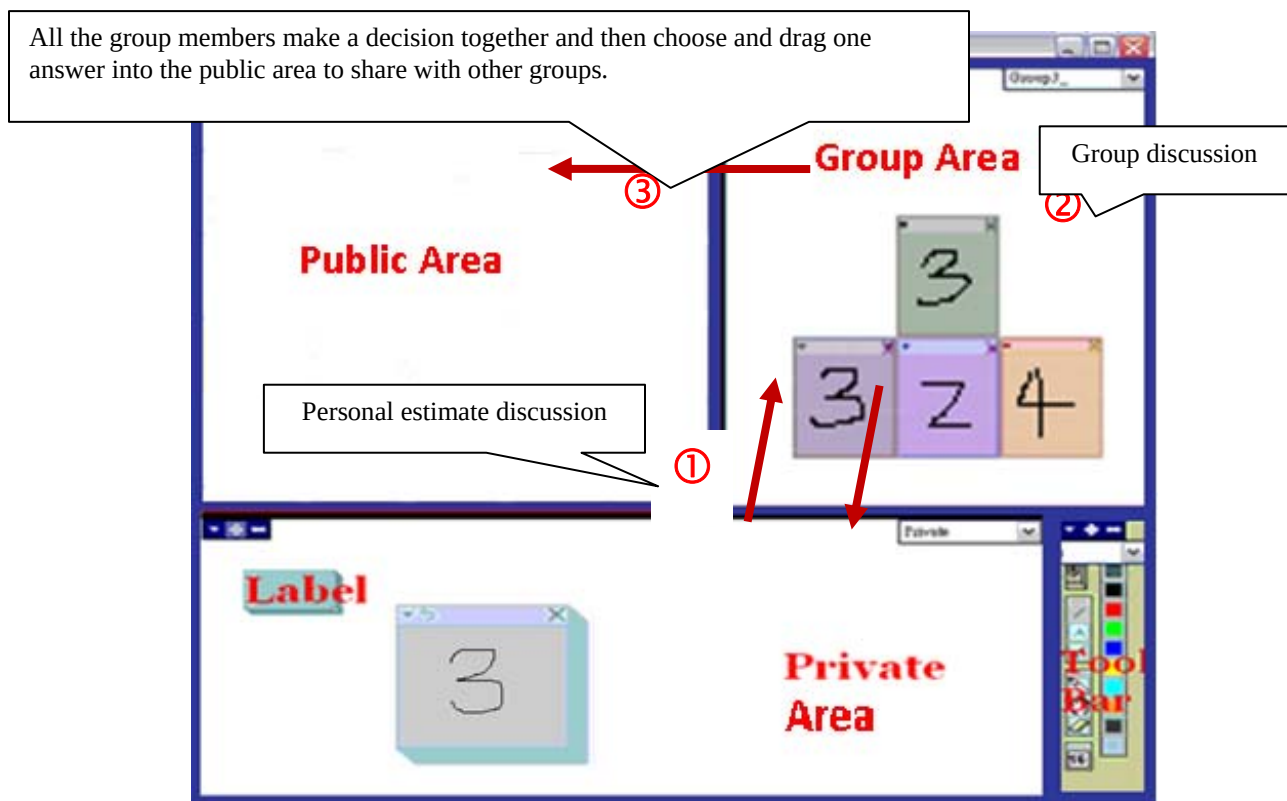


Figure 4. Example of group cooperation -- group discussion

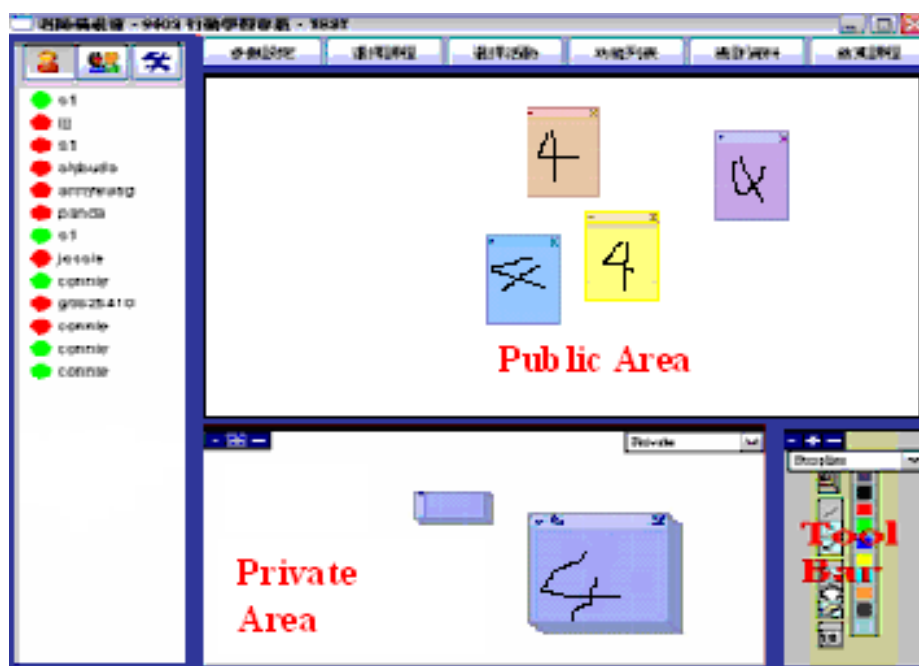


Figure 5. Example of the final results of group cooperation

After all the strategies included in a unit are introduced to students, a series of similar estimation problems is employed to train each individual to master the taught estimation strategies, namely, the individual practice stage. During this stage, the estimation problems are projected on the screen individually, and each student is asked to write down their answer on an e-sticky note in the private area, before dragging it to the public area (as shown in Figure 3). When the time is up, the teacher leads the whole class in discussing and deciding on the correct answer. Appendix A. (b) shows the practice problems used to help the students master the compatible number and rounding strategies. Finally, during the group cooperation stage, a challenge problem is projected on the screen, and all groups are asked to conduct intra-group discussion, select the most appropriate estimation strategy and also provide the correct estimate. Each group member first writes an estimate on their e-sticky note in the private area, and then drags the note to the group area, as shown in Figure 4. While conducting group discussions, a group member can change or insist their estimate depending whether they agree with the opinions of others. As soon as they reach agreement, group members drag their final estimate result to the public area for sharing with other groups, as shown in Figure 5. Finally, the teacher leads the class to confirm the estimate results and also encourages each group to share their reasons for strategy selection. Appendix A. (c) illustrates an example of a challenge problem used during the group cooperation stage.

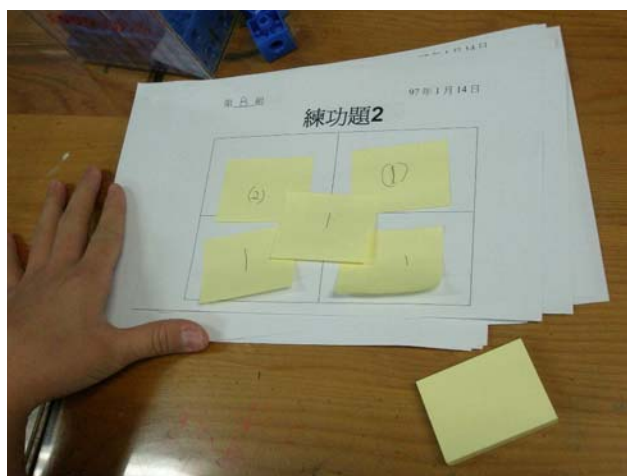


Figure 6. Sticky notes containing student estimates (the control group)

Sticky notes

A stack of sticky notes was provided to each of the estimation groups within the control group. While practicing estimation strategies or solving estimation problems, the students in the control group used these sticky notes to record their ideas or estimation results, thus facilitating sharing with others (as shown in Figure 6).

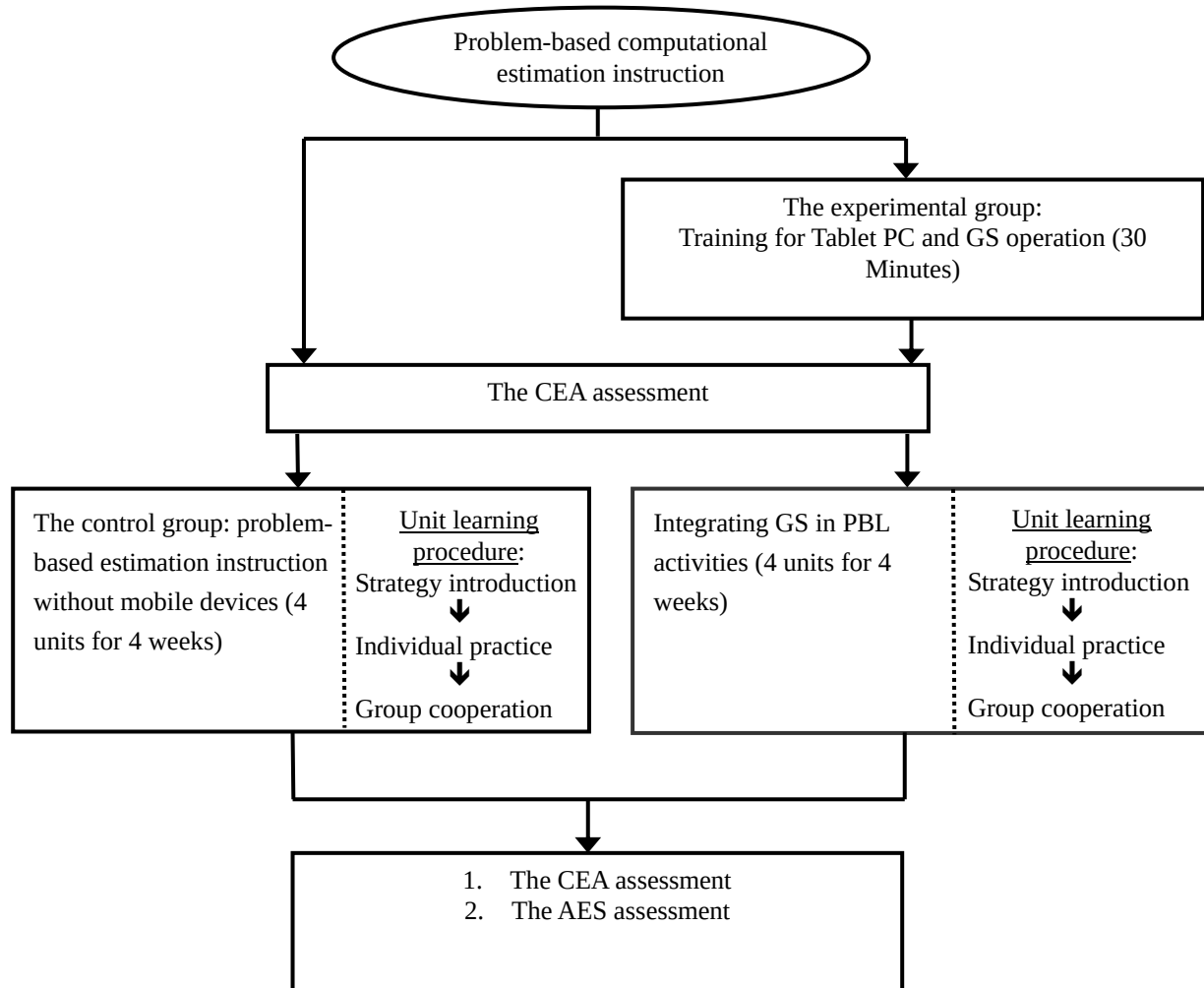


Figure 7. Experimental design and procedure of problem-based computational estimation instruction

Procedure

Figure 7 summarizes the experimental procedure. Before treatment, as shown in Figure 7, the experimental group received 30-minutes of training on using the Tablet PC and GS system, after which all students were administered a pre-test involving CEA assessment. Then four units, each lasting 80 minutes, were taught during the 4-week experiment. Each unit comprised three instruction stages: strategy introduction, individual practice, and group cooperation. Each student in the experimental group was equipped with a Tablet PC. The students logged into GS, and the teacher then grouped them into small estimation groups of three or four members. During the strategy introduction stage, the three essential phases of teaching estimation proposed by Reys (1986) were embedded in various learning activities following a “personal estimation – whole class judgment” cycle. The teacher first presented a problem-based story to the class and led them in helping the main character in the story to solve problems. After the character encountered a computational estimation problem, the teacher asked each student to estimate the solution. Students wrote or typed their ideas or estimates on the e-sticky notes and dragged them to the public area for sharing with the whole class (see in Figure 3). Subsequently, the class discussed various estimation

strategies and selected the best. Once the class reached agreement, the teacher continued the story and led the class to solve another problem to help the students practice estimation and learn the target estimation skills. The story was followed by a series of practice problems, comprising the individual practice stage. All students were asked to solve the estimation problems and shared and discussed their solutions with the class.

The group cooperation stage followed soon after the individual practice stage, during which students learned the target skills contained in a single unit. During this stage, the teacher presented a real world problem and asked students to cooperate to develop a suitable solution. Each member of each small estimation group wrote down their estimate on an e-sticky note and then dragged it to the group area to show their groupmates (see Figure 4). The group members then discussed and tried to reach agreement on a strategy to be shown in the public area, as shown in Figure 5. The teacher then led the class in assessing the estimates of the various groups.

In contrast with the experimental group, the students in the control group received estimation instruction materials and instruction flow identical to those described above, but simply wrote down their estimates on the sticky notes, as shown in Figure 6.

Upon completion of the treatment, all 28 subjects were re-administered a post-test dealing with the CEA assessment. The students were also administered the AES assessment to solve a real world problem, with the strategies they used to do this being recorded.

Results

Comparison of computational estimation skills

Results of the Assessment of Computational Estimation Ability

The computational estimation ability of all students was tested twice (both before and after treatment). The alpha was set to .05.

Table 1 lists the means and standard deviations for the computational estimation ability scores. Two-way (test $\times$ group) analysis of variance reveals that the group is insignificant ($F(1,52) = 0.45, p > .05$), meaning the scores do not differ between the two groups. The test is significant ($F(1,52) = 12.20, p < .05$), indicating a difference between the pre- and post-test scores. The interaction between group and test is insignificant ($F(1,52) = 0.01, p > .05$), meaning no level varying differences exist. Additionally, further tests of the progress between the pre- and post-test conditions for the two groups showed that the experimental and control groups both achieved significant improvement in their computational estimation skills ($F(1,52) = 5.84, p < .05$ for the experimental group; and $F(1,52) = 6.36, p < .05$ for the control group). However, although the standard deviations of the two groups reduced between the pre- and post-test, the more condensed score distribution for the performance of the experimental group demonstrated a smaller difference in computational estimation abilities between the students of the experimental group.

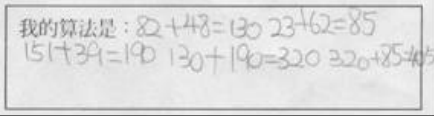
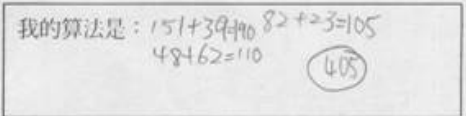
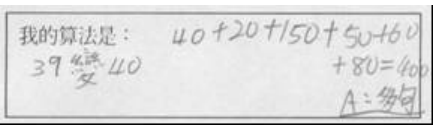
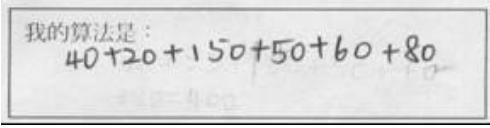
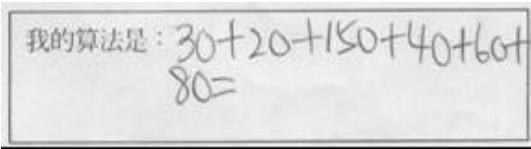
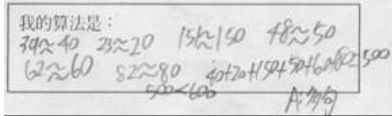
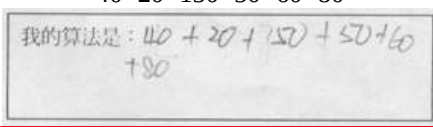
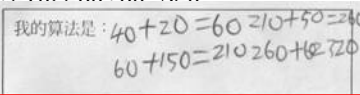
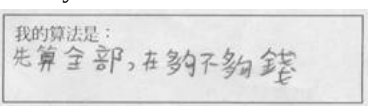
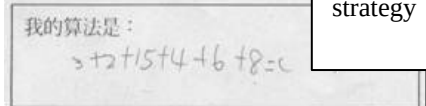
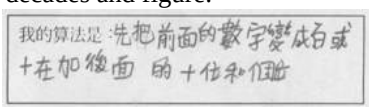
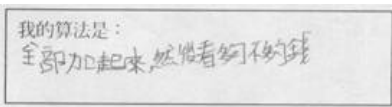
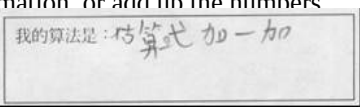
Table 1. Means and standard deviations for the scores of ability of computational estimation

Test	Experimental group (N =14)		Control group (N = 14)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Pretest	12.86	4.49	12.14	3.53
Post-test	16.14	3.18	15.57	3.01

Comparison of Metacognition Knowledge of Computational Estimation Abilities

Besides the CEA assessment, all participants were asked to solve a real world problem following the post-test. Eight students (students 1 to 8) in the experimental group applied estimation strategies to solve the problem, as shown in Figure 8, where each cell presents the original estimates of students (the scanned rectangle) and the corresponding English translation.

Compatible numbers strategy

No.	Estimation approach	No.	Estimation approach
1	My approach: $82+48=130$, $23+62=85$ $151+39=190$, $130+190=320$, $320+85=405$ 	2	My approach: $151+39=190$, $82+23=105$ $48+62=110$ 405 
3	My approach: 39 change to 40 , $40+20+150+50+60+80=400$ Answer: Enough 	4	My approach: $40+20+150+50+60+80$ 
5	My approach: $30+20+150+40+60+80=$ 	6	My approach: $39 \approx 40$, $23 \approx 20$, $151 \approx 150$, $48 \approx 50$ $62 \approx 60$, $82 \approx 80$, $40+20+150+50+60+180=500$ $500 < 600$, Answer: Enough 
7	My approach: $40+20+150+50+60+80$ 	8	My approach: $40+20=60$, $210+50=260$ $60+150+210$, $260+60=320$ 
9	My approach: I will count the all parts, and estimate if there is enough money or not. 	10	My approach: $3+2+15+4+6+8=()$ 
11	My approach: First, I will change the numbers in front to hundreds, or decade, then I will add them with the numbers of decades and figure. 	12	My approach: I will add up all the numbers, and then see if there is enough money or not. 
13	My approach: Use estimation or add up the numbers 	14	My approach: Use estimation. 

Rounding strategy

Figure 8. Student estimation methods in the experimental group

Seemly-rounding strategy		Seemly rounding strategy	
No.	Estimation approach	No.	Estimation approach
1	My approach: 39 is calculated to 40, 23 is calculated to 25, 151 is calculated to 150, 48 is calculated to 50, 82 is calculated to 80 Add the whole parts, and use estimation. 我的算法是：39算40, 23算25, 151算150, 48算50, 82算80, 加起来看看, 用估算的方法	2	My approach: 40 45 375 < 600 20 60 150 80 我的算法是：40 45 375 < 600 20 60 150 80
3	My approach: 48 is changed to 50, 151 is changed to 150 39=40 我的算法是：48變50, 151變成150 39=40	4	My approach: Use estimation, and add up the numbers which are closed to each other. 我的算法是：用估算, 將比較接近的數加起來。
5	Seemingly rounding strategy: Add the whole parts, and see if the money is not. 我的算法是： 把全部加起來, 看錢夠不夠	6	My approach: 100+30+20+80+40+60=320 我的算法是： 100 30 20 80 40 60 +100
7	My approach: Add everything together. 我的算法是： 全部加在一起	8	My approach: First, I will try the simple approach, and then I will try the harder one. 我的算法是： 先把簡單的算法算一算, 再算難的算法。
9	My approach: Add everything together. 我的算法是： 全部都加起來	10	My approach: 9+3+1+8+2+2=25 30+20+150+40+60=300 300+25=325, Answer: Enough 我的算法是：9+3+1+8+2+2=25 30+20+150+40+60=300 300+25=325 14. 如果還有學估算的機會, 我想再參加。
11	My approach: Use estimation. 我的算法是：用估算的方式	12	My approach: Use addition. 我的算法是：用加法
13	My approach: 3+2+4+6+8=23 4+3+51+8+2+2=75 我的算法是：3+2+4+6+8=23 4+3+51+8+2+2=75	14	My approach: 我的算法是：

Figure 9. Student estimation methods in the control group

Notably, students 1 and 2 used a compatible numbers strategy, while students 3 to 8 employed a rounding strategy. In contrast, only two students, students 1 and 3, from the control group seemed to clearly describe their estimation strategy. However, the judgment of student 3 regarding the estimation strategy was based only on the processing of the three numbers (48, 151, and 39), but whether student 3 knew how to manipulate the other three numbers (23, 62, and 82) is uncertain. Furthermore, the strategy used by student 1 appeared a rounding strategy, but this was not entirely correct because of the way the number 23 was rounded. Student 1 “rounding” 23 to 25 is not consistent with the rounding strategy as defined in this study. The rounding strategy involves rounding a number to the closet larger decade (round-up) or the closet smaller decade (round-down). The strategy adopted by student 2 suffered the same problem as that of student 1. Furthermore, the number processing result of the estimate of students 2 was unclear because no relationship existed between the substituted and original numbers. Figure 9 illustrates the estimation strategy based on the results of the control group.

By comparing estimation strategies used in the two groups (the experimental and control groups), chi-square analysis, this study used Yate’s correction of continuity to correct the chi-square testing results owing to the small sample size, and demonstrated significant differences between the two groups ($\chi^2_{(1,1)} = 3.89, p < .05$). This analysis demonstrates it is significantly more common to apply an estimation strategy to solve a real world problem in the experimental group than in the control group. The combination of the problem-based instruction approach with mobile device thus appears to help students cultivate their ability to apply estimation strategy.

Results of in-class observation

Two observers observed the processes of personal estimation and intra-group cooperation, focusing on individual estimation, self-reflection on individual estimations, and group cooperation. Students from both groups were actively involved in most of the estimation activities. However, students from the control group rarely modified their estimates during the practicing stage, while students from the experimental group did. Students from the latter group dragged back their e-sticky notes and re-dragged modified estimates (on another e-sticky note) to the shared area after comparing their estimates with those of others. During the group cooperation stage, the control group frequently encountered a situation in which certain students dominated the discussion and estimation strategy selection. Most small estimating groups there were two or three students who typically just listened to their groupmates explaining why they chose a particular problem solving strategy, and then reached agreement with minimal discussion. Unlike those in the control group, students in the experimental group were more eager to display their e-sticky notes and express their ideas, and sometimes they were unable to reach agreement.

Discussion

Computation estimation skills are important to student mathematical skills. However, computational estimation skills are difficult to teach in math class. Most teachers in Taiwan ask students to calculate a precise answer first, and then make an “estimate”. Owing to a lack of training in flexible thinking, most students tend to calculate answers to problems without considering the characteristics of the numbers or how they are related. Although researchers have proposed various approaches, including regular instruction in problem solving, to computational estimation instruction, few studies have attempted to implement such problem-based approaches in daily instruction on computational estimation, and nor have many studies assessed its effects on student computational estimation abilities. Based on the comparison of the scores of the pre- and post- tests for CEA assessment, the three-staged problem-based estimation instruction scenario (strategy introduction, individual practice, and group cooperation) proposed here was found a useful means of developing student estimation skills. Given regular and explicit introduction and practice, students belonging to the two groups achieved significant progress in computational estimation skills. This finding is consistent with the arguments of Trafton (1988) and van de Walle (2005). However, based on further comparison of the standard deviations between the two tests (pre- and post-test) for the two groups, involving GS in a problem-based estimation instruction scenario promotes estimation skill development for most students in the experimental group rather than only benefiting those with high abilities.

Furthermore, according to Lemaire and Lecacheur (2002), younger learners (e.g., six graders and fourth graders) favored the round-down over the round-up strategy, and almost always selected the former, probably because the rounding processes were easier to execute. Lemaire and Lecacheur inferred two possible causes for this

phenomenon: first, the round-up strategy requires calculating the differences between unit digits and the closest larger decades; second, round-up processes require more working memory for storing the decade digits, which were not the original digits from the problems. However, regarding student application of the rounding strategy in this study, students were found to flexibly use both rounding strategies, up and down. For example, student 6 of the experimental group flexibly used the rounding strategy to process the numbers according to their characteristics (e.g., rounding up 39 to 40, rounding down 23 to 20, rounding down 151 to 150, rounding up 48 to 50, rounding down 62 to 60, and rounding down 82 to 80). This finding further shows that the proposed instruction approach appeared able to help students overcome the mental effort required to implement the round-up strategy.

Regarding the results of AES assessment, this study found that significantly more students in the experimental group than the control group could choose appropriate strategies for solving real world problems. This result appeared that the mobile-device-supported problem-based computational estimation instruction helped students develop metacognition knowledge of estimation strategies. This outcome may result from regular student self-reflection regarding the estimates, as well as discussion and cooperation in each small estimation group in the experimental group, as confirmed via in-class observation. Although the students in the control group were also grouped in small estimation groups, encouraged to cooperate and discuss the task together, and learned the target estimation skills by performing problem-solving activities, students working in small groups tended to perform “dominated learning”. In the control group, students with higher target abilities frequently dominated the “cooperative learning”, while students with lower target abilities almost always listened to and agreed with the estimation approach, or with results provided by their group mates. This situation resembles the series of studies conducted by Lan, Sung, and Chang (2007 & 2009). The lack of self-reflection and self-estimation appears to prevent students from developing metacognition knowledge of estimation strategies, even when their performance as measured by the CEA assessment improved.

Conclusion

This study proposed a three-stage problem-based estimation scenario involving the implementation of a problem-solving based approach to estimation instruction. From the analytical results, the three-stage problem-based instruction scenario appears to help students develop their estimation skills. Additionally, blending this scenario in a mobile-device-supported cooperative learning environment helped students cooperate and thus appears to benefit not only the development of estimation skills in elementary students, but also that of metacognition knowledge of estimation strategies. Furthermore, this study demonstrates that the change of student computational habits, from directly performing calculations without first discovering the characteristics of the numbers involved and their interrelationships to applying flexible thinking to select an appropriate estimation strategy for solving an authentic problem, is critical to the development of numerical sense and manipulation ability. The findings of this study have increased understanding of the impact of mobile technology on student cooperative learning and estimation skill development. The problem-based instruction scenario proposed in this study provides a potential answer to the question of Goodman (1991) regarding when to introduce various estimation strategies to students, as well as the activities that offer potential to help students acquire estimation skills. The proposed scenario also provides math teachers with an easy to implement approach for teaching computational estimation. However, hardware limitations meant that the sample size in this study was small. Future studies should use larger sample sizes and consider students from different grade levels. Additionally, according to Norman and Schmidt (1992) and Hmelo-Silver (2004), the effects of the proposed approach might last up to several years, increasing estimation knowledge intention. However, because of the short treatment period, this study lacks evidence clarifying the existence of such an effect. Therefore, the long-term effect of integrating mobile technology in PBL activities related to estimation instruction deserves attention in future.

Acknowledgments

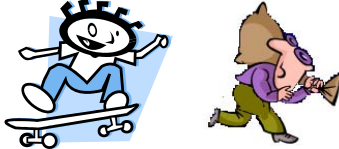
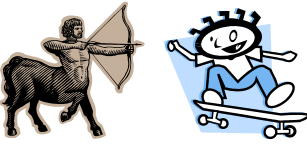
This research was supported by the grants from the National Science Council, Republic of China, under contracts no. NSC 97-2511-S-003-051-MY3, NSC 96-2520-S-003-012-MY3, NSC 97-2631-S-003-002, and NSC 96-2520-S-003-013-MY3.

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Appendix A. Sample unit used to train students in the compatible number and rounding strategies

(a) Strategy introduction: a fragment of a story line used to teach students the strategies of compatible number and rounding.

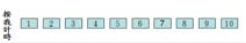
① Xiao-Xin found that his dog, Xiao-Bai, was kidnapped and caged in a kindergarten by a bad guy. Therefore, he hurried to the kindergarten to rescue Xiao-Bai. 	② Suddenly, a turtle goblin appeared, stopped Xiao-Xin, and said “Answer my question or you will never be able to save your dog. Remember, you have only 10 seconds to give the answer. Ha! Ha! Ha!” 
③ Then, the turtle goblin waved her hands, and a math problem appeared in the air. The problem was “$999+9999=?$”	④ Xiao-Xin gave the correct answer, and the turtle goblin let him go despite being very unhappy with the outcome.
⑤ Xiao-Xin continued on his way to the kindergarten, but then a centaur unexpectedly appeared and blocked Xiao-Xin’s path. 	⑥ The centaur also asked Xiao-Xin to answer his question in 10 seconds. To be allowed to continue his journey Xiao-Xin had to solve the following problem. The question was: Which is the correct answer to “$198-19-78=?$” $198-19-78=?$ (1)111 (3)110 (2)101 (4)119
⑦ ...	

(b) Individual practice: examples of the practice problems used to help each student master the strategies of compatible number and rounding (with students having 10 seconds to solve each problem).

①

$6+12+74=?$

(1)92
(2)144
(3)82
(4)94



②

$37-18-17=?$

(1)19
(2)36
(3)2
(4)12



③

$99+99=?$

(1)199
(2)198
(3)200
(4)188



④

$67+99=?$

(1)100
(2)166
(3)190
(4)200



(c) Group cooperation: an example of a challenge problem used in group cooperative learning activities.

挑戰題



媽媽到迪化街辦年貨，香菇一斤603元，瓜子一斤99元，橘子一斤9元，糖果一斤8元，媽媽身上有 1500元，如果買了半斤香菇、6斤瓜子、12斤橘子和19斤糖果，請問媽媽的錢夠不夠？



Mom is going to Di-Hua street to do Chinese New Year shopping. The prices for the goods she wants are as the follows: **dried mushrooms**, 603 NTD per Kg; **sunflower seeds**, 99 NTD per Kg; **oranges**, 9 NTD per Kg; **candy**, 8 NTD per Kg. Mom has NTD \$1500. She wants **0.5 Kg of dried mushrooms**, **6 Kg of sunflower seeds**, **12 Kg of oranges**, and **19 Kg of candy**. Does Mom have enough money for her shopping? (15 seconds)

User Acceptance of Mobile Knowledge Management Learning System: Design and Analysis

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ABSTRACT

Thanks to advanced developments in wireless technology, learners can now utilize digital learning websites at anytime and anywhere. Mobile learning captures more and more attention in the wave of digital learning. Evolving use of knowledge management plays an important role to enhance problem solving skills. Recently, innovative approaches for integrating knowledge management into practical teaching activities have been ignored. This is the first study to focus the design of a mobile knowledge management learning system that encourages learners to acquire, store, share, apply and create knowledge. When learners use different mobile devices to learn, larger screens perform better than smaller ones in the task performance and system working quality. Analyzed by learning achievements, the experimental group has a rather significant effect in adopting mobile knowledge management learning system than the control group of traditional classroom lectures. After evaluating the system acceptance by questionnaire survey, the experiment results indicate that (1) perceived easy to use can positively predict perceived usefulness by learners, (2) perceived easy to use and perceived usefulness can positively predict behavioral intention of the system acceptance. Perceived usefulness is the key factor for learners' willingness to be guided through the system's learning process.

Keywords

Mobile Learning, Knowledge Management, User Acceptance

Introduction

People are using wireless technology more often because information retrieval can occur at anytime or anyplace (Wong & Hiew, 2005). Distance learning has developed along with computer hardware and telecommunication (Schwiderski-Grosche & Knospe, 2002). Mobile phones, personal digital assistants (PDA), and laptops come standard with built-in wireless encourage learners to access the information network at anywhere (Dickinger, Heinzmann, & Murphy, 2005). The technology oriented economy of the 21st century focuses on sharing, organizing, managing and creating information. This indicates that competition will be driven by knowledge revolution in the future. Training students to apply knowledge continues to be important as society evolves. Integrating knowledge management into practical teaching activities is one of the best methods for learners to enhance their abilities in knowledge management and problem solving.

Previous knowledge management approaches focus on business aspects rather than education (Allee, 1997; Beckman, 1997; Hendriks, 1999; Maryam & Dorothy, 2001). Innovative approaches for turning knowledge management into practical teaching activities have been ignored. This paper presents the framework of a mobile knowledge management learning system that encourages learners to acquire, store, share, apply and create knowledge. The experiments were carried out the system performance using a mobile phone-size, handheld computer-sized and conventional laptop interface. With all three mobile interfaces, substantial different was demonstrated in completing tasks by way of knowledge management learning model. A survey questionnaire was also used to understand the cognitive perception of learners after they used mobile knowledge management learning system. The research model uses the theory of Technology Acceptance Model (TAM) based on their learning processes (David, 1989; Vankatesh & David, 2000). This model emphasizes surveying individual attitudes toward information technology, and has been widely employed in many significant studies of user attitudes (Liaw & Huang, 2003; Liaw, Huang & Chen, 2007). The understanding of learners' attitudes can help effectively expand system functions and meet learners' needs.

The remainder of this paper is organized as follows: Next section details the framework of the mobile knowledge management learning system. This this followed by the description of the knowledge management learning model and learning activities. Finally, the experiment results are discussed and conclusions are drawn.

Design of Mobile Knowledge Management Learning System

Recent articles on web-based learning focus on the display of multimedia contents and embedded functions (Goh & Kinshuk, 2002). Such articles rarely consider topics of interaction, such as the support for multiple platforms, user mobility and collaboration. Many web-based learning systems focus on static presentation in reference to supporting multiple platforms. These circumstances are not supportive to the learner's educational needs, environment, or network bandwidth conditions. Mobile learners differ from desktop learners in that mobile learners have an urgency to meet their educational demands.

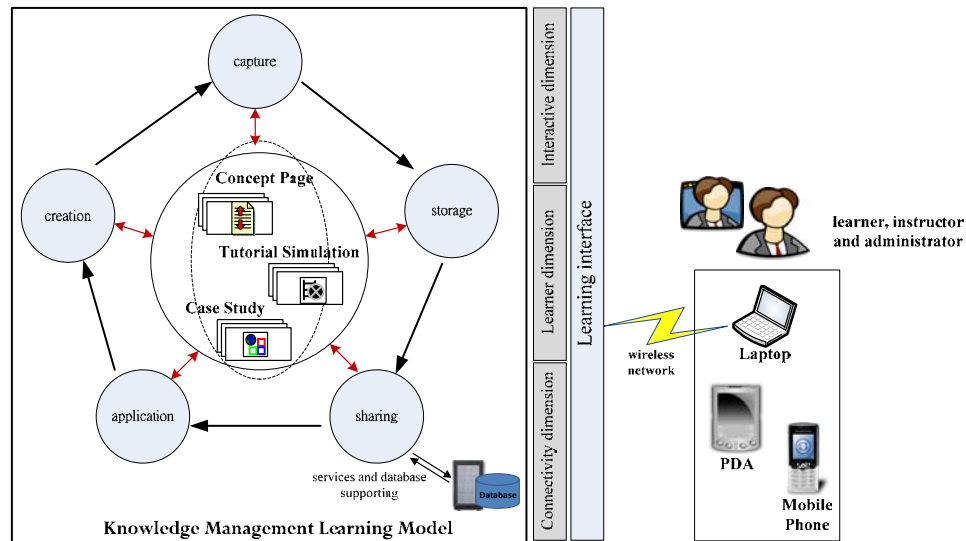


Figure 1. The framework of mobile knowledge management learning system

As more people being practicing mobile learning, the frequency of accessing information during every day events increases. The mobile knowledge management learning system supports multiple platforms for illustration and communication efficiently. The adaptation framework is displayed in Figure 1. It illustrates the interaction dimension, the learner dimension, and the connectivity dimension. Each dimension is described as follows (Chen, Yang & Zhang, 2000):

- **Interaction dimension**
The purposes of designing interactive learning strategies are to increase knowledge, enhance motivation, and provide different methods of learning (Moore & Kearsley, 1996; Ritchie & Hoffman, 1997). The literature review indicates three types of interactive learning strategies: concept pages, tutorial simulations and case studies (Cheng & Gramoll, 2001). Each strategy requires completely different types of interaction. Concept pages explain the detailed process of knowledge technology through hypermedia links. When a topic is selected, these pages provide general views, technological assistance and key points. Tutorial simulations are significantly more interactive and are developed using macromedia flash software. Each tutorial simulation consists of several learning objectives. Each learning object is expected to be achieved by the end of the simulation. Case studies reflect the efforts made by learners. They help learners to understand potential challenges when they start to work. In these situations, learners are able to communicate with teachers and share results. This increases motivation for other learners.
- **Learner dimension**
Learner profiles increase understanding of their learning styles. Information presented on these profiles includes grades, studying schedules, learning preferences, and login times. A powerful web database which can access this information can assist in analyzing different learning styles.
- **Connectivity dimension**
The connectivity dimension consists of online real-time operation and off-line asynchronous operation. When designing the two operations, mobile equipment capacity, internet reliability, and encrypted cookies have been considered.

According to Figure 1, learners browse the learning material through wireless mobile devices connected to the mobile knowledge management learning system. After a successful login, the system will identify the profile settings and determine individual interactive learning strategies, schedules, and connection type. This kind of environment allows learners to connect and communicate with each other in real-time; it also incorporates group learning. Through various resources, teachers can control learning schedules which enhances the quality of the education.

Knowledge Management Learning Model and Learning Activity

Many published studies examine the operations and nature of knowledge management. Beckman believed that knowledge management consists of 8 main steps: “identify, acquire, select, store, share, apply, create and sell.” (Beckman, 1997). Allee articulated that knowledge management involves four levels: capture, sharing, application and creation (Allee, 1997). Maryam and Dorothy’s approach showed similarities to Allee’s (Ritchie & Hoffman, 1997). While considering the above proposals, this study organizes the knowledge management process into five parts: acquire storage, sharing, application and creation. Each concept and its operation are explained in Figure 2. During knowledge acquisition, learners actively access course related information. Learners start organizing knowledge during the storing step. The sharing step involves collaborating with other learners on collected knowledge and experience. During the stage of knowledge application, understanding how to classify and store knowledge is obtained. The last stage of knowledge creation, learners create knowledge through sharing and application.

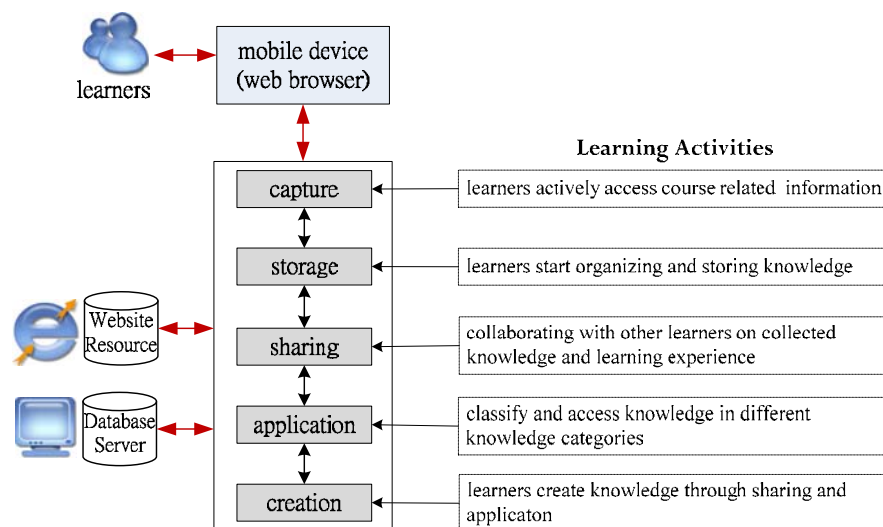


Figure 2. The illustration process of knowledge management learning activity

This paper converts the knowledge management process into practical teaching methods. Without being limited by a classroom, learners can browse materials and share the experience with others. They can also personalize knowledge organization and save it through the wireless network. Learners can carry out self-learning which enhances problem solving skills. Learning activities are described as follows. When designing methods for knowledge acquiring, teachers should organize materials and analyze them by applying a network bandwidth. This principle should guide learners when browsing materials and teach them how to acquire relevant knowledge and store information. The mobile knowledge management learning system offers each student a personal account storing and sharing information. It also records each student’s schedule. Knowledge sharing methods should show how many articles users have posted to encourage the exchange and creation of knowledge. Group learning is recommended so that learners can participate in an organized way. Created knowledge has been divided into application of prior knowledge and exploration of new knowledge. The best method guides students in sharing, self-improvements, and knowledge creation.

Experimental Evaluations

Analysis of System Performance

In order to evaluate task performance and system qualities in mobile devices, two types of experiments are performed. Experiments focus on the learner's ability to complete tasks with each interface. Performance was measured by how long it took to complete the tasks and the number of successfully completed tasks. A total of 132 elementary education majors were divided into 22 groups of six. Different mobile devices including mobile phones, PDAs and laptops were tested. Table 1 displays system performance in group learning. For laptop learners, the performance is twice as good as those using mobile phones, but only slightly better than those using a PDA. PDAs had the best performance average mean rating due to convenience. Since laptops are heavier and the screens of mobile phones are too small to read effectively, the PDA is used as the main mobile device in the following experiment of learning achievements.

Table 1. Task performance using different devices

Mobile Device	Time to complete task		Success Ratio
	Mean(sec)	S.D.	
Mobile Phone	1608	153	52%
PDA	1009	104	94%
Laptop	959	115	97%

Analysis of Learning Achievement

This experiment analyses learning achievement by applying the quasi-experimental design method. The sampling was carried out in units of class and the mobile knowledge management learning system was adopted for the experimental group during course teaching. The teaching content was about the course of computer and instruction which contained three units: computer introduction, webpage design, and flash animation. The experiment group consisted of 68 elementary education majors who were given access to the course material through a PDA interface. The control group of 64 learners was exposed to traditional teaching methods. They were not informed of the teaching experiment to avoid the Hawthorne Effect. After statistical verification, the individual achievements in each group were not significantly different than compared to the previous semester, which indicates that the initial learning behaviors were the same in both groups. The experimental data analysis represented different teaching methods as independent variables, posttest results as dependent variables, and the pretest results as covariates for a one-way analysis of covariance (ANCOVA). After excluding pretest achievements on posttest subjects, as shown in Table 2, $F=50.298$, $p=0.000<0.001$. The posttest achievement level is significantly different due to the different teaching methods the learners were exposed. The learning achievement of the subjects who participated in the mobile knowledge management learning system is significantly better than those who did not.

Table 2. Summary of covariance analysis of the posttest results

	Sum of Square	df	Mean Square	F	Sig.
Contrast	6263.312	1	6263.312	50.298	0.000
Error	16063.515	129	124.523		

Analysis of User Acceptance

This paper aims to evaluate learner acceptance of the mobile knowledge management learning system based on their learning processes. The research model uses the theory of Technology Acceptance Model as shown in Figure 3 (David, 1989; Vankatesh & David, 2000). The research variables included learners' perceived easy to use, perceived usefulness and behavioral intention of the system acceptance. We proposed three hypotheses.

H1: Learners' perceived easy to use can positively predict their perceived usefulness.

H2: Learners' perceived easy to use can positively predict the system acceptance

H3: Learners' perceived usefulness can positively predict the system acceptance.

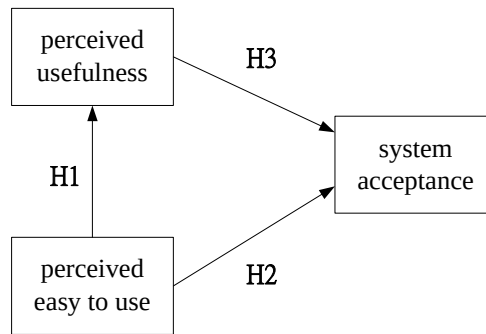


Figure 3. Research Model and Hypothesis

The evaluation was conducted by questionnaire survey which was comprised of 3 parts: perceived easy to use, perceived usefulness and behavioral intention. The results were measured by the 7-point Likert scale (Zhou, 2002). The questionnaire was designed to find out about the learner acceptance of this system. Academic experts reviewed the content validity of the questionnaire. Items less discriminating were deleted and those with ambiguous wording were revised. SPSS statistical software analyzed the experiment data. Before the factor analysis, Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity tested the correlation of the variables to determine whether the variables were suitable for factor analysis (Hair, Black, Babin, Anderson & Tatham, 2009). According to the results, the value of KMO was 0.868, indicating excellent correlations among these variables. The value of chi-square was 868.336 which was significant in Bartlett's Test of Sphericity, indicating that this study was suitable for factor analysis. A principle component analysis (PCA) was conducted for the factor analysis. Three main factors could be extracted from the 11 items analyzed. Based on the Varimax orthogonal rotation, there are five items for factor 1, three items for factor 2, and five items for factor 3. The factors were named according to their characteristics: perceived usefulness, perceived easy to use and behavioral intention. The factor loading and reliability of all items are shown in Table 3.

Table 3. Reliability and factor analysis

No.	Items	Factor loading	Cronbach's α
Factor 1: perceived usefulness			
1.	I think that this system is helpful to my learning.	0.77	0.854
2.	I think that this system can help me better understanding the learning contents.	0.70	
3.	I think that using this system in the course of computer and instruction is a good choice.	0.77	
4.	I think that the mobile device provided by this system is good for learning.	0.74	
Factor 2: perceived easy to use			
6.	I think that this system is easy to use.	0.85	0.855
7.	I think that this system is convenient to use.	0.88	
8.	I think that this system is easy to understand.	0.73	
Factor 3: system acceptance			
11.	I think that this system can enhance my learning intention.	0.88	0.916
12.	I will continue to use this system in learning in the future.	0.88	
13.	I am willing to use system to acquire, store, share, apply and create knowledge.	0.77	
14.	I think that this system provides a good learning approach.	0.85	

To determine if perceived easy to use can predict perceived usefulness, discussing whether perceived easy to use has significant predictability for perceived usefulness, perceived usefulness serves as a dependent variable and perceived easy to use serves as an independent variable. As shown in Table 4 displays that perceived easy to use can explain behavioral intention of the system acceptance with variance explained of varying by 27.5%, and the adjusted R² means the explanatory power of 26.9%. As shown in Table 5 shows that when F is 49.199, $p=0.000<0.001$ which is significant. This means that the independent variable of perceived easy to use and the dependent variable of perceived usefulness have significant correlation. This study then further conducted a post hoc test of independent

variables as shown in Table 6. After executing the coefficient estimation of stepwise multiple regression, the Beta coefficient is 0.524 and the t value is 7.014 ($p=0.000$).

Table 4. Summary of multiple regression model

Model	R	R square	Adjusted R square	Std. Error of Estimate	Change Statistics				
					R square Change	F Change	df1	df2	Sig. F Change
1	0.524	0.275	0.269	0.786	0.275	49.199	1	130	0.000

Table 5. ANOVA Summary

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	30.411	1	30.411	49.199	0.000
Residual	80.354	130	0.618		
Total	110.765	131			

Table 6. Coefficients Summary

Model	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta			
1 (Constant)	3.458	0.395			8.747	0.000
perceived easy to use	0.489	0.070	0.524		7.014	0.000

The behavioral intention of the system acceptance is a dependent variable, and perceived simple device operation, and perceived usefulness are independent variables used to determine if one can predict the other. In Table 7, perceived usefulness is selected as a variable in Model 1 which explains the behavioral intention of the system acceptance with variance explained by 32.6%. The adjusted R^2 is the explanatory power of 32.1%. Perceived easy to use is also selected which explains the dependent variables varying by 5.3%, and F is 10.968 ($p=0.001$). Model 2 has two variables included perceived usefulness and perceived easy to use. This observation explains the dependent variables varying by 37.9%, and only decreases to 36.9% after adjustment.

Table 7. Summary of multiple regression model

Model	R	R square	Adjusted R square	Std. Error of Estimate	Change Statistics				
					R square Change	F Change	df1	df2	Sig. F Change
1	0.571	0.326	0.321	0.847	0.326	62.810	1	130	0.000
2	0.615	0.379	0.369	0.816	0.053	10.968	1	129	0.001

In Table 8, when F is 39.297, $p=0.000<0.001$ shows that the independent variables of perceived usefulness and perceived easy to use correlate with the dependent variable of behavioral intention. We conclude that the system is accepted because of its perceived usefulness. This study conducted a post hoc test of independent variables, shown in Table 9. After executing the coefficient estimation of stepwise multiple regression, perceived usefulness is included in Model 1. This variable predicts the dependent variable of behavioral intention. The Beta coefficient is 0.571 and the t value is 7.925 ($p=0.000$). In the coefficient estimation of Model 2, perceived easy to use is added where Beta coefficient is 0.27 and t value is 3.312 ($p=0.001$). The Beta coefficient of perceived usefulness is reduced to 0.429 and t value is 5.269 ($p=0.000$), which indicates that the effect of the variable of perceived usefulness is reduced after eliminating perceived easy to use.

Table 8. ANOVA Summary

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	45.026	1	45.026	62.810	0.000
Residual	93.193	130	0.717		
Total	138.220	131			
2 Regression	52.329	2	26.165	39.297	0.000
Residual	85.890	129	0.666		
Total	138.220	131			

Table 9. Coefficients Summary

Model	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta			
1 (Constant)	1.819	0.503			3.614	0.000
perceived usefulness	0.638	0.080	0.571		7.925	0.000
2 (Constant)	1.225	0.517			2.369	0.019
perceived usefulness	0.480	0.091	0.429		5.269	0.000
perceived easy to use	0.281	0.085	0.270		3.312	0.001

Conclusions

This paper proposes a novel mobile knowledge management learning system. It is based on the knowledge management theory of acquire, store, share, apply, and create knowledge during the learning process. Mobile phones, PDAs, and laptops were used in the experiment to determine system performance. A successful ratio of completed tasks and the degree of satisfaction in the quality of the system were demonstrated by these three mobile interfaces. The experiment results indicate that task performance and system quality were better with devices that had a larger screen. The mobile knowledge management learning system allows learners to collaborate through an online interaction mechanism. When the learners perceived the system to be beneficial, they intentionally increased their performance of knowledge application.

When analyzing learning achievements during a teaching course, the learners who were exposed to the mobile knowledge management learning system achieved more than those who were limited to a classroom. According to learner feedback, the reasons for higher achievement were: (1) There was more variety of learning materials such as sharing website links of relevant learning knowledge; (2) Illustrations were much more effective and advanced than in a textbook. Learners wanted more animations and videos to make learning more interesting. (3) Learners had their own storage space without classroom restrictions. They could easily acquire new knowledge by collaborating with other learners.

We found that perceived easy to use can predict perceived usefulness. The easy to use mobile knowledge management learning system can improve learning, and enhance the usefulness of computer instruction. Additionally, perceived easy to use and perceived usefulness can predict behavioral intention of the system acceptance. The prediction indicates these two variables affect learner's acceptance of the mobile knowledge management learning system. The perceived usefulness can interpret behavioral intention with the variance explained of 32.6%. This value is higher than that of perceived easy to use explained the behavioral intention with the variance explained of 5.3%. In other words, this system can be accepted by learners due to its usefulness in learning.

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Social Learning Networks: Build Mobile Learning Networks Based on Collaborative Services

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ABSTRACT

Recently, the rising of Web 2.0 has made online community gradually become popular, like facebook, blog, etc. As a result, the online knowledge sharing network formed by interpersonal interaction is now a major character of Web 2.0, and therefore, by this trend, we try to build up a collaborative service mechanism and further set up an analysis mechanism under which. A similarity analysis was conducted on learners' personal data in order to recommend learning partners of the same interests and specialties to learners. Under this recommendation mechanism, we can support Mobile Computer-Supported Collaborative Learning activities (MCSCL), building up learner-oriented mobile learning knowledge networks.

Keywords

Social learning networks, mobile learning networks, learning community, community of practice, collaborative service

Introduction

The emergence of Web 2.0 not only accelerates the development of diverse communities but also promotes socialization of the Internet (Huang et al., 2009). Lots of social software tools are created along with Web 2.0. The socialization of the Internet has become powerful and trendy. It inspires social networking websites such as Blog, Facebook, etc. The mechanism of socialized Internet improves close interpersonal relationships and provides nonverbal communication media such as multimedia audio-visual objects, images, pictures, and other diverse media. By communicating and sharing with others through resourceful media, interpersonal interaction becomes closer.

Nowadays many researches try to use the trend of Web 2.0 to push forward a new learning model, for example, applying Blogs in learning and conducting knowledge sharing through Blogs. As a result, Huang et al. (2009) brought up the idea of supporting collaborative learning by Blogs. In view of knowledge sharing, Yang & Chen (2008) also put forward a learning model established by collaborative learning through knowledge sharing based on social networks. Furthermore, due to the progress of wireless Internet and mobile devices, the mobile learning environment has gradually become stable and mature, for example, the mechanism of providing learning services in the mobile learning environment. As a result, Huang et al. (2008) brought up an annotation service to support mobile collaborative learning. In addition, Kuo & Huang (2009) put forth an authoring tool to support the adaptive presentation of learning resources on mobile devices. These studies all aim at supporting collaborative learning, and also promoting sharing resources with each other through social networks. Further than that, these studies integrate with the idea of mobile learning, all together putting forward the learning service mechanisms needed in collaborative learning, such as annotation services or authoring tool. These mechanisms enable smooth learning, creating a new learning model. Therefore, the important research issue at present is how to provide efficient learning services to support learners' needs when learning.

Nowadays, many researches are devoted to technical support and application (Yang, 2006; Yang et al., 2007, Huang et al., 2008), however, the online collaborative learning model not only needs technical support, but more importantly, is to conduct interaction with people. As a result, to interact with what sorts of people is the most concerned issue of researches at present. In recent researches, focusing on exploring the formation of new groups, Chen, Kinshuk, Wei, & Yang (2008) brought up the idea of using a self-contained group area network to support mobile collaborative learning. Another researcher Yang & Chen (2008) put forth the idea of knowledge sharing communities to be formed based on social networks. From the above, we know that it appears to be more important

to focus on how to find suitable people to conduct interaction and how to form CoP (Communities of Practice) under social networks to support the collaborative learning model.

Furthermore, through the services of Social Software such as Blog, Wiki, Facebook, Del.icio.us, Flickr, etc., social networking between users is established. This social networking helps users locate people with shared interests and thus form CoP. Through these social platforms, collective intelligence is realized. Afterwards, people can bring different CoPs together to form CoIs (Communities of interest) which can provide unique opportunities to bring social creativity alive by transcending individual perspectives. Accordingly, some researchers assert that social network mainly puts emphasis on building various CoPs so that users can share and exchange information with each other based on their similar interests (Rachel, 2008).

Indeed, products of knowledge sharing and creating by users are mostly on certain social platforms. For example, Flickr allows users to share pictures or images and Del.icio.us allows users to share bookmarks. These products are the aggregate of collective intelligence. However, real collective intelligence should not be limited to sharing and creating products. The most significant resources are producers of these products. As Diederich & Iofciu (2006) pointed out, “using tag-based profile can give more recommendations than standard object-based user profiles.” It means that producers play an important part in forming collective intelligence. If users can find those who share the same interests with them and interact with each other, innovation of knowledge and new world would be inspired by collective intelligence.

On the other hands, although the Internet technology has made it possible for people to collaborate effectively without staying physically together, they have led to the unintended consequence of increasing isolation among people with respect to their academic peers. In bygone times, the inconvenience of having to share resource sites (for example, computer centers and unscheduled laboratory use) afforded opportunities to develop computer-oriented social groups for virtual collaboration. Computer Supported Cooperative Work (CSCW) provides a virtual collaboration technology that offers participants a promising option of not being physically present at cooperation. Applied to collaborative learning, CSCW techniques allow students to study in a virtual team without physically staying at a common place (Weinberger, & Fischer, 2006). Computer-Supported Collaborative Learning (CSCL) was thus coined in 1996 (Koschmann, 1996) to refer to adopting CSCW technology to provide a computer and network-supported collaborative learning platform for students to study cooperatively to acquire knowledge (Yang & Chen, 2008).

While there have been significant efforts in developing mobile collaborative learning environments for existing groups, little work has been done to help people find proper partners in Internet communities. In our vision, qualitative principles and strategies from traditional higher education research and practices should be normalized and quantified into computer-understandable and -interpretable rules, and boost automatic formation of cooperative groups. Based on above literature, researchers, therefore, employed recent mobile technologies in collaborative learning to enhance learners’ learning effect, accompanying with the existing theory-based CSCL to support online collaborative learning. As a result, some researchers integrated the two theories and called it mobile CSCL (MCSCL) (Zurita, Nussbaum, & Salinas, 2005).

This study aims to promote Internet-based informal collaboration over CSCW and MCSCL by exploring the plausibility of providing system-level support and services for the forming of collaborative groups dynamically. Our outcome will lead to a plug-in into the existing Web-based platform, providing intelligent social grouping services. Based on our study and surveys, we focus on exploring how to exploit knowledge and social networks on top of historical data to help students establish subgroups of cohorts that may become “communities of practice”. The term “community of practice” is borrowed from social science and here refers to a group of participants with common interests of a particular subject. Participants here refer to the individuals who (1) find similarity with other learners and possess related information, (2) are willing to exchange and share information with others.

Literature Review

Research results and practices from fields such as educational communication, social science, and psychological science have provided a variety of guidelines for people to dynamically form proper teams and groups. Among others, many researchers have proven that social relationships and interactions have significant impacts on

collaborative learning (Yang & Chen, 2008; Chen, Kinshuk, Wei, & Yang, 2008). Fischer et al. (2002) also concluded that social relationships have an impact on knowledge acquisition in a collaboration mode. The technique of social network is thus used to represent a determinable networking structure of how people know each other (Yang & Chen, 2008). A social network can be formalized into a net structure comprising nodes and edges. In such a network, nodes represent individuals or organizations. Edges that connect nodes are called ties, which represent the relationships between individuals and organizations, either directly or indirectly. The strength of a tie (weight of an edge) indicates the strength of the relationship.

Many kinds of ties may exist between nodes in a social network. One popular tie is a social interaction tie which refers to the structural link created through social interactions between individuals in a social network (Yang & Chen, 2008). Ahuja et al. (2003) suggested that an individual's centrality in an electronic network of practice can be measured using the number of social ties an individual has with others in the social network. Tsai & Ghoshal (1998) reported that social interaction tie has positive impacts on the extent of inter-unit resource exchange. Wasko & Faraj (2005) discovered that the centrality established by social interaction ties significantly impacts the helpfulness and the volume of knowledge contribution. Kreijns et al. (2005) concluded that social interactions largely affect group forming and group dynamics.

Moreover, there are researches centering on "human." Artiles et al. (2005) used "people name" to locate people, so that in this way, they solved problems of naming ambiguity and the same name. They designed WePS (Web People Search) as a test platform. Users inputted "people's names" to search for relevant people resulting in a ranking list. Although it is helpful to search people by their names, it is possible to lose people whose names seem to be similar to the users. Accordingly, researches of locating people of similar fields by analyzing documents were conducted. Some researchers (Wan, Gao, Li, & Ding, 2005) proposed a method to search for relevant "people" from relevant people-document and provided resolution for the above mentioned problem to find out people of relevant fields. Diederich & Iofciu (2006) proposed another method to locate people in the website, using tag-based profiles to find people with similar interests. In terms of this, if people in similar fields can be located in a social network and thus gathered to form a CoP through community activities, collective intelligence is realized. It will highlight the efforts of the people search service. Other researchers such as Mori et al. (2008) proposed an important finding. They discovered that finding relevant people in certain fields is important to collaborative system. Thus, they recommended a people search interface and tool which requires users to input information about those who are searched for before people search. In this way, search results of the target people can be more accurate. According to the above mentioned relevant researches, the research of using "human" as a resource in the era of Web 2.0 becomes significant. In this paper, the research emphasizes the importance of searching "human" and forming a CoP.

Since the inception of CSCW in 1984 (Grudin & Poltrock, 1997), it has provided a virtual collaboration technology that offers participants a promising option of not being physically present at a cooperation. Applied to collaborative learning, CSCW techniques allow students to study in a virtual team without physically staying at a common place (Weinberger & Fischer, 2006). Computer-Supported Collaborative Learning (CSCL) was thus coined in 1996 (Koschmann, 1996) to refer to adopting CSCW technology to provide a computer and network-supported collaborative learning platform for students to study cooperatively to acquire knowledge (Yang & Chen, 2008). More specifically, Internet-based CSCL is also referred to as Web-Based Collaborative Learning (WBCL) (Hron & Friedrich, 2003) which is the focused area of this research. Throughout this paper, we will use CSCL and WBCL interchangeably. WBCL differs from the conventional collaborative learning in several significant perspectives such as social communication situation, message exchange, cognitive load, and participation of learners (Hron & Friedrich, 2003). Kollias et al. (2005) studied, from a teacher's perspective, how WBCL can complement and improve classroom study. Hron & Friedrich (2003) examined beyond-technique factors of WBCL. Through the development of two WBCL environments, Rubens et al. (2005) summarized a set of pedagogical principles for building up WBCL systems.

However, the most important issue of CSCW or mobile CSCW is how to find suitable learning partners, especially when the trend of online social network has gradually formed. The important thesis in this paper is how to recommend suitable learning partners to learners to conduct collaborative learning. As a result, we try to build up a collaborative service to support learning activities over MCSCL. In another respect, through this recommendation mechanism, learners can conduct social activities driven from the same interests and specialties; and further, to learn from each other based on the concept of knowledge sharing in this kind of social activities to form the so-called mobile learning knowledge networks.

Building Mobile Learning Network Based on Collaborative Services

“Human” is a set of knowledge or content producer, but current search techniques are all fixed on “objects” such as files, resources, and the specific information and knowledge documents located by Google Search and ignore the producers behind these resources, that is “human”. Therefore, in this paper, “human” is considered as “intelligence resources” and “objects” shared out by these people on del.icio.us, namely bookmarking resources, are considered as “knowledge resources.” However, how can “intelligence resources” and “knowledge resources” be identified through platforms of networking websites? Undoubtedly, this is what this paper is going to discuss and center on, especially the “intelligence resources.” Therefore, the Internet resources tagged by collaborative tags are used as the medium to analyze the similarity degree between each other’s interests. From this relationship, “intelligence resources” that include similar interests are located and through further interaction, communities of practice are therefore established. Through these community activities, innovation and sharing of collective intelligence are realized. On the other hand, people can also find relevant “knowledge resources” they need through collaborative tags.

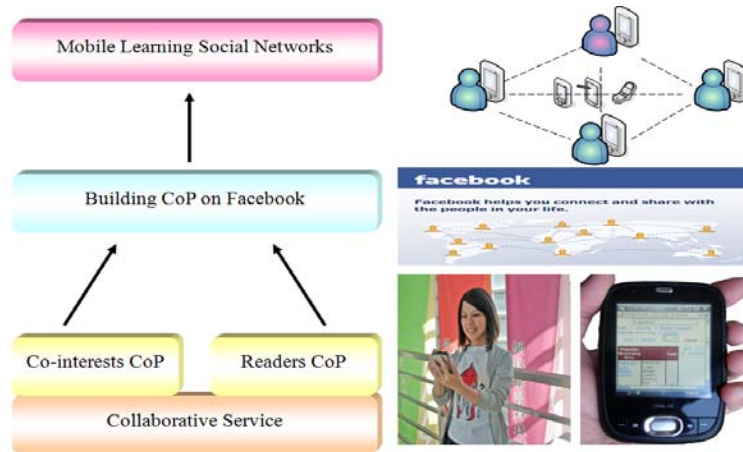


Figure 1. Collaborative services for mobile learning social network framework

On account of the above concept, the idea of collaborative service brought up in our paper focuses on finding people as shown in Figure 1, mainly recommending learning partners in similar interests or knowledge domains to learners and thus forming the so-called learning communities. As a result, we conducted a co-interest analysis on the Internet resources shared out by learners on Del.icio.us. and formed an interest-based CoP through this analysis mechanism; in addition, we analysed learners’ reading interests, examining their library’s circulation records to introduce readers of the same reading habits to each other and thus formed a reader’s Cop. Therefore, through the combination of the two learning-partner-recommendation mechanisms, a mobile learning social network was then built. Below we will explain the mechanisms of interest-based CoP and reader’s CoP in details.

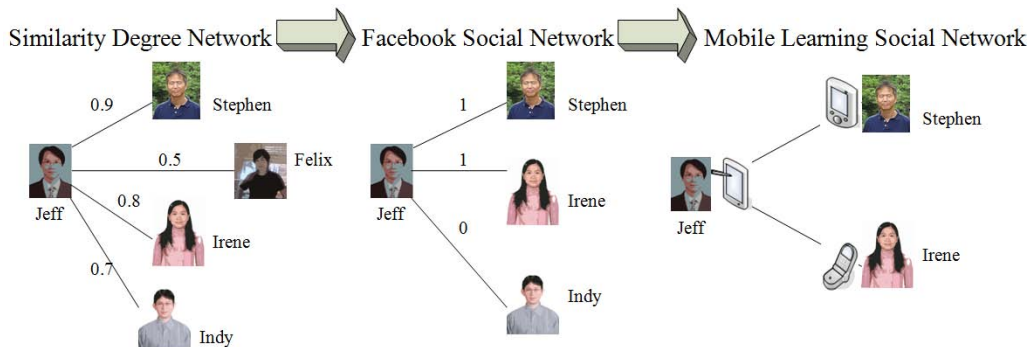


Figure 2. A three-layer mobile learning network-based collaborative services

As shown in Figure 2, the first level represents Interest Similarity Degree Network which is calculated by the collaborate service to provide a recommendation list of learning partners who have similar interests with Jeff. For

example, there're four people, Stephen, Indy, Irene and Felix, who have similar interests with Jeff, and their similarity degrees are 0.9, 0.7, 0.8 and 0.5 respectively. Among all, Stephen with 0.9 has the highest similarity degree with Jeff. The second level represents Facebook Social Network, indicating the willingness of the two people to build up friendship through Facebook. For example, the recommendation list will be provided to Jeff, and he will take the initiative to make contact and interaction with people in the list. If both of them are willing to build up friendship with each other, the edge will be marked as 1, and 0 on the contrary. The third level represents Mobile Learning Network which is formed by the interaction of each other through mobile devices.

For example, when Jeff collects some website resources about studying abroad in the US on the Internet, he wants to find a partner so that they can share experiences with each other. He has an iPod with him, so he connects to the platform we designed and gets a recommendation list through the learning partner recommendation mechanism. The list includes Stephen, Indy, Irene, and Felix, and because Felix only has 0.5 similarity degree, so Jeff decides to leave him out and contacts with the other three. He then logs in Facebook with his iPod to invite them to become his friends. Due to Indy doesn't have the reciprocal intention, only Stephen and Irene accept Jeff's invitation and become his friends, and thus the Facebook Social Network is formed. From then on, Jeff interacts with Stephen and Irene through mobile devices. At the time when Jeff goes abroad to the US, he shares his experiences with his friends and thus the mobile learning network is formed.

Social Bookmarking Based on People Search for Intelligent Interest Group

The term "Community of Practice" was first proposed by Etienne C. Wenger in 1998. He thought that community of practice was an informal group in the corporation. He also claimed that it was not an organization aiming at completing specific tasks and missions. Thus, it was different from the organized units of formal task-oriented missions. Instead, it belonged to spontaneous informal groups formed by sharing specialized knowledge and emotions. Through social interactions and exchanges in this group, members could learn social skills, share knowledge and the process of problem-solving, and even develop innovative thinking. In this way, collective intelligence was realized.

Furthermore, Wenger made a simple definition of CoP (Communities of Practice). He said, "Communities of Practice are groups of people who share a passion for something they do and who interact regularly to learn how to do it better." (Wenger, 2000). Wenger further said, "A CoP is a group of professionals who share a common interest for a domain or a specific topic." (Wenger, McDermott & Snyder, 2002). That is, the passion of sharing and the interests of people are the driving force of a CoP. Based on the passion of sharing and the interests of people, this paper used Del.icio.us, a global website of social sharing, as the experimental data set. By analyzing the resources users were interested in and the tags people placed on the resources, we could get the similarity degree between users and then formed a CoP. A CoP bridged their relationships through the same interests, provided motivation to one another, and developed the interactive model of innovative collaborations.

In terms of Wenger's viewpoints, this paper tried to analyze the degree of similarity between users from the sharing mechanism of social tagging. Thus, Del.icio.us was used as the data set of this experiment. After calculating by the revised algorithm, people with similar interests were analyzed and located. The collaborative service platform based on social-bookmarking is presented in Figure 3. Users input key words or phrases in section A for the analysis of tags, resources and people. The results of analysis are displayed by names in section D. After searching and comparing, the relevant resources are listed in section B. When users click on the names listed in section D, the system will display all the information about the target group in section C.

Through this mechanism, the original static sharing was replaced by the interactive sharing of dynamic communication and thus community ecology of collective intelligence was realized. Owing to the communities, passive users were inspired to share actively.

Applying VSM to Find Similar Co-interest People

Vector Space Model (VSM), first proposed by Salton in 1984 (Salton et al., 1984), was originally used to categorize documents. Firstly, the related characteristics of document contents are asserted, and then the representative

characteristic items are extracted from each document. After that, Vector Space is transformed by these characteristic items, and used to calculate similarity degree. Finally, these documents are categorized by the degree of similarity. However, the similarity-based method was used not only in verbal texts but also in nonverbal fields (You & Chen, 2006). As long as the characteristic points related to an object are identified and transformed into a digital vector space model, similarity measurement can be conducted; for example, measuring similarity degree between graphs, web page and so on.

The research and application of similarities have been generally adopted in many fields as a mean of computing the similarity between objects. Cosine similarity-based method was first used in this field to measure similarities between contents. Through the measurement, documents could be categorized. On the other hand, some researchers used similarity-based method to searching for documents. They computed the similarity between key words and the content of documents, ordered it based on the degree of similarity, and displayed the results to users (Yencken et al., 2008) .

Cosine similarity utilizes the distance between two identical sets of base and dimension vectors to measure the angle between two context vectors (You & Chen, 2006). The value is among 0 to 1. When the angle between two vectors is smaller, the cosine value is smaller and close to 1, which means that the similarity between the two vectors is considerable. On the contrary, the similarity between the two vectors is low when the value is close to 0. For example, the assumptions in the two n-dimensional vector spaces, namely a and b respectively, are [a1, a2, ..., an] and [b1, b2, ..., bn], and then a and b's cosine similarity degree in mathematics is as follows:

$$Sim(a, b) = \cosine\theta = \frac{a \cdot b}{\|a\| \|b\|} = \frac{\sum_{i=1}^n a_i * b_i}{\sqrt{\sum_{i=1}^n a_i^2} * \sqrt{\sum_{j=1}^n b_j^2}}$$

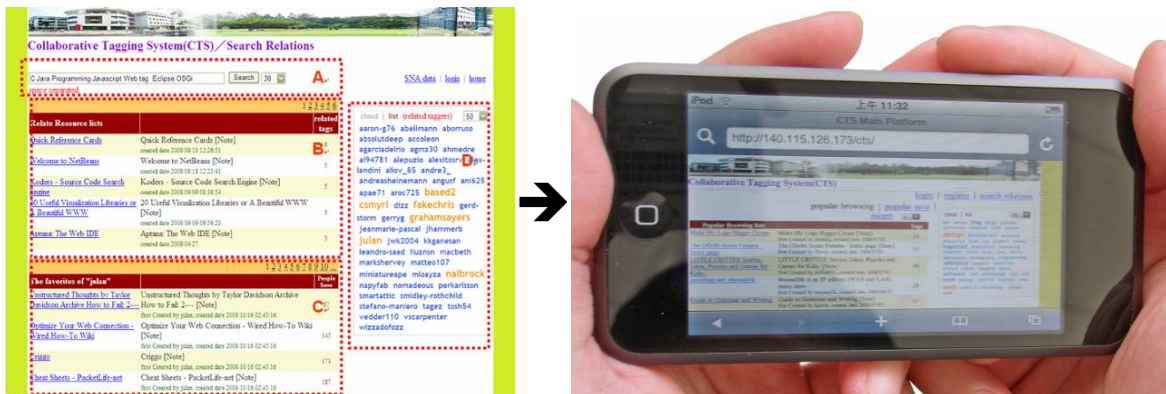


Figure 3. Collaborative services based on Social-Bookmarking

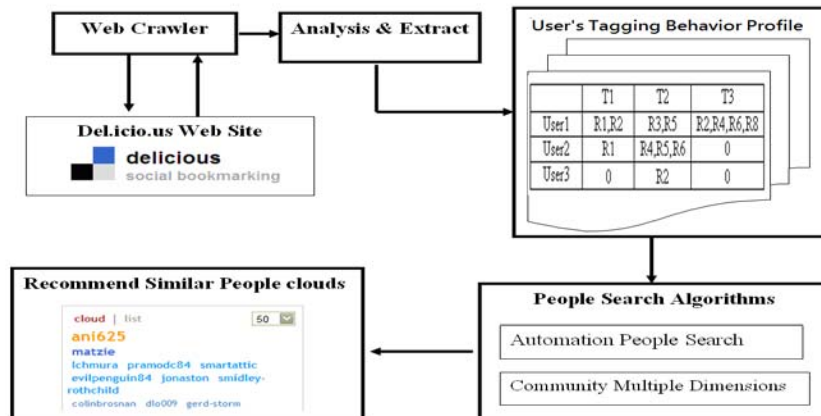


Figure 4. People search process of collaborative services

To put Social Community into practice, this paper was based on the social platform, Del.icio.us, to collect the experimental data. In figure 4, we designed Web Crawler to collect data, and then obtain users' behavioral data through analysis and extraction mechanism. These behavioral data, including the three related essential factors, "people", "tags" and "resources", forms the Data Set of User's Tagging Behavior Profile. People who are similar to users would be located by the formula for calculating similarity we amended, and partners could accommodate to loginers. That is, once users log onto the system, the system would automatically come up with a list of people having similar interests to users by People Clouds.

Furthermore, the system provides a multi-dimensional community of practice which is composed of multi-interests or professional searching inputted by users. For example, when users input three key words, C++, Java, and ASP, the system will find partners who concurrently satisfy these three interests, and show them to users by People Clouds.

This collaborative services propose a searching algorithm to recommend partners with similar interests to people and thus form a community. We analyzed tags marked by users and resources that users were interested in to find people with similar interests. People with similar interests are the driving force to form CoPs which will realize the innovation and communication of collective intelligence. Fortunately, we have had obvious contribution to the social networking, especially in recommending people with similar interests to each other on the globally tag-sharing data set. The platform we developed not only can find people with similar interests, but also can find multi-professional people and thus form a multi-dimensional community by inputting the same interest items. In mobile learning networks, we will conduct social knowledge mining to the community. Then, we will use Social Network Analysis to analyze the roles everyone plays, and further form knowledge networks.

Library 2.0 Based on People Search for Intelligent Reader Group

Library 2.0 and Knowledge Sharing Community

Michael Casey (2005) mentioned the phrase "Library 2.0" in his personal blog, LibraryCrunch, on September, 2005. Casey & Savastinuk (2006) thought that Library 2.0 is the key of library service in the next generation, providing services that can fulfill readers' needs. In addition, Library 2.0's core is reader-oriented, encouraging readers to share their knowledge and communicate with each other. In addition to appeal to readers with the new arrival book service, it also provides better services to existing readers and encourages them to form reader's communities. They also thought that readers are collective researchers, being able to share knowledge with each other, come up with new categories and set up tags for books (Casey & Savastinuk, 2006). Therefore, they suggested that libraries consider applying the related elements of Web2.0 in library communities, like using wiki, blogs such social software in order to encourage readers to interact with each other and provide new knowledge to other members.

As a result, knowledge sharing plays an important role in library service. Libraries should further provide a service to learners which enables them to build up reader's communities through reading and inspires them to share knowledge with each other. Providing information of new arrival books is not the main focus of Library 2.0, it is more important to find a group of people with the same reading interests, introducing them to each other based on the system analysis so that they can form reader's communities automatically and letting reading broaden their horizons as well as expanding a new interpersonal knowledge network. Knowledge sharing researcher Senge (1997) pointed out that knowledge sharing and information sharing are different. Information sharing purely provides information, but knowledge sharing contains the willingness of not only conveying what they know to others, but also helping others understand and learn the meaning of knowledge. From the above, we know that knowledge sharing is the activity of interpersonal knowledge communication, which is an even more important role in managing learning communities. Kulkarni et al. (2000) indicated that members in a community of practice share professional knowledge, solve problems, and do social activities mainly through interaction. Allee (2000) defined "community of practice" as that people share the same vision of one knowledge domain, and through participation, they form a community and establish practical abilities by the knowledge they create. The three aspects discussed here are knowledge, community and practicality. From the above, we know that sharing the same vision is a major motivation to form a community; therefore, in view of Library 2.0, we bring out the collaborative service mechanism, and under which, people with the same interests are located and recommended to interact all together.

Knowledge Sharing in Communities of Practice

Regarding the formation of community of practice, Nickols (2003) especially pointed out that a community of practice is all about members in an organization having the advantages to share knowledge, experiences and insights into things with members of the same interests and goals during work. As a result, community and knowledge sharing seem to be inseparable. Forming a knowledge sharing group through the same interest is actually forming a community of practice. However, how to promote knowledge sharing within a community and enhance the cohesion between community members are also an important research issues. Kuo & Young (2008) pointed out in their research that the attitude of knowledge sharing is the key to conduct knowledge sharing. If knowledge sharing can help an organization solve problems, and then further increase a person's values in the organization, people would consider sharing their knowledge. This perspective conforms to the purpose of libraries, providing books to readers so that after reading, they can enhance their own values and the ability to solve problems. If a library can only provide books to readers, then it is just a static knowledge database; but if it can provide readers the opportunities to share and communicate with each other, then it is a dynamic knowledge sharing. With this interaction mechanism, knowledge acquiring and absorbing are not just of one direction. Alavi & Leidner (2001) sorted out some scholars' viewpoints about knowledge. They thought that knowledge is a process that includes the creation, sharing and spread of it. Simply speaking, knowledge is a sharing process. Nickols (2003) pointed out that the advantage of a community of practice is that it can promote the interaction between members in order to create new knowledge and share out the best practicality experiences. Once the knowledge is built, community members can acquire from it and further enhance their learning activities. The knowledge sharing process can also help members develop their identifications in the community so that they would be more willing to stay. Even if someone leaves the community, the knowledge he/she once provided will not be taken away. As a result, knowledge sharing plays an important role in a library, and it is the community of practice that can provide the knowledge sharing mechanism. Based on the above, we can find out readers with similar reading interests by examining their circulation records, providing them a recommendation ranking list which comes from the system in order to encourage them to form a reader community, establish a knowledge sharing network and at the same time, expand their interpersonal relationships.

A trend of Library 2.0 service was created because of the thriving of Web 2.0. Therefore, library service should not be limited to lending service only; more importantly, it should help readers to form reader communities and further conduct knowledge sharing through the communities. Based on the above trend, this study investigated readers of the same fields by examining their circulation records. The results will be recommended to the readers to create reader communities. The purpose of this study is to examine whether readers' satisfaction towards this recommendation service is positive after using it.

Building Communities of Practice Based on Similar Readers

Based on the above statement, we hope to help a reader find his/her learning partners of similar interests, who may read the same book or study the same domain, by examining past circulation records. Moreover, find out other readers or groups of high connection with this reader by the similarity algorithm to form a reader community. In this community, all members can share knowledge, experiences and suggestions with each other. By this knowledge transfer model, they can build up a reader community to conduct knowledge sharing within which. As a result, we consider these learning partners as members of a community of practice, and will utilize the advantages of the community to encourage them to study and increase the identification of each other.



Figure 5. Recommend Similar Reader Ranking Cloud

The idea of collaborative services in this study focuses on finding people. In addition to learning partner recommendation based on Social Bookmarking mentioned above, we also provide reader community recommendation by examining their library's circulation records. Its main purpose is to introduce co-learners with similar reading interests to each other in order to form the so-called learning communities. As a result, we can conduct the analysis with learners' reading interests to build up mobile learning social networks.

For example, as shown in Figure 5, when Irene is searching for learning partners with similar interests through iPod, she can compare their similarity degrees according to library's circulation records as a recommendation reference. The recommendation result, Similar Reader Cloud, will show up via iPod, as shown in the right photo in Figure 5, using Tag Cloud to indicate the similarity degree. The biggest font represents the person who is most similar to Irene.

Methodology

The Research Model and Hypotheses

Figure 6 depicts our research model, noting that we applied the idea of collaborative services in searching for interest- based CoPs and reader's CoPs, and conducted User Satisfaction Survey to evaluate learner's satisfaction towards the two services we provided. The research hypotheses are as below.

- H1: Knowledge Sharing Attitude has a positive influence on satisfaction towards Collaborative Services.
- H2: System Quality has a positive influence on satisfaction towards Collaborative Services.
- H3: Information Quality has a positive influence on satisfaction towards Collaborative Services.
- H4: Service Quality has a positive influence on satisfaction towards Collaborative Services.

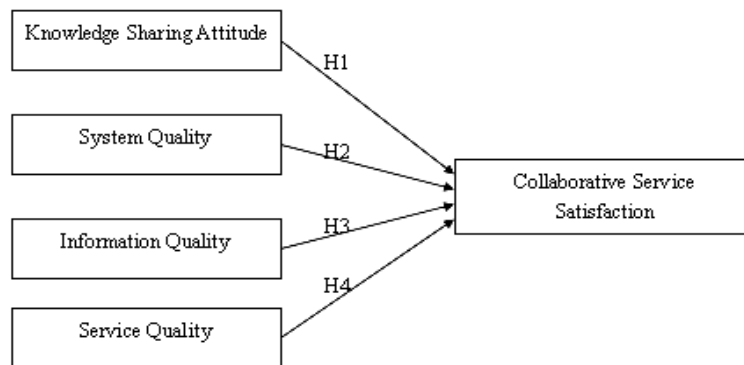


Figure 6. Research model

Research Framework

In our research, we conducted a questionnaire survey to determine user satisfaction towards the collaborative service platform. Through this service, users can find learning partners in similar domains and thereby enhance their learning intention and increase their satisfaction towards the service. Therefore, we brought in four research variables, Knowledge Sharing Attitude, System Quality, Information Quality, and Service Quality, to observe the overall situation. Figure 7 is the research framework based on the relationship between System Environments and research variables. The details are explained as follow:

- The effect of Knowledge Sharing Attitude in Mobile Learning Social Networks.
The so-called knowledge sharing attitude refers to learners' attitudes towards knowledge sharing, considering that only through sharing explicit or tacit knowledge can contribute to self-improvement. As a result, in this research, learners interacted and shared knowledge with each other through mobile learning social networks and then we observed their knowledge sharing attitudes by the questionnaire survey.

- The effect of System Quality in Collaborative Services
The so-called system quality refers to the degree of convenience for learners to provide and access information in the collaborative service platform. Therefore, we endeavored to assist learners in finding their learning partners in similar domains, and provided a recommendation ranking list to learners according to their similarity degree, hoping this service could increase learner satisfaction and encourage them to conduct active learning.
- The effect of Information Quality in Collaborative Services
The so-called information quality refers to whether the information from the collaborative service platform is useful, accurate, clear and valuable enough to fulfill readers' needs. The system helped learners find their learning partners in similar domains to conduct interactive learning. Learners felt that the recommendation ranking list provided from the system was useful, valuable, complete, and clear.
- The effect of Service Quality in Collaborative Services
The so-called service quality refers to whether learners can acquire instant services and this provision function is prominent. This viewpoint conforms to the idea of mobile learning which also emphasizes that learners' needs are fulfilled instantly, such as accessing information. This study aimed at providing instant lists of interest-based CoP or reader 's CoP to learners from the collaborative service platform, and completing learners' requests under mobile learning environment so that users thought the service was reliable and positive.

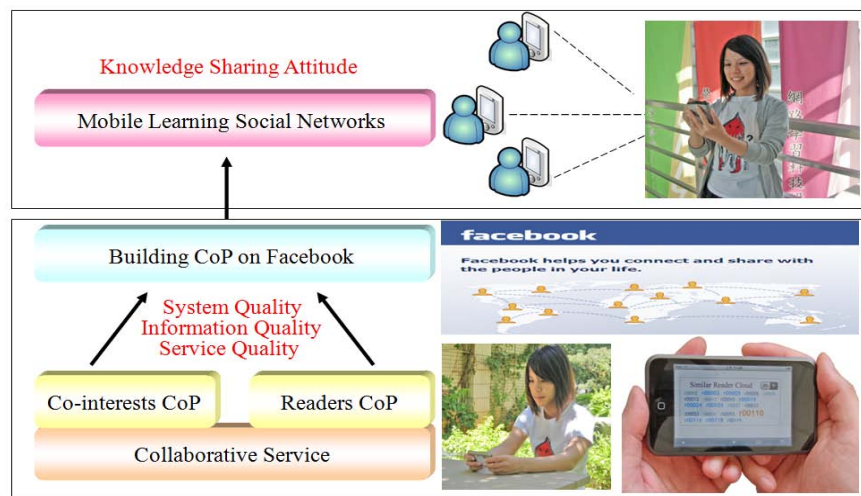


Figure 7. Research Framework

Questionnaire Evaluation

This research utilized questionnaire to evaluate learner satisfaction towards the collaborative service platform. Total five research variables are listed in Table 1 including Knowledge Sharing Attitude, System Quality, Information Quality, Service Quality and the satisfaction towards the collaborative service platform. In this research, Seven-point Likert scale was used to measure the five research variables. Each point indicates different level of users' subjective feeling to the sentence, ranging from 1 to 7.

As to the knowledge sharing attitude scale, this research referred to the scale items of Bock et al. (2005). As to the system quality scale, this research referred to the scale items of Wixom & Todd (2005) and Wang et al. (2007). As to the information quality scale, this research referred to the scale items of Michael & Khaled (2007). As to the service quality scale, this research referred to the scale items of Pitt et al. (1995) and Kang & Bradley (2002). As to the satisfaction scale towards collaborative services, this research referred to the scale items of Bhattacharjee (2001). Once each question is examined, if the factor loading reaches 0.4, the correlation reaches 0.6, and the extreme value and T-test are with high significance, then this question wouldn't be discarded, otherwise discarded.

Table 1. Research variables and operational definitions

Research Variable	Operational Definition
Knowledge Sharing Attitude	Learners' attitudes towards knowledge sharing, considering that only through sharing explicit or tacit knowledge can contribute to self-improvement.
System Quality	The degree of convenience for learners to provide and access information in the collaborative service platform
Information Quality	Whether the information from the collaborative service platform is useful, accurate, clear and valuable enough to fulfill readers' needs.
Service Quality	Whether learners can acquire instant services and this provision function is prominent.
Satisfaction towards the Collaborative Service Platform	Learner's satisfaction after using the collaborative service platform.

In this research, 233 questionnaires were sent out, 161 questionnaires were returned, and the response rate was 69%. The participants must finish 25 questions, and those who had identical answers throughout all questions or gave answers not conforming to the negative items would be excluded, and thus the rest would be considered as effective questionnaires. After screening out all ineffective questionnaires, total 147 subjects completed effective questionnaires (71 males and 76 females), and the valid rate among the received questionnaires was 91.3%. Participant's identity: 98 students, 49 faculties, and no teachers. College: 32 people in Engineering, 4 people in Technology, 39 people in Management, 14 people in Humanities and Social Sciences, 48 people in Informatics, and 10 people in Electrical and Communication Engineering.

Reliability Analysis

Maximum likelihood factor analysis was applied for all the questions of knowledge sharing attitude, system quality, information quality, service quality, and the satisfaction towards the collaborative service platform. The Cronbach's Alpha were 0.91, 0.83, 0.83, 0.82, 0.96 respectively and the explained variance were 67.73%, 46.32%, 56.95%, 53.60%, 85.05% respectively. The results indicated that there was internal consistency.

Correlation Analysis

As shown in Table 2, knowledge sharing attitude and three other factors that affect the success of information system, which are system quality, information quality and service quality, had a positive correlation with the satisfaction. It means that the higher degree of positive attitude ($r=.50$, $p<.01$) a learner has towards knowledge sharing attitude, the higher degree of satisfaction he would have towards the collaborative service platform. The higher degree of positive attitude ($r=.83$, $p<.01$) a learner has towards system quality, the higher degree of satisfaction he would have towards the collaborative service platform. The higher degree of positive attitude ($r=.82$, $p<.01$) a learner has towards information quality, the higher degree of satisfaction he would have towards the collaborative service platform. The higher degree of positive attitude ($r=.78$, $p<.01$) a learner has towards service quality, the higher degree of satisfaction he would have towards the collaborative service platform. The correlation coefficient between each variable and the satisfaction was over 0.45, and among all, system quality and the satisfaction had the highest correlation coefficient, which was 0.83.

Table 2. Correlation Analysis of each Research Variable

	Mean	Standard deviation	Knowledge Sharing Attitude	System Quality	Information Quality	Service Quality
Knowledge Sharing Attitude	5.55	.79	1			
System Quality	5.10	.68	.52**	1		
Information Quality	4.97	.71	.48**	.78**	1	
Service Quality	5.01	.69	.45**	.79**	.75**	1
Satisfaction towards Collaborative Services	4.99	.88	.50**	.83**	.82**	.78**

Note : * $p<0.05$, ** $p<0.01$, *** $p<0.001$

Regression Analysis Results

In order to understand the causation between each variable, and also to verify the hypotheses in this research, regression analyses were used as shown in Table 3. Due to College was the only significant variable in population statistics variables and different colleges might result in different ways of using the system, in order to determine causation between variables, we had to control the potential extraneous variable. As a result, in this research, after we used college as a controlled variable among the population statistics variables, learners' knowledge sharing attitudes could significantly predict their satisfaction towards the system ($\beta=.48$, $p<.001$), and the explained variance was 22%; system quality could significantly predict their satisfaction towards the system ($\beta=.78$, $p<.001$), and the explained variance was 44%; information quality could significantly predict their satisfaction towards the system ($\beta=.45$, $p<.001$), and the explained variance was 8%; service quality could significantly predict their satisfaction towards the system ($\beta=.21$, $p<.01$), and the explained variance was 1%.

From the results above, the more useful learners think knowledge sharing is, the higher satisfaction they would have towards the system, and thus would support Hypothesis 1 in this research. The more convenient learners think it is when they interact with others and share or require knowledge in the system, the higher satisfaction they would have towards the system, and thus would support Hypothesis 2 in this research. The more help learners think the information system provides, the higher satisfaction they would have towards the system, and thus would support Hypothesis 3 in this research. The more reliable learners think the system is or the better instant services they obtain, the higher satisfaction they would have towards the system, and thus would support Hypothesis 4 in this research.

Table 3. Regression Analyses of each Research Variable

	User Satisfaction				
Population Statistics Variable	M1	M2	M3	M4	M5
College	.19*	.08	.03	.02	.01
ΔR^2	.03*				
Knowledge Sharing Attitude		.48***	.08	.04	.04
System Quality			.78***	.46***	.35***
Information Quality				.45***	.38***
Service Quality					.21**
ΔR^2		.22***	.44***	.08***	.01**
R²	.03	.25	.69	.77	.78
Adjusted R²	.03	.24	.68	.76	.77
F	5.18*	24.24***	106.11***	117.69***	101.26***
df1	1	2	3	4	5
df2	145	144	143	142	141

Note : ** $p<0.01$

Results and Discussion

This study brought out a personalization-based community member recommendation system. The main service it provides is called Collaborative Services. The purpose of this service is to offer this platform so that learners can interact with other reader's CoP or interest-based CoP that are similar to them. Moreover, we used the mobile learning social network formed by this recommendation service to discuss the effect of knowledge sharing attitudes in the satisfaction towards collaborative services. We also discussed the effect of system quality, information quality, and service quality, which are the factors that affect the success model of information system, in the satisfaction towards collaborative services. Based on the above analysis results, the verified results of each research hypothesis are listed in Table 4, and we'll discuss them one by one.

Table 4. The verified results of each research hypothesis

Research Hypothesis	Result
H1: Knowledge Sharing Attitude has a positive influence on satisfaction towards Collaborative Services.	Support
H2: System Quality has a positive influence on satisfaction towards Collaborative Services.	Support
H3: Information Quality has a positive influence on satisfaction towards Collaborative Services.	Support
H4: Service Quality has a positive influence on satisfaction towards Collaborative Services.	Support

- Knowledge sharing attitude has a positive influence on the collaborative service platform

Raban & Rafaeli (2007) pointed out that knowledge sharing attitudes will influence people's willingness to share knowledge in information system. Other than that, Ho & Huang (2009) thought knowledge sharing attitudes have a positive influence on the satisfaction. As a result, in this research, learners interacted and shared with each other through mobile social learning networks, and then we utilized this questionnaire survey to observe their knowledge sharing attitudes. According to the above statement and the results of this research, we found out that if a learner held a positive perspective on knowledge sharing attitudes, which means that he thought knowledge sharing could benefit others and was valuable, he therefore was more willing to share knowledge with others in the system, and thus resulted in positive influence on the satisfaction towards the system.
- System quality has a positive influence on the collaborative service platform

According to the previous researches (Delone & Mclean, 2003; Wixom & Todd, 2005; Wang et al., 2007), these researchers thought that system quality would affect user satisfaction towards systems. The results of this research also confirmed that learners had positive attitudes towards the mobile learning / knowledge sharing platform, personalized information, and an user-friendly and easy-operation system interface provided by the collaborative service platform, and thus resulted in positive influence on the satisfaction towards the collaborative service platform.
- Information quality has a positive influence on the collaborative service platform

According to Delone & Mclean (2003), they thought that system quality would affect user satisfaction towards systems. This system helped learners find their learning partners in similar domains to conduct interactive learning. Furthermore, the research results also confirmed that learners had positive attitude towards information acquired from the collaborative service platform, they considering it useful, complete, clear and valuable, and thus resulted in positive influence on the satisfaction towards the collaborative service platform.
- Service quality has a positive influence on the collaborative service platform

According to previous researches (Delone & Mclean, 2003; Pitt et al., 1995; Kang & Bradley, 2002), these researchers thought that service quality would affect user satisfaction towards systems. The results of this research also confirmed that due to the collaborative service platform was able to instantly provide interest-based CoP or reader's Cop to learners, and complete their requests under mobile learning environment, they thought that the service was reliable and positive, and therefore indicated that learners had positive attitudes towards service quality which led to positive influence on the satisfaction towards the collaborative service platform. According to the results of the research, overall, the participants were satisfied after using the collaborative service platform under mobile learning environment, especially the interest-based CoP or reader's CoP lists. Some other learners suggested that every university should have this kind of system because it can provide the opportunity to expand their learning and social space. Furthermore, recommended interest-based CoP and reader's CoP are the key to form community relationships that they can find friends who share the same interests.

Conclusion

In this paper, we brought out the idea of collaborative services to help learners find their learning partners. We used Social Bookmarking as a base to recommend co-interest learning partners; other than that, we utilized school library's circulation records to recommend learning partners from reader's CoP. We tried to help learners find learning partners with similar interests or reading interests in order to form the so-called learning communities. Building up the analysis mechanism under this collaborative service mechanism, we conducted the similarity

analysis on learners' personal data in order to recommend learning partners who have the same interests and specialties to learners. Through this mechanism, we could support learning activities over MCSCL, building up learner-oriented mobile learning knowledge networks. Furthermore, we used the mobile learning social network formed by this recommendation service to discuss the effect of knowledge sharing attitudes in the satisfaction towards collaborative services. We also added three other factors regarding the system, which are system quality, information quality, and service quality, to discuss the effect on the satisfaction towards collaborative services. The result indicated that this service mechanism had a positive influence on user satisfaction because it provided the opportunity to expand their learning and social space. On account of this, as for the formed communities, we'll further observe and study from them through the SNA (Social network analysis) in the future.

Acknowledgement

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A Mobile Device and Online System with Contextual Familiarity and its Effects on English Learning on Campus

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ABSTRACT

In this study, a mobile device and online system, StudentPartner, is proposed to help students learn English on campus using multimedia and GPS support. Two activities, exploring the campus in English and English presentation, were designed to stimulate students' deep engagement and interaction with the system. Since students are very familiar with the campus as context, these activities elicit interest and playfulness. An experiment using the proposed system was conducted on the university campus for six months. The results show that positive perceptions of an activity, especially that of exploring the campus, significantly influenced users' intentions to utilize the proposed system. In addition, it was found that users' performance in the English presentation activity was significantly correlated with their achievement in learning. Thus, the proposed system, when combined with these two activities is an effective and enjoyable method of learning English that utilizes the concepts of contextual familiarity and the exchange of ideas through presentations.

Keywords

Mobile learning, English learning, Language learning, GPS, Student engagement

Introduction

It is currently necessary for students to learn English if they hope to engage international persons or companies in their future careers. The goal of this research is thus to design a system to facilitate university students' communications in English, not only in class, but also on campus in their daily lives.

One factor affecting language learning is learning motivation. Krashen (1983) said that high learning motivation would work both to lower anxiety as well as eliminate barriers and that a hunger for knowledge would make success easier. How to design good activities to enhance motivation is thus very important. In addition, interaction with others is a good method for learning a language (Brown, 2001; Wu, 1992). For example, we can learn from teachers and peers in interactive activities, and our language ability can be enhanced by asking questions face to face. Language learning can also benefit from real-life situations, which can also help build the pragmatic, cultural, and linguistic components of L2 competence in an integrated manner (Li, 1984). CLT (communicative language teaching) emphasizes that language should be practiced in real-life situations and with authentic language input, creative language output, and through more listening and speaking (Penner, 1995; Rao, 2002; Sun & Cheng, 2002). In short, everyone should ideally develop their language abilities from real life.

Most people now have a mobile device, most often a mobile phone, in both developed and developing countries. We can make use of the ubiquity of such devices to learn anytime and anywhere (Sharples, 2000). One can also approach and explore learning contexts independently using mobile devices, thus leading to the possibility of developing new learning methods. For example, individuals could download educational contents into a local database on their mobile device and access the data directly, giving them greater levels of freedom. Moreover, mobile devices offer multimedia services, and a wide variety of interesting and engaging applications have already been developed for them, such as PIM (Personal Information Management), GPS and games.

English is often taught using uninteresting topics in a relatively passive classroom context, which can have adverse effects on both students' levels of interest and achievement. In this research, we focus on a scenario in which English learning occurs in a context that is both familiar and interesting to students, i.e., the university campus and its neighborhood. Moreover, students can choose learning topics and forms of presentation that are both more enjoyable and meaningful to them. This system not only enhances learning motivation but also helps the students to learn useful, realistic English. Our system, named StudentPartner, combines a map of the campus with the GPS functions

in mobile devices to support two-stage campus-based English learning activities. Moreover, students working with this system can share English messages with each other and collaborate in learning.

The purpose of the research is the following:

1. To investigate the perceived acceptance of our system and its activities, including usefulness, playfulness, interestingness and usability.
2. To study the relationship between system usage, English presentation, and learning achievement.
3. To find the relationship between system usage on the Internet and in the mobile environment.

Literature Review

Mobile Devices

Klopfer and Squire (2008) indicate that mobile devices share some specific features: (a) portability, as handhelds can be taken to different locations; (b) social interactivity, as they can be used to collaborate with other people; (c) context sensitivity, as handhelds can be used to gather real or simulated data related to particular locations; (d) connectivity, as they enable connection to data collection devices, other mobile devices, and to a network; (e) individuality, as they can provide scaffolding to meet personal needs and to undertake investigations of specific situations. Huang, Lin, and Cheng (2010) implemented a mobile plant learning system to allow teachers and students to learn about plants outdoors.

In addition to these advantages, mobile devices also have some disadvantages. Albers and Kim (2001) highlighted three specific items that affect user access to information via handheld devices: (1) users find text on a mobile device screen more difficult to read than that on paper; (2) presenting graphical information is limited with regard to the complexity of the image and size; and (3) challenges to interactivity are increased due to the lack of a mouse and keyboard, as well as limited screen size. Some work has been done to overcome these disadvantages. Jones, Buchanan, and Thimbleby (2003) recommended pre-processing of pages for better usability on a small screen and suggested that this might be adopted for vertical rather than horizontal scrolling. Albers and Kim (2001) suggested that the user should be able to drag up and down on the entire screen with a stylus. Huang, Kuo, Lin, and Cheng (2008) developed a context-awareness synchronous learning system by enabling students to access lessons using mobile devices. Based on both the disadvantages and suggestions outlined above, we designed our system by following certain rules derived from existing human interface research. However, the problems of small screen size and consequently limited space for interactive interfaces are difficult to overcome, so our system can be used in both a mobile environment and as a regular website accessed by larger devices, such as desktop computers, to offer a way around these problems.

Learning English

In countries where English is not an official language, there is obviously a lack of an immersive environment for learning English. Moreover, most students are anxious about learning English in the context of a formal classroom because they are afraid of making mistakes. In addition, Jakobson (1970) claimed that the factors influencing language learning, by percentage, are as follows: aptitude, 33%; sentiment, 33%; intelligence, 20%; and other items, 14%. Furthermore, his research showed that aptitude in learning a foreign or second language is related to a learner's motivation and confidence in learning the language. Students with greater motivation and more confidence have better outcomes. In addition, students will learn from interaction and thus accumulate experience slowly but in a stable way. Significant benefits can be seen when Language learning is practiced in real-life. Therefore, learning activities that simulate real-life situations can help build the pragmatic, cultural, and linguistic components of L2 competence in an integrated manner (Li, 1984). The pedagogical features of CLT (communicative language teaching) include authentic language input, creative language output, real-life language practice, and more listening and speaking (Penner, 1995; Rao, 2002; Sun & Cheng, 2002). Therefore, the best way to learn a language is to learn in daily life. However, Tsou (2005) noted that oral practice in language classrooms remains important to language learners, especially for EFL (English as Foreign Language) learners, since this is where the majority of students' language practice occurs.

Multimedia can assist in learning language by delivering content in various forms that are both more realistic and more engaging. Consequently, such systems have long been utilized in language learning. For example, John (1995) introduced a system that combined texts, pictures, audio and video to present material and achieve interactive learning in a student center.

Building on earlier work, this research proposed one ubiquitous system that can offer students a contextually aware multimedia environment to explore campus life using English. Because this system promotes interaction in an engaging and enjoyable manner, it can be used to enhance students' language learning.

Ubiquitous Computer-Supported Collaborative Learning

Collaborative learning means that learners form groups to undertake activities in a manner that involves sharing, interaction and negotiation. Mevarech (1993) notes that collaborative learning can be more interesting for students than individual learning. Ushioda (1996) also shows that collaboration can enhance students' motivation. However, conducting collaborative learning in class can lead to a number of problems with regard to coordination, communication, and negotiation (Zurita & Nussbaum, 2004). Although desktop computers could solve some of these problems, issues still remain, such as interrupted interactions due to students focusing on their own computers. Therefore, Zurita and Nussbaum (2004) proposed Mobile Computer-Supported Collaborative Learning (MCSCCL) to address these problems. In his study, two experiments were conducted in math and linguistic learning in an elementary school, and collaborative activities, both with and without mobile technological support, were analyzed through observation and interviews. The results showed that MCSCCL can offer favorable outcomes with regard to portability, immediacy, and other characteristics that are useful for collaboration. However, this earlier study was only conducted using mobile devices to investigate collaboration in class and not for contextual learning. In this study, we present a system called Ubiquitous Computer-Supported Collaborative Learning (U-CSCL), which incorporates a contextual application for on-campus English learning. We also introduce learning activities for each topic to stimulate discussion and promote collaboration. The three activities are designed such that, first, a campus-related topic is given; for example, food that is available nearby may be noted, and then students can go to the related stands or restaurants to see or even eat the food. Finally, after visiting the site, the students can make a presentation in English to share their experiences and learn from each other.

Interactive English Learning

The ability to use a language is promoted by continuous interactivity (Brown, 2001; Wu, 1992). Dewey (1916) long ago confirmed that communication and interaction are important elements in the process of education. Language researchers also place considerable emphasis on the relationship between the active responses of a learner and the proficiency they acquire (Ericsson, Krampe & Tesch-Romer, 1993). Adding interaction to any learning activity is thus necessary to achieve effective outcomes.

Christie and Stone (1999) noted that peer-to-peer interaction is not a one-way knowledge transfer from experts to novices, and should be undertaken in a flexible way that allows both two- and multi-way communication. Meanwhile, Lamy and Goodfellow (1999) also suggested that second language learners could exchange their experiences through asynchronous discussion using a computer system, and they found that this kind of reflective learning could enhance student motivation and efficiency by enabling the sharing of opinions and discussion of related subjects.

In light of these studies, we have designed a two-step activity. In the first step, participants use the mobile device to explore the campus, exchanging messages with others via asynchronous interaction. In the second step, the students can share their experiences in the classroom and give feedback in face-to-face interaction.

Technology Acceptance Model

The Technology Acceptance Model (TAM) was developed by Davis (1989) based on the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975). In the TAM there are two beliefs focused on information system acceptance: "perceived usefulness" (PU) and "perceived ease of use" (PEOU).

Perceived usefulness is defined as the degree to which a user believes a specific system could increase his/her abilities in undertaking a particular task, and the main point of PU is expectations a user has when faced with a piece of technology. As long as he/she thinks the system might help in some way, the attitudes he/she expresses will be positive.

Perceived ease of use is defined as the degree to which a user thinks a specific system is easy to operate, and the point of PEOU is the functionality of the system. As long as users think that it is easy to use the system, they will have a positive attitude towards it, and this will affect their behavior.

We utilize the TAM in our framework and use relevant items in PU to predict user attitudes and then to examine the correlation between attitude and actual time spent using the system.

Knowledge Maps and Tracking

A knowledge map makes concepts and messages visible and makes the connections between them easy to follow (McCagg & Dansereau, 1991; Davenport & Prusak, 1998). Patterson, Dansereau, and Newbern (1992) mentioned that reading a knowledge map is better than reading text when we seek to recall messages in collaborative learning. Moreover, in an online context, messages tend to be both complex and made of multimedia elements, and knowledge maps can help express clearly the elements they contain (Wang, 2002). Finally, knowledge maps can define nodes and the links between them to create a meaningful space (Newbern & Dansereau, 1995). We apply the concept of knowledge maps in our system using tracking functions and GPS to help build a network of related information, and all users can post text messages that are related to a specific location. Users can then follow these messages to different places and access contextual information about those places, thus opening the way for more meaningful learning experiences.

System Design

Based on the above literature review, this study proposed a UCSCL system supported by integrating web-based and mobile technologies and designed an English campus learning system. First we introduce the CSCL mechanism, and then the features of the English campus learning system.

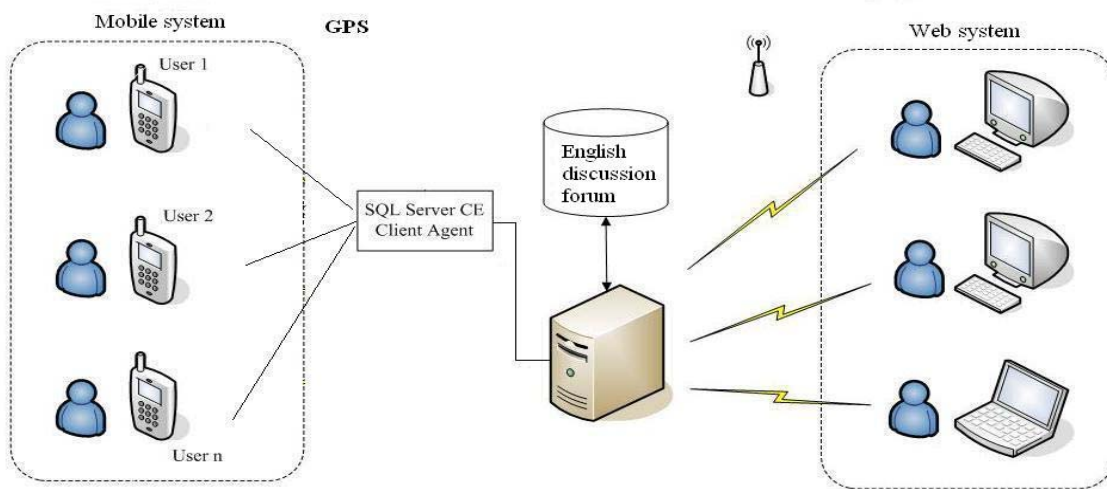


Figure 1: The Ubiquitous Computer-Supported Collaborative Learning (UCSCL) Environment

U-CSCL Environment

This study implements a UCSCL system that provides a collaborative environment ubiquitously and contextually by integrating web-based and mobile technologies, as shown in Figure 1. Based on UCSCL, we also designed an

integrated multimedia hybrid forum called the “StudentPartner campus English learning system.” In addition to using mobile devices, students can also use desktop or laptop computers to access, share and upload information and multimedia files. Students can then use mobile devices to retrieve information and multimedia contents for access both online and offline. For example, students can use smart phones to record images, video or audio when they want to describe the environment around them and post their ideas in the StudentPartner system to share with other group members. Afterwards, students can synchronize the local database to a central database server to achieve information consistency. In this way, students can practice collaborative learning in a ubiquitous and contextual manner.

English Campus Learning System

This section introduces the features of the English learning system presented in this work: GPS with real-context; GPS tracking; multimedia posting; information synchronization and consistency; and system backup and rebuilding.

GPS with Real-context

Our system relies on GPS so that it knows where students are and can send them contextually relevant information. Students can also post messages about their surroundings to share with others, and these can contain multimedia content.

GPS Tracking

Our system offers a tracking function with GPS support in a mobile environment. Students can thus enable the tracking function before posting messages, and then the following messages in the same tracking will be linked together. When students wish to recall messages later, the system can help them to memorize related content and thus enhance English learning.

Multimedia Posting and Reading via Mobile Devices/Web Environment

When students explore the campus using our system, they can send and receive multimedia messages. This multimedia capability not only helps enhance students’ listening and speaking but also brings an important element of playfulness. Students can synchronize their latest posts to the local database in their mobile devices, so that even if they are off-line, they can still access the data needed for their studies. In addition, students can read data not only on their mobile devices but also from a desktop or notebook computer, using the related Web environment. The proposed system is thus very flexible and can be used in a variety of situations.

Information Consistency and Synchronization

Data synchronization allows students to synchronize the local database in their mobile devices with the central database online through a wireless (Bluetooth or WiFi) or wired network. There are several mobile clients, but there is only one server with the central database. Mobile clients can input data, add multimedia files and read messages offline. When mobile clients connect to the network, they can synchronize the new information (which is input or captured in the offline environment) with the server database using SQL Server CE Agent. After the local database is synchronized, mobile users can get the latest information from the Internet, and Web-based users can also access the latest information posted from the mobile environment.

System Backup and Rebuilding

The central database backs up all data (including personal information, multimedia data and collaborative discussions) for recovery in case any mobile device crashes or runs out of power. Therefore, students can easily reinstall the StudentPartner system and recover their databases, guaranteeing that no information will be lost.

User Interface

The user interface and activities in the StudentPartner campus English system are described as follows.

The user interface of the mobile system

The user interface of the mobile StudentPartner system is divided into three frames, as shown in Figure 2. In the top frame are shown various categories of learning content; in this case “To eat,” “Living,” and “Transportation,” and all related posts in each category can be shown in a tree structure. In the middle frame are satellite maps of the campus to show students where they are and the posts related to their surroundings. Students can scroll the map with a stylus. In the bottom frame, the posts are shown in order of time posted. Because the screen on a mobile device is relatively small, students can hide the top or bottom frames to have a bigger campus view, as shown in Figure 3. In addition, students can also zoom in and out of the map to get more detailed information.

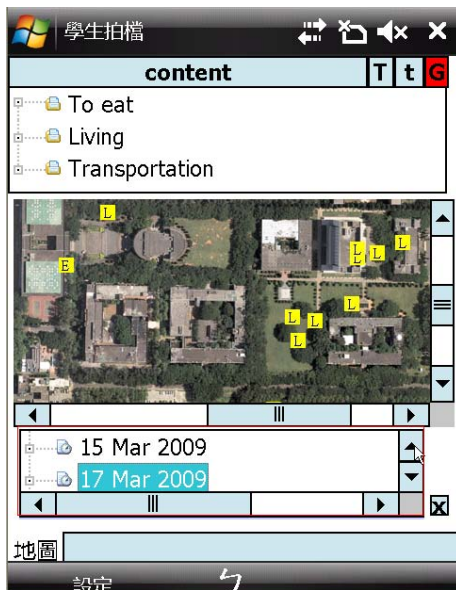


Figure 2: Layout of the mobile interface

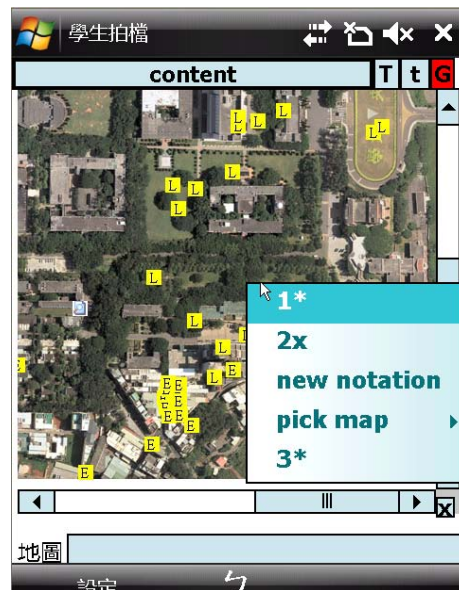


Figure 3: Full screen campus map

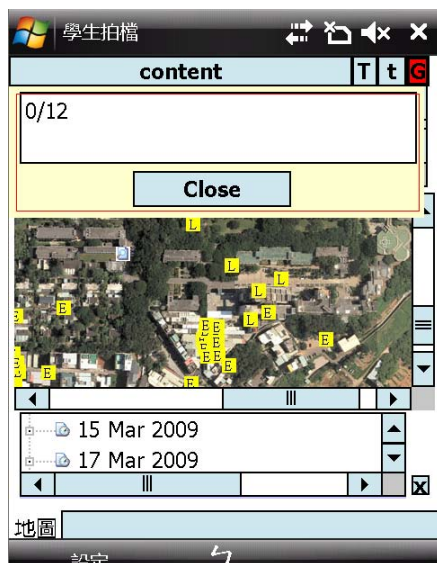


Figure 4: GPS function

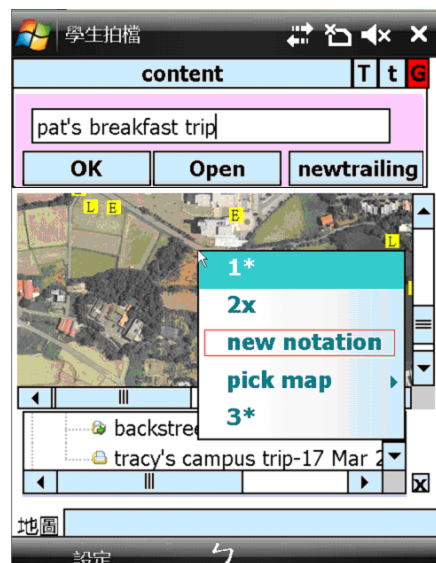


Figure 5: Posting a message

When students explore the campus, they can use the GPS function, as shown in Figure 4, so that both they and the system know where they are on the map. They can click on the small icons representing posts on the map to read the contents. The icon “L” indicates a “Living” post; “E,” “Eating”; and “T,” “Transportation.” If students wish to comment on items near their location, they can click on the map to post new messages, as shown in Figure 5.

The tracking function can link messages together with lines to provide one convenient way to recall related messages. Students can thus enable tracking, as shown in Figure 6, and post a series of related messages. When they are finished, the messages can be retrieved by clicking on *open trail* in Figure 7.

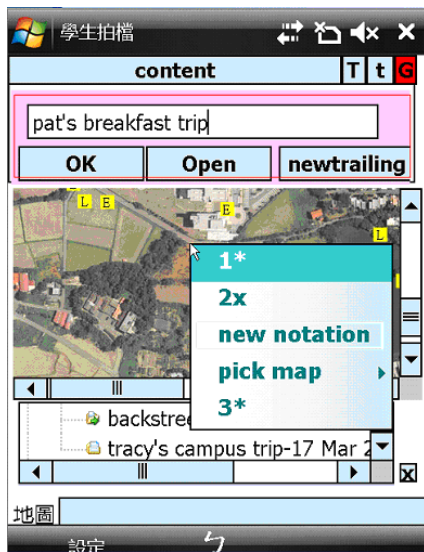


Figure 6: Enabling the tracking function

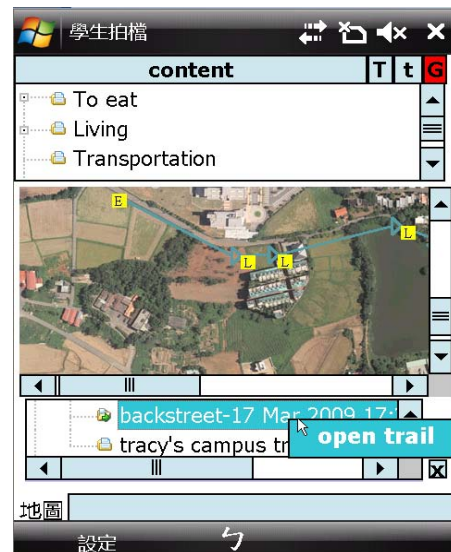


Figure 7: Lining up the tracking posts

The user interface for posting input is shown in Figure 8. The post can contain text, photos, video and audio. Messages are thus enriched by multimedia, and students can have meaningful and enjoyable learning experiences while they study speaking and writing in English. When students want to read a message, they can select a post in the forum on the top frame or click on the icon of the campus map in the middle frame in Figure 9. If students want to know the location of the post on the campus map, they can click on the location button and the related position will be shown. Figure 10 shows that the multimedia content in a post can be accessed by opening the attached files.

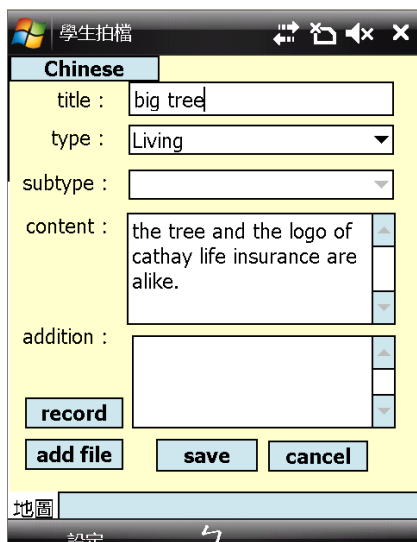


Figure 8: The interface for the message input

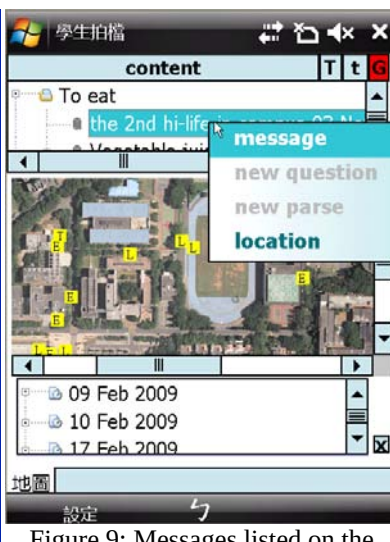


Figure 9: Messages listed on the forum and tagged on the map

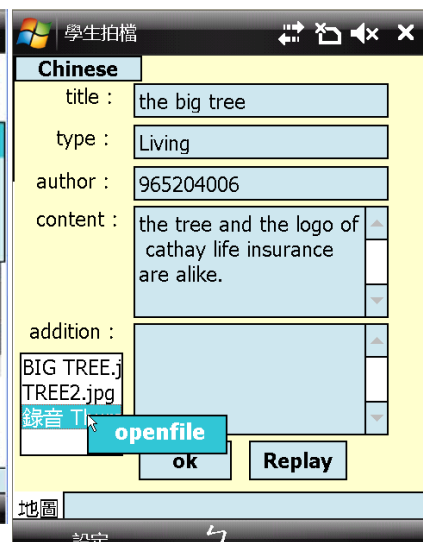


Figure 10: Reading text messages and opening multimedia files

The user interface of the online StudentPartner system

During presentation activities in the classroom, students employ the online StudentPartner system, as shown in Figure 11, to share their experiences exploring the campus in English. They can use the tracking function to make their presentation read like a narrative, as the speaker can talk from the first icon and then follow arrows to review the succeeding messages. Students can also make use of multimedia elements that they gathered on their exploration in their presentations, and the audience can offer opinions and ask questions as needed, which will also stimulate natural discussion. Thus, users can improve their listening, speaking, and reading skills.

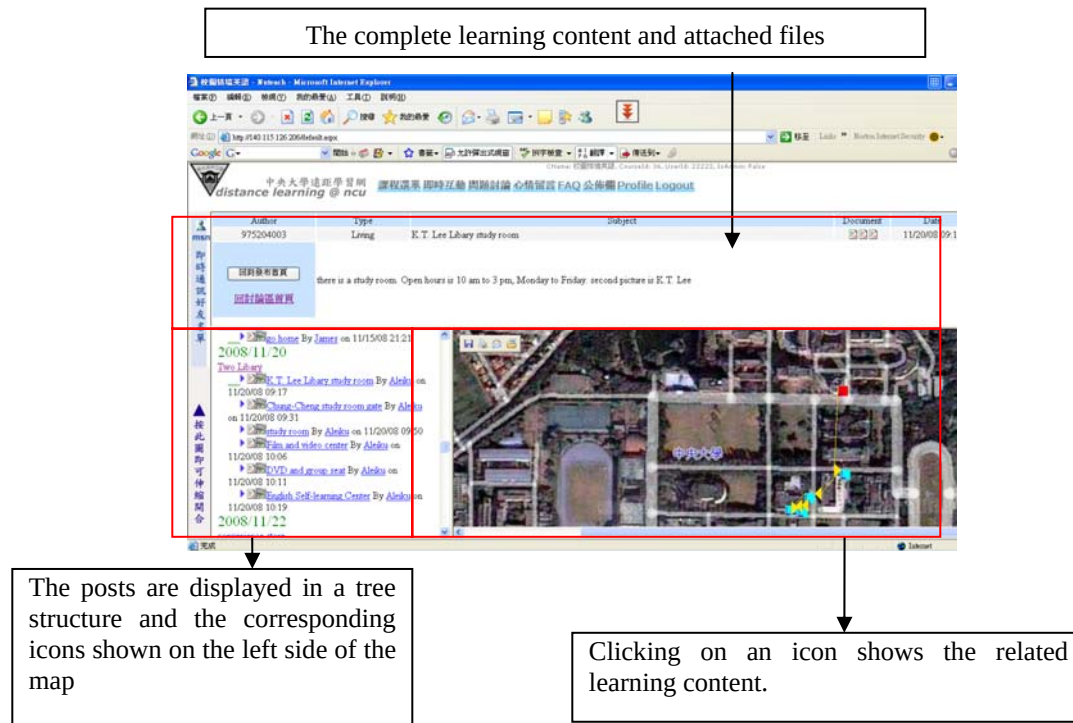


Figure 11: The user interface of the web system

Research Design

Research Structure

The TAM was employed in this research for discussing the relationships among users' perceptions.

The details of the research terms in Figure 12 are as follows:

1. System ease of use
System ease of use, according to Davis (1989) is related to the degree to which a user thinks a specific system is easy to manipulate. In the research, this was rated using questionnaires.
2. System usefulness
System usefulness, according to Davis (1989), is the degree to which a user believes a specific system could increase their work performance, with work in this case being replaced by learning. This dimension consists of three variables: usefulness of the multimedia feature, usefulness of GPS with real-context, and overall system usefulness. And they are described as follows:
 - **Usefulness of Multimedia aspect:** to measure users' perception of the usefulness of the multimedia in the system to English learning.
 - **Usefulness of GPS with real context:** to measure users' usefulness perception of GPS with real context to English learning.

- **Overall system usefulness:** to measure users' perception of the usefulness of overall system of English learning.

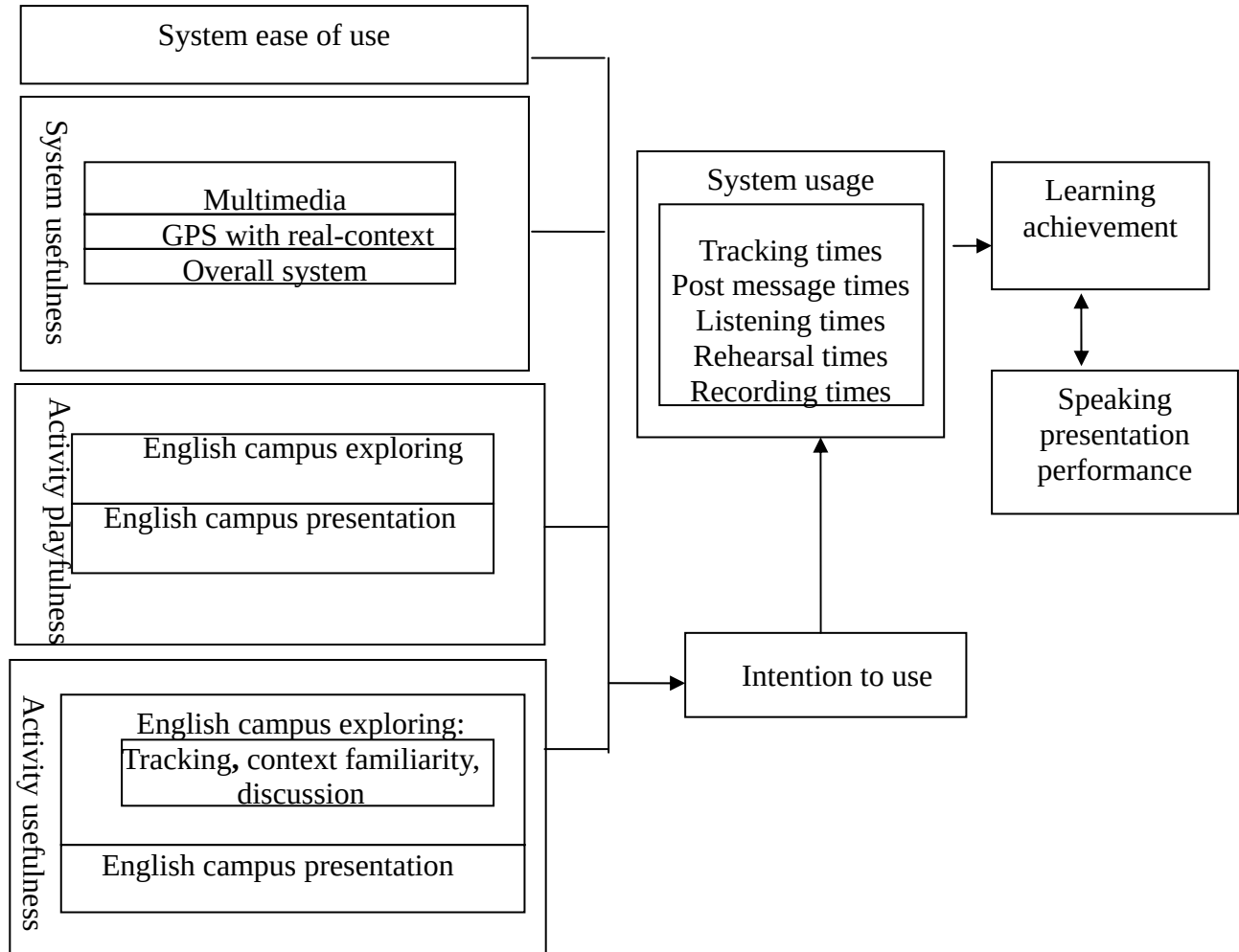


Figure 12: The structure of research variables in the study

3. Activity playfulness

Activity playfulness is derived from the definition by Moon and Kim (2001), and in this research it indicates to what degree users feel interest and enjoyment when they undertake the English learning activities. This dimension separately investigates the following two variables: playfulness in the campus-exploring activity and that in the presentation activity.

- **English campus exploring activity:** to measure the level of interesting and enjoyment users feel when they do the English campus exploring activity, which is conducted in the campus, outside of classroom.
- **English campus presentation activity:** to measure the level of interesting and enjoyment users feel when they do the English campus presentation activity in the classroom and have some discussion and brainstorming.

4. Activity usefulness

Activity usefulness, according to Davis (1989), is defined as the degree to which users perceive that the activity could help their English learning. The dimension consists of five variables:

- **Campus exploring activity:** to measure the level of usefulness users perceive when they do the activity, specifically with regard to these three elements:
 - **Tracking activity:** to measure user perceptions of the usefulness of tracking with regard to their English learning.

- o **Context familiarity:** to measure user perceptions of the usefulness of context familiarity with regard to their English learning.
 - o **Interaction:** to measure user perceptions of the usefulness of discussion with regard to their English learning.
 - **Presentation activity:** to measure user perceptions of the usefulness of the classroom presentation activity and the related discussions and brainstorming sessions.
5. Intention to use
Intention to use, according to the definition by Selim (2003), is related to an “individual’s perceptions about the characteristics of the target technology as explanatory and predictive variables for acceptance behavior.”
 6. System usage
System usage, according to the definition by Ajzen and Fishbein (1980), is related to “the actual times of some behavior using target system.” The research defines system usage as the number of times users actually employ the proposed system during the experiment, and this dimension consists of five variables:
 - Tracking times: The number of tracking events produced by the learner.
 - Posting times: The number of posting-message events produced by the learner.
 - Listening times: The number of times the learner listened to other learners’ voice recordings.
 - Rehearsal times: The number of times the learners listened to their own recordings.
 - Recording times: The number of voice recordings produced by the learner.
 7. Learning achievement
Learning results are the final learning outcomes for a student. We tested the listening and reading abilities of students with TOEIC and the speaking and writing abilities with the GEPT. We invited one native English speaking teacher to grade the speaking and reading tests.
 8. Speaking presentation performance
The speaking presentation section has two parts: delivering the presentation and giving feedback. In grading the presentation, we followed the guidelines of Testing for Language Teachers (Hughes, 2003), and one native English speaking teacher gave grades with respect to accent, grammar, vocabulary, fluency and comprehension, as shown in Table 1.

Table 1: The speaking standard

Points/ Focus	5	4	3	2	1
Accent	Target-like	Marked foreign accent but it does not interfere with understanding	Foreign accent that requires concentrate listening	Frequent gross errors	Unintelligible
Grammar	No more than five errors	Occasional errors	Frequent errors	Constant errors	Entirely inaccurate
Vocabulary	Accurate, precise and extensive	Adequate and precise	Adequate and general	Inaccurate and only useful for survival	Inaccurate and Limited
Fluency	Effortless and smooth	Occasionally hesitant	Frequently hesitant	Constantly jerky	Halting and fragmentary
Comprehension	Target-like comprehension ability	Normally-educated comprehension ability	Requires occasional repetition	Requires constant rephrasing	Understands too little for the simplest type of conversation

Experimental Design

Ten graduate students (six males and four females) participated in the experiment. The experiment lasted from November 2008 to April 2009. The participants used PDA phones with the mobile StudentPartner application to undertake the English campus exploring activity using the Eating, Living and Transportation sections; they also used the online StudentPartner to share their experiences and then conducted the presentation activity in the classroom.

The students were able to synchronize the local (PDA phone) and central (Internet) databases to keep current with the latest posts.

After the experiment, the system usage log and questionnaires were used for data collection and analysis. Finally, interviews were conducted to find the reasons behind our statistical findings.

In the experimental design, participants used PDA phones to explore the campus. With GPS support, they could post text messages as well as multimedia files, using the PDA's camera and voice recorder. Afterwards, participants used what they had learned and found in exploring the campus to conduct English presentations in the classroom several days later.

Participants were asked to explore the campus following the three criteria in the experiment: (1) a fixed topic, such as food, living or transportation, was given, and each participant was asked to explore the topic on campus—for example, the eating topic would cover local restaurants and the quality of the food or its cost; (2) life on campus, such as discussing daily routines, where to have breakfast, when to go to class, lunch, or lab and so forth; (3) the favorite food or drink of each participant—for example, pointing out the best beverages stores, explaining why a particular drink is their favorite and sharing related experiences. Furthermore, students were asked to visit the stores and restaurants recommended by others to experience the food and drink for themselves. Afterwards, all of the participants come back to the classroom and exchanged ideas and experiences in their subsequent class presentations.

Experimental Results and Discussion

This study investigates the factors that affected student perceptions in using the campus English learning system. The factors include the following variables and their effects on learning: system ease of use and system usefulness, which are related to the system itself; activity playfulness and activity usefulness, which are related to the activity design; usage intentions and time spent in using the system. In this section, the above relationships are tested using both simple regression and multiple regression techniques.

Analysis of the effects on usage intentions of perceptions of the system and activities

Simple Regression

We used simple regression analysis to predict how the four independent factors—system ease of use, system usefulness, activity playfulness, and activity usefulness—affected usage intentions.

Table 2: Simple regression on the independent variables with regard to usage intentions

Independent variables	R	Adj R	F	B	β	t-value	Sig.
System ease of use	.533	.474	9.122	.341	.730	3.020(*)	.017
System usefulness	.735	.701	22.14	.126	.857	4.705(**)	.002
Activity playfulness	.890	.877	64.926	.273	.944	8.058(***)	.000
Activity usefulness	.766	.737	26.184	.151	.875	5.117(***)	.001

*p<.05, **p<.01, ***p<.001

Table 2 shows the predictive degree of system ease of use for usage intentions. The overall value of R^2 was originally .533, but changed to .474 after we adjusted for the small number of samples. This variable had 47.4% explanatory power in predicting usage intentions. Regression reached a significant level ($F=9.122$, $p=.017$). The overall value of R^2 for the predictive ability of system usefulness was originally .735 but was changed to .701 after the above adjustment. This variable had 70.1% explanatory power with regard to predicting usage intentions. The regression reached a significant level ($F=22.14$, $p=.002$). The students thus thought that system usefulness was more important than system ease of use.

The overall value of R^2 for the predictive ability of activity playfulness was .890, but changed to .877 after our adjustment. This variable had 88.7% explanatory power in predicting usage intentions. The regression reached a

significant level ($F=64.926$, $p=.000$). With respect to t with regard to on intention to use, the overall value of R^2 for the predictive ability of activity usefulness was .766 but changed to .737. This variable had 73.7% explanatory power in predicting usage intentions. The regression reached a significant level ($F=26.184$, $p=.001$). The students thus thought that activity playfulness was more important than activity usefulness.

Table 3: Simple regression on the system usefulness with regard to usage intentions

Independent variables	R	Adj R	F	B	β	t-value	Sig.
Multimedia	.630	.584	13.64	.324	.794	3.693(**)	.006
GPS with real context	.724	.690	21.016	.487	.851	4.584 (**)	.002
Overall system	.624	.577	13.292	.260	.790	3.646 (**)	.007

* $p<.05$, ** $p<.01$, *** $p<.001$

Table 3 shows the predictive ability of the effects of multimedia, of GPS with real context, and the overall system on usage intentions. As shown, the overall values of R^2 were originally .630, .724, and .624 for the effects of multimedia, of GPS with real context, and the overall system on usage intentions, respectively; but these values changed to .584, .690, and .577, respectively, after adjusting for our small sample size. The independent variables had 58.4%, 69%, and 57.7%, respectively, explanatory power for predicting intention to use. The regression reached a significant level ($F=13.64$, $p=.006$; $F=21.016$, $p=.002$; and $F=13.292$, $p=.007$, respectively). These results suggest that the students thought system usefulness was more important than system ease of use.

Table 4: Simple regression on the activity playfulness with regard to usage intentions

Independent variables	R	Adj R	F	B	β	t-value	Sig.
English campus exploring activity	.850	.832	45.508	.434	.922	6.746(***)	.000
English presentation activity	.813	.789	34.669	.627	.901	5.888 (***)	.000

* $p<.05$, ** $p<.01$, *** $p<.001$

Table 4 shows the predictive ability of English campus exploring activity playfulness with regard to the usage intentions. The value of R^2 as a whole was originally .850, but it was changed to .832 after an adjustment due to the small number of samples. The independent variables had 83.2% explanatory capability with regard to predicting intention to use. The results of the testing model indicate that the regression reached a significant level ($F=45.508$, $p=.000$). With respect to the predictive ability of English presentation activity playfulness with regard to intention to use, the value of R^2 as a whole was originally .831, but it was changed to .789 after an adjustment due to the small number of samples. The independent variables had 78.9% explanatory capability with regard to predicting usage intentions. The results of the testing model indicate that the regression reached a significant level ($F=34.669$, $p=.000$). The students thus thought that the English campus exploring activity was more playful than the presentation activity.

Table 5: Simple regression on the activity usefulness with regard to usage intentions

Independent variables	R	Adj R	F	B	β	t-value	Sig.
English campus exploring activity	.631	.585	13.691	.188	.794	3.7(**)	.006
English presentation activity	.564	.509	10.341	.333	.751	3.216 (*)	.012

* $p<.05$, ** $p<.01$

Table 5 shows the predictive ability of English campus exploring activity usefulness with regard to the intention to use. The value of R^2 as a whole was originally .631, but it was changed to .585, after an adjustment due to the small number of samples. The independent variables had 58.5% explanatory capability with regard to predicting usage intentions. The results of the testing model indicate that the regression reached a significant level ($F=13.691$, $p=.006$). With respect to the predictive ability of English presentation activity usefulness with regard to usage intentions, the value of R^2 as a whole was originally .564, but it was changed to .509 after an adjustment due to the small number of samples. The independent variables had 50.9% explanatory capability of predicting usage intentions. The results of the testing model indicate that the regression reached a significant level ($F=10.341$, $p=.012$). The students thus thought that the English exploring activity was more useful than the English presentation activity.

Table 6: Simple regression on the activity usefulness in “English campus exploring activity” with regard to usage intentions

Independent variables	R	Adj R	F	B	β	t-value	Sig.
Tracking	.257	.164	2.770	.257	.507	1.664	.135
Context familiarity	.825	.803	37.661	.809	.908	6.137 (***)	.000
Interaction	.627	.581	13.470	.467	.792	3.670 (**)	.006

*p<.05, **p<.01, ***p<.001

Table 6 shows the predictive ability of the usefulness of the Tracking activity does not effect the usage intentions. With respect to the predictive ability of the usefulness of context familiarity with regard to usage intentions, the value of R^2 as a whole was originally .825, but it was changed to .803 after an adjustment due to the small number of samples. The independent variables had 80.3% explanatory power with regard to predicting usage intentions. The results of the testing model indicate that the regression reached a significant level ($F=37.661$, $p=.000$). For the predictive ability of the usefulness of Interaction with regard to usage intentions, the value of R^2 as a whole was originally .627, but it was changed to .581 after an adjustment due to the small number of samples. The independent variables had 50.9% explanatory power for predicting intention to use. The results of the testing model indicate that the regression reached a significant level ($F=13.470$, $p=.006$). The students thus thought that context familiarity was useful for learning English because if they are familiar with the context and materials it will reduce their learning anxiety.

Multiple Regression

We also used multiple regression analysis to predict how the four independent factors named above affect usage intentions.

Table 7: Multiple regression on the activity playfulness with regard to usage intentions

	Independent variables	B	β	t-value	Sig.
R2 =.890	Activity playfulness	.273	.944	8.058***	.000
Adj. R2 =.877					
(F=64.926, p=.000)					

*p<.05, **p<.01, ***p<.001

Table 7 shows the predictive ability of activity playfulness on the usage intentions. The value of R^2 as a whole was originally .890, but it was changed to .877 after an adjustment due to the small number of samples. The independent variables had 87.7% explanatory power with regard to predicting intention to use. The results of the testing model indicate that the regression reached a significant level ($F=64.926$, $p=.000$), and thus the students perceived that activity playfulness is an important factor.

Table 8: The multiple regression on the activity playfulness in “English campus exploring activity” with regard to usage intentions

	Independent variables	B	β	t-value	Sig.
R2 =.850	Campus English exploring	.434	.922	6.746***	.000
Adj. R2 =.832					
(F=45.508, p=.000)					

*p<.05, **p<.01, ***p<.001

Table 8 shows the results of a multiple regression on the predictive ability of English campus exploring activity on usage intentions. The value of R^2 as a whole was originally .850, but it was changed to .832 after an adjustment due to the small number of samples. The independent variables had 83.2% explanatory power for predicting intention to use. The results of the testing model indicate that the regression reached a significant level ($F=45.508$, $p=.000$), which means that the students thought the English campus exploring activity was more enjoyable than the English presentation activity.

Table 9: The multiple regression on the system usefulness in “GPS with real-context” with regard to usage intentions

	Independent variables	B	β	t-value	Sig.
R2 =.724	GPS with real- context	.487	.851	4.584(**)	.002
Adj. R2 =.690					
(F=21.016, p=.002)					

*p<.05, **p<.01

Table 9 shows the predictive ability of GPS with real-context on the usage intentions. The value of R^2 as a whole was originally .724, but it was changed to .690 after an adjustment due to the small number of samples. The independent variables had 69% explanatory power for predicting intention to use. The results of the testing model indicate that the regression reached a significant level (F=21.016, p=.002), meaning that the students felt that the feature of GPS with real-context was important for English learning.

Table 10: The multiple regression on the activity usefulness with regard to usage intentions

	Independent variables	B	β	t-value	Sig.
R2 =.631	English campus exploring activity	.188	.794	3.7001(**)	.006
Adj. R2 =.585					
(F=13.691, p=.006)					

*p<.05, **p<.01

Table 10 shows the predictive ability of the English campus exploring activity on the usage intentions. The value of R^2 as a whole was originally .585, but it was changed to .631 after an adjustment due to the small number of samples. The independent variables had 58.5% explanatory power for predicting intention to use. The results of the testing model indicate that the regression reached a significant level (F=13.691, p=.006), meaning that the students thought the English campus exploring activity was more useful than the English presentation activity.

Table 11: The multiple regression on the activity usefulness in “context familiarity within the English campus exploring activity” with regard to usage intentions

	Independent variables	B	β	t-value	Sig.
R2 =.825	Context familiarity	.809	.908	6.137 (***)	.000
Adj. R2 =.803					
(F=37.661, p=.000)					

*p<.05, **p<.01, ***p<.001

Table 11 shows the predictive ability of context familiarity within the English campus exploring activity on the usage intentions. The value of R^2 as a whole was originally .825, but it was changed to .803 after an adjustment due to the small number of samples. The independent variables had 80.3% explanatory power for predicting intention to use. The results of the testing model indicate that the regression reached a significant level (F=37.661, p=.000). This means that the students felt context familiarity was useful for learning English because if they were familiar with the context their anxiety would be lessened.

Analysis of willingness to use, system usage, presentation performance and learning achievement

This study hypothesizes that students’ willingness to use affected system usage in the experiment. Based on this hypothesis, the correlation between willingness to use and system usage was tested using the Pearson correlation analysis.

The results showed that none of the factors was significantly correlated with willingness to use in this context. In the detailed investigation, using five-point scale, the questionnaire survey showed that the system was scored over four points on average by the students and no student stated that they were “Unwilling to use again,” meaning they had the tendency to use the system. However, the proposed system actually shows low usage, meaning that there is no significant correlation between willingness to use and system usage. In the interviews, we found that since the experiment was not conducted in a formal course, most of the participants were too busy with their studies to take advantage of the system. In addition, the students said that they were not used to carrying the PDA phone with them at all times. The third reason for low system usage was that the students said that the help of an English expert was required in their English posts, since they did not know whether their spoken or written English was correct.

Similarly, none of the factors of system usage were significantly correlated with learning achievement; the main reason was because the system usage was too low.

There is a significant correlation between learning achievement and English presentation performance (.779**). When a participant's performance in their spoken presentation is high, their learning achievement is also high, which means that students should practice giving presentations so that their English abilities will be improved.

Comparison of system usage via mobile devices and website

Table 12: Comparison between mobile device and website usage by Wilcoxon matched-pairs signed ranks test (n=10)

	Z-value
Read messages on mobile device	2.803**
Read messages on web	
Open photos on mobile device	2.805**
Open photos on web	
Listen to voice recordings on mobile device	2.524*
Listen to voice recordings on web	

*p<.05, **p<.01

As shown in Table 12, the correlation between system usage on mobile devices and on the web is significant when reading messages (2.803**), viewing photos (2.805**) and listening to voice recordings (2.524*) on both platforms. It is found that most users usually recall the messages on the web. Thus, if discussion forums are planned for mobile devices, it should be considered that the message can be easily accessed via mobile devices.

Findings and Implications

The questionnaires and interviews show that the students thought our system was useful for learning English. In addition, the students thought that using multimedia, replying to each others' posts, and using GPS in a real-life context could help them; context familiarity and sharing their experiences in useful and enjoyable activities were especially helpful. In future studies, we will investigate the effect of combining multimedia and context familiarity on learning languages in daily life.

Some interesting findings were obtained during the experiment. In the first several weeks, participants needed to use printed handouts before their presentations but did not need to do so after several weeks. This means that our activities did enhance students' English speaking ability and confidence. We thus found that learning from daily life is helpful and enjoyable for students learning a language. In this study, students could use their existing knowledge about campus life to learn English with the help of the proposed mobile and web systems, and thus they felt very interested in the activities offered. Meanwhile, the learning threshold was low enough and the students thus had little anxiety; therefore, the students had more confidence in learning and speaking English.

Conclusions

A mobile and online system, StudentPartner, was proposed in this study to help students learn English with two activities, English campus exploring and English class presentations. The participants felt that these activities were both enjoyable and interesting, as well as stimulating of useful interactions and discussions. Therefore, the proposed system is helpful for English learning.

The proposed system offers multimedia support for listening and speaking, and the tracking function can help users to learn the language because it can combine relevant information. When users look back at the tracking messages, their knowledge could be easily recalled and organized, thus strengthening memorization and learning. In addition, the users indicated that using GPS with the campus map was helpful because the geographical information could not

only be combined with the context and their prior knowledge but also could strengthen linkages with their existing experience. In addition, users could use the mobile devices to learn English offline, anytime and anywhere. Although the students could choose to use either the mobile or web system, it was found that the users usually went online to read the messages because the screen of the mobile device was too small. In contrast, users usually posted messages using mobile devices because message posting usually took place outside.

We have modified the system interface of mobile StudentPartner according to suggestions from previous studies. Users can drag the map on the screen and scroll up or down when there is more information to be shown. The themes in the learning activities offer flexibility, so that the students can choose a topic according to their own interests. In this way, the students can enhance their learning motivation and end up with improved learning outcomes.

There are some clear directions for future research. We intend to set up a formal class to experiment with a professional teacher and materials to improve the learning achievement of class participants. In addition, the number of participants in this study was very small because we did not have many mobile devices to use. It is hoped that more subjects could take part in future studies.

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A Study of Contextualised Mobile Information Delivery for Language Learning

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ABSTRACT

Mobile devices offer unique opportunities to deliver learning content in authentic learning situations. Apart from being able to play various kinds of rich multimedia content, they offer new ways of tailoring information to the learner's situation or context. This paper presents the results of a study of mobile media delivery for language learning, comparing two context filters and four selection methods for language content. Thirty-five people (18 male, 17 female; $M = 31.06$ years, $SD = 8.93$) participated in this study, divided over seven treatments in total. The treatment groups were compared on knowledge gain, and the results indicated that the results differed significantly. The results found indicated an effect of both context filters as selection methods on the learner performance. In addition, the results indicated a cost/benefit trade-off that should be taken into account when developing contextualised media for learning.

Keywords

Contextualised language learning, Mobile learning, Mobile information delivery, Context filters, Empirical Study

Introduction

Undoubtedly, language is one of the most important of mankind's abilities. As Pinker, S. (1994) puts it: "For you and I belong to a species with a remarkable ability: we can shape events in each other's brains with exquisite precision." The communication Pinker hints at is only possible if we are able to understand each other's languages; an increasingly important ability in a world that is rapidly internationalising, not in the least because modern-day technology allows us to communicate over large distances and across language boundaries. A perfect example of such technology is a mobile phone, which not only simplified and increased communication possibilities, but also led to communication virtually anywhere and anytime. In addition, these increasingly powerful handhelds, now often referred to as "smart phones", provide other types of connectivity next to voice communication, and are often used to access all sorts of information on the move. In this paper, we will explore mobile technology supporting second language learners to communicate in a non-native language.

The importance of communication in a target language has been stressed by several theories of second language learning. While each of the theories has a different viewpoint on language learning, all of them see language learning as an essential social process. First, the input and interaction theories of second language learning emphasise the role of social interaction for target language input, output, and interaction. These theories have been based two hypotheses. On the one hand, the interaction hypothesis (Long, M. H., 1981, 1983, 1996) states the importance of language interaction to increase the comprehensibility and usefulness of language input for the individual language learner. Especially, the role of negotiation of meaning between a native and non-native speaker is an essential part of the research inspired by this hypothesis. On the other hand, the output hypothesis (Swain, M., 1985, 1995) states that certain aspects (syntax and morphology) of a second language are most effectively developed in second language production. According to Swain, language output raises consciousness of problems and gaps in current knowledge, can provide opportunities to tests hypotheses about the second language, and allows the language learner to reflect on the language explicitly. Second, the socio-cultural perspectives to second language learning are grounded in socio-cultural and activity theory (Vygotsky, L. S., 1962, 1978) in which language is seen as a tool for making meaning in the collaboration with target language speakers. Thus, the socio-cultural perspectives also consider language interaction but their emphasis is more on the social motive for second language learning. In this sense, the emphasis of these theories is on self-regulation through private speech to gain control over the language task (Frawley, W. & Lantolf, J., 1985), the influence of personal characteristics and interests on social interaction (Coughlan, P., & Duff, P. A., 1994; Roebuck, R., 2000), and language feedback of native speakers to scaffold a second language learner (Aljaafreh, A., & Lantolf, J. P., 1994; Nassaji, H., & Swain, M., 2000). Last, the sociolinguistic perspectives consider the second language learner as part of communities of practice and investigate

the role of the learner's identity, emotions, and social position in a learner's development of a second language (Bremer, K., Roberts, C., Vasseur, M.-T., Simonot, M., & Broeder, P., 1996; Heller, M., 1999; Norton, B., 2000; Ochs, E., & Schieffelin, B., 1995; Pierce, B. N., 1995; Wenger, E., & Lave, J., 1991). Moreover, the sociolinguist perspectives see language learning as a situated activity, in which the influence of the learning context on the learner is essential. Summarising, the second language theories mentioned here all emphasise the social aspect of language learning in which both language production as language input in real-world scenarios with target language speakers are important. Thus, the possibility to access information anywhere and anytime makes mobile devices a welcome tool to support a second language learner in real-world interactions with target language speakers.

A variety of studies already investigated the opportunities of mobile devices for language learning. Kukulska-Hulme, A. and Shield, L. (2007) distinguish between using mobile devices in a more passive manner for learning content distribution and using them to encourage interaction of the second language learners in their target language environment. Most of the current mobile language learning studies aim at the former content distribution and offer vocabulary training in previously unused time slots, instant lookup of vocabulary anytime and anywhere, and repetition in the form of quizzes and surveys. For example, Levy, M., and Kennedy, C. (2005) describe learning Italian vocabulary via SMS messages that were sent at specific time intervals. Likewise, Fisher, T., Pemberton, R., Sharples, M., et al. (2009) provide an example of an extended e-book reader that allows the second language learner to instantly look up vocabulary and listen to a native pronunciation. Last, Thornton, P. and Houser, C. (2005) investigated the effects of e-mails with English vocabulary sent to mobile devices owned by Japanese students, and described the combination of textual information (explanations, quizzes) and video material for mobile language learning. In contrary to these more passive mobile language learning approaches, mobile learning solutions supporting target language interaction are largely left unconsidered (Petersen, S. A., & Divitini, M., 2005). To address this lack of solutions Petersen, S. A., and Divitini, M. (2005) provide two scenarios for community-based mobile language learning, one of which focuses at interaction between students in a native and students in a non-native environment. Similarly, Kukulska-Hulme in her review of MALL also emphasises the importance of real-world interaction, and stresses the lack of mobile language learning solutions for speaking and listening (Kukulska-Hulme, A., & Shield, L., 2007). An interesting example of a context-aware mobile language learning system aimed at real-world interaction is JAPELAS (Ogata, H., & Yano, Y., 2004) that provides the learner with the correct Japanese politeness expressions based on a learner profile, location, and the person addressed. What's more, Ogata, H. and Yano, Y. (2004) present TANGO, a mobile learning system that uses RFID-tagged real-world objects to teach vocabulary. Another example of mobile support for language interaction is the LOCH system that supports second language learners to carry out tasks in a Japanese target language environment (Paredes, R. G. J., Ogata, H., Saito, N. A., et al., 2005; Ogata, H., Yin, C., Paredes R. G., et al., 2006). In addition, the tasks carried out with LOCH were all focused on communication in the target language and were supported by a teacher that could view the GPS location of the students to give location-specific feedback.

While the research mentioned above, considers language interaction at both the object and location level, it did not explore the effects of the learner context on the interactions in the target language. Thus, the influence of using different context granularities (object-based vs. location-based) to provide second language support at varying levels of specificity is not clear. A critical question that remains unanswered is whether there are differences between the efficiency of learning support provided by object-based and location-based information delivery. Moreover, if there are any differences there are any circumstances in which either of these granularities proves more efficient. Related to that, the context filters available can result in different forms of user interactions that may also influence the learner performance. In the study presented here, we aim to address part of these questions and present an evaluation of a language-learning tool that focuses on interaction support for second language learning. More specifically, we compare the effectiveness of object-based filters against location-based filters, and investigate the effects of several levels of mobile user interaction ranging from the users providing all context information themselves to the system automatically detecting the user's context. It is expected that the more specific object-based filter leads to a more specific interaction with the learning content, and therefore a better learner performance. In addition, we expect that the automatic context detection will prove less of a burden on the learner and will prove the more efficient. The evaluation was carried out in a lab setting, where a number of rooms were equipped with objects according to a certain theme (market, restaurant, etcetera). In this paper, we adapt a framework for evaluating mobile learning from a technological (desirability, usability) and an educational perspective (effectiveness) that was proposed in (Sharples, M., 2009). The results of the evaluation with this framework will be presented in this paper.

Method

Designs

This study used a between-groups design, with two independent variables: the context filter (with two levels: room filter and object filter) and the selection method used (with four levels: semacode-based, number-based, list-based, and location-based). The dependent variable was the immediate knowledge gain calculated from the number of correct answers given in the pre-test questionnaire and the post-test questionnaire.

The context filter independent variable was based on the context dimension of the reference model presented in (De Jong, T., Specht, M., & Koper, R., 2008). The room filter delivers the learning content based on location context, i.e. the room the learner is located in. The object filter delivers learning content based on identity context, more specifically the object the learner is currently interacting with. In this respect, the location-based filter provides learning content for a more general context than the object filter.

The selection method independent variable specifies the variations of user interfaces that were used during the experiment, each with a different form of user control. Each variation acquired the context information via a different selection method: either directly from the learner (number-based or list-based), semi-automatically (semacodes), or automatically (location-based). In the number-based and list-based variations, the learner provides the context information respectively by (1) entering an object or room number in a text field, or (2) by choosing a room or object from a list with all possibilities available. The semi-automatic variations identified the object or room context by the semacode they were tagged with, and finally, the automatic variation detects the learner's room location using a location tracking system.

Each treatment variation in the study employed another combination of *the selection method* and *the context filter*, all of which are given by table 1. Because a location-based object filter was not available seven instead of eight treatments were tested.

Table 1: Overview of the seven treatment groups that were used				
	Selection method			
Context Filter	Semacode-based	Number-based	List-based	Location-based
Room Filter	SRF	NRF	LRF	LORF
Object Filter	SOF	NOF	LOF	x

The dependent variable, *the knowledge gain (KG)*, was calculated with the following formula:

$$KG = (\sum KQ_{post_i} - \sum KQ_{pre_i}) / i, \text{ where } i = 25. \quad (1)$$

Equation 1 calculates the knowledge gain, as a ratio, by subtracting the total number of correct answers of the pre-test ($\sum KQ_{pre}$) from the number of correct answers of the post-test ($\sum KQ_{post}$) for all participants, and dividing the results by the total number of questions in the tests i . The minimum knowledge gain is therefore 0, the maximum knowledge gain equals 1.

The manipulated variables led to the formulation of the following hypotheses:

- Hypothesis 1: *learners using an object filter (SOF, NOF, LOF) will have a higher knowledge gain (KG) than those using a room filter.* We expect the specificity of the context information to influence the learning experience. In particular, we think that learning content filtered with more specific object context information, will lead to more specific interaction with the objects, and therefore will lead to better learning performance.
- Hypothesis 2: *learners using a selection method that requires fewer actions (SRF, SOF, LORF) to access content will have a higher knowledge gain (KG) than those requiring more actions.* We expect the interaction with the learning content in the mobile software will also influence the learner performance. A more efficient user interface that requires fewer actions from the learner, in our case the semi-automatic semacode-based (SRF, SOF) and automatic location-based (LORF) selection methods, will lead to more efficient information access and a better learner performance.

Participants

Thirty-five people (18 male, 17 female; $M = 31.06$ years, $SD = 8.93$) participated in this study. All participants were volunteers. Most of the participants spoke Dutch as their native language ($n = 26$), however some spoke German ($n = 6$), Chinese/Cantonese ($n = 1$), Tamil ($n = 1$), and Spanish ($n = 1$). Only two participants stated they were to some extent acquainted with Hindi, the rest was not. Dutch pre-test and post-test questionnaires were given to those who spoke Dutch, while the other participants received a translated English version of the questionnaire (see Appendix A and B). Participants were randomly and evenly distributed over the seven treatments (see table 1).

Apparatus

Participants were equipped with an iPhone 3G device (<http://www.apple.com/iphone/>) to access web-based language learning software optimised for these devices. The language learning software was a mobile phrase book for learning Hindi that uses contextual information to filter the learning content. The phrase book contained learning content consisting of a picture of an object, a textual representation of the Hindi word for the object, and an audio fragment for the word created by a native speaker. Moreover, the learner could view an enlarged version of the picture with a higher level of detail. For each of the treatments in table 1 another variation of the mobile language learning software was developed. The software was developed in PHP and the learning content was adapted to be rendered on small screens.

Figure 1 shows three screenshots from the language learning software for one of the variations (SRF) using a user-entered room number (zone) to filter a list of language content. At start-up, all content is displayed (left screenshot); the learners can scroll through the list and view detailed information for each object: an image (middle screenshot), text, and an audio representation of the word. When the learners enter a room they can filter the learning content by entering the room number (right screenshot); only the list of learning content for the room number entered is displayed.

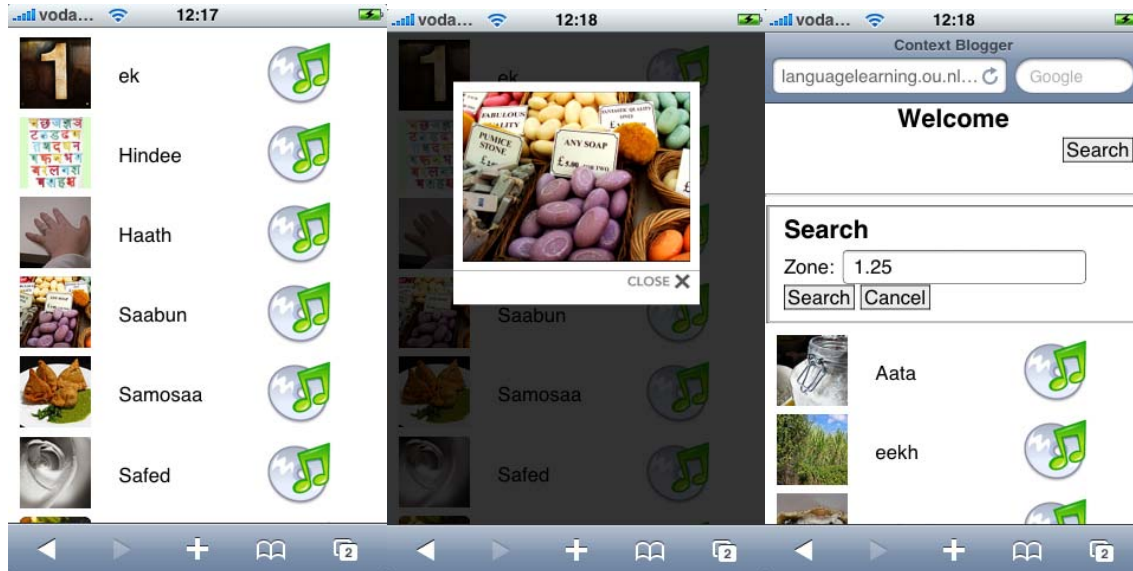


Figure 1: One variation of the language learning software using a room context, number-based selection method (SRF) to filter the learning content

Procedure

The experimental procedure consisted of three parts: a pre-test phase, a learning phase, and a post-test phase. In the pre-test phase participants were randomly assigned to one of seven treatments. Furthermore, they were given a pre-test questionnaire, in which all participants were also given a treatment-specific textual instruction on how to use the

software (see Appendix A for an example). Apart from the textual instruction the pre-test questionnaires were exactly the same. During the learning phase the participants were equipped with an iPhone 3G and a version of the software for the treatment they were assigned to. Just before the start of the learning phase, an extra verbal instruction was given to the participants on how to use the software. In the learning phase, the participants had to explore six rooms in the CELSTEC Medialab, all of which had a number of posters which each depicted an object. All participants were given exactly thirty minutes to learn as much of the Hindi vocabulary for the depicted objects as possible. The post-test phase comprised a post-test questionnaire testing the vocabulary learnt (see Appendix B), a usability evaluation measuring the hedonic and pragmatic quality of the software (Hassenzahl, M., Burmester, M., & Beu, A., 2001; Hassenzahl, M. et al., 2000) and an interview about the desirability of the software using the Microsoft Desirability Toolkit (Benedek, J., & Miner, T., 2002). An audio recording was made of each interview using a laptop computer and Apple's Garageband software (<http://www.apple.com/ilife/garageband/>).

Results

The results are treated separately by desirability, usability, and knowledge gain.

Desirability

The interview on the desirability of the software revealed that the software was overall rated as positive. Nevertheless, the participants listed some shortcomings and suggested a number of improvements and additions to current version of the software. First, most participants suggested to add a translation of the Hindi words in either Dutch or English. In addition, a search function was requested that made it easier to find language content on demand. Related to that, a lot of the participants recommended making the categories in the language content more explicit in the software. In general, the learners claimed that when the implicit categories in the learning content became clear to them, it helped them learn more efficiently. Especially, they thought the organisation of learning content into higher-level categories was necessary, and some even requested an option to organise the learning content into categories themselves. Some participants proposed more personalisation to the learning content, adapting the learning content in the software to their personal interests. Moreover, most participants requested an interaction history in which learning content previously accessed could be quickly found back. The history would serve as a way to repeat words efficiently; the repetition in some of the variations of the software was not straightforward and learners stressed its importance for learning. Another idea to improve the efficiency that was put forward was the possibility to access objects related to the object that was currently accessed. In addition to that, the learners would like to see related sentences for each object and language content in a sentence context. Last, the participants using the semacode-based approaches stated that the software was slow, and that the semacode tags were often not recognised. This led to frustration and less effective content access.

Usability

The usability was measured using a standardised usability evaluation that measured (1) the pragmatic quality (PQ), that describes how successful the users are reaching their goals using the software, (2) the hedonic quality – identity (HQ-I), which describes to what extent users identify themselves with the product, (3) the hedonic quality – stimulation (HQ-S), measures to what extent the users experience the software as innovative and stimulating, and (4) the attractiveness (ATT), describes a global quality value for the product. The mean values and standard deviations for the usability measure for each of the treatment groups are reported in table 2; a usability measure is reported on a scale of -2 to 2, where a higher value corresponds to a better score.

On average the number-based treatments are valued highest in terms of usability ($M = 1.25$, $SD = .34$), while the list-based approaches are valued lowest ($M = 1.04$, $SD = .31$). Furthermore, the room-based treatments outperform the object-based treatments in all usability aspects (see figure 2). Overall the list-based object filter (LOF) was evaluated worst in terms of usability ($M = .74$, $SD = .31$): it was ranked lowest for PQ, HQ-I, and ATT. Conversely, the number-based room-filter (NRF) was evaluated best ($M = 1.40$, $SD = .52$): it ranked highest in HQ-S and ATT. Last, the location-based room filter (LORF) has the highest pragmatic quality PQ ($M = 1.60$, $SD = .85$).

Table 2: Mean values (*M*) and standard deviations (*SD*) for the usability measures (PQ, HQ-I, HQ-S, ATT) for each of the treatment groups

Context Filter	Selection method							
	Semacode-based		Number-based		List-based		Location-based	
	M	SD	M	SD	M	SD	M	SD
PQ								
Room Filter	1.11	.80	1.43	.50	1.20	.89	1.60	.85
Object Filter	1.17	.69	.97	.98	.96	1.11		
HQ-I								
Room Filter	.89	.80	.71	.97	.94	.94	.83	.94
Object Filter	.54	.77	.87	.65	.36	.59		
HQ-S								
Room Filter	1.31	.86	1.49	.43	1.43	.63	.60	.69
Object Filter	1.23	1.04	1.40	.92	.63	.48		
ATT								
Room Filter	1.83	.27	1.97	.45	1.80	.49	1.63	.44
Object Filter	1.49	.20	1.14	.19	1.03	.34		

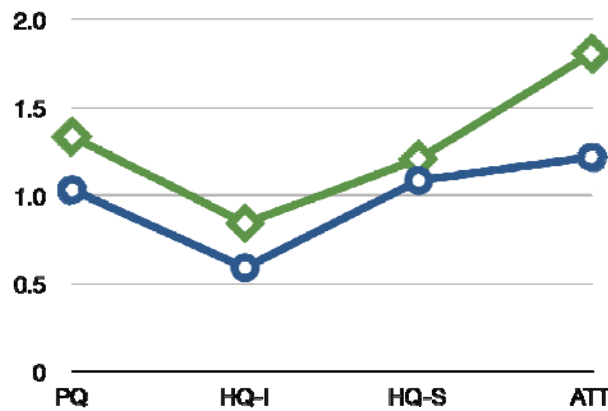


Figure 2: usability measures (PQ, HQ-I, HQ-S, ATT) for the room filter (diamonds) and object filter (circles) groups

As part of the usability the number of actions needed to access learning content was also considered. Table 3 lists the mean number of actions needed per room to access all the learning content available for that room; where a lower number of actions is better because it corresponds to a smaller burden on the learner to access all learning content. In this case, a more specific learning context requires a more specific filtering of the learning content; the object-based filter will deliver learning content for one object only, while the higher-level room filter delivers learning content for all of the objects available in the room. Therefore, to access learning content for a higher-level context, by using a lower-level object-based filter, more actions are required of the learner: after all, for each object an action has to be carried out to access the learning content. The location-based room filter required fewest actions to access all learning content, while the number-based object filter required most.

Table 3: Mean number of actions necessary per room for each of the treatment groups

Context Filter	Selection method			
	Semacode-based	Number-based	List-based	Location-based
Room Filter	2	3	2	1
Object Filter	37	55.5	37	

In general, across all treatments, the software was rated as technological and cautious on the negative side, and as manageable, inviting, and good on the positive side. Although all of the variations of the software were rated as very attractive, the usability evaluation reported that there was still room for improvement in terms of usability and hedonic quality in all cases.

Knowledge Gain

The results show that the learner performance on the pre-test was not significantly affected by the treatment group, $F(6, 28) = .39$, *ns*. In addition, the self-evaluated abilities to learn languages and to learn languages quickly did not differ significantly for the treatment groups, $F(6, 28) = 0.6$, *ns* and $F(6, 28) = 1.03$, *ns* respectively.

For each of the participants the knowledge gain was calculated from the pre-test and post-test using Equation 1. Table 4 lists the mean knowledge gain and the standard deviation for each of the treatment groups, where a high knowledge gain corresponds to a better learner performance. It can be seen that the group using a semacode-based object filter (SOF) on average performed worse, while the group using a location-based room filter (LORF) performed best.

<i>Table 4: Mean knowledge gain (M) and standard deviations (SD) for each of the treatment groups</i>								
	Selection method							
	Semacode-based		Number-based		List-based		Location-based	
Context Filter	M	SD	M	SD	M	SD	M	SD
Room Filter	.35	.24	.38	.20	.47	.04	.62	.13
Object Filter	.22	.12	.37	.14	.35	.18		

The results show that the knowledge gain was significantly affected by the treatment given to the participants, $F(6, 28) = 2.93$, $p < .05$, $r = 0.79$. Moreover, the effect of the context filter on knowledge gain was also significant, $F(1, 33) = 5.70$, $p < .05$, $r = 0.42$. Last, the knowledge gain was also significantly affected by the selection method, $F(3, 31) = 4.88$, $p < .05$, $r = 0.69$. Levene's tests for all of these comparisons turned out to be non-significant, supporting the assumption of homogeneity of variance.

Pair-wise t-tests with Bonferroni correction used as post hoc tests revealed a significant difference between the semacode-based object filter (SOF) treatment and the location-based room filter (LORF) treatment ($p < .05$). Moreover, the room-based context filter differed significantly from the object based ($p < .05$). Last, a significant difference was also found between semacode-based and location-based selection methods ($p < .05$). All other comparisons were non-significant.

Discussion

The participants were randomly distributed over the treatment groups. Furthermore, the results show that all participants had similar scores on the pre-test, and self-evaluated their language abilities similarly. Therefore, it can be safely assumed that the participant's language expertise was evenly distributed over the treatment groups and any differences measured were caused by the experimental manipulations.

Hypothesis one is not supported by the results. Although a significant difference between the room filter and object filter approaches has been found, from the post hoc analysis and the mean knowledge gains reported in table 4, we can conclude that this is due to a significant difference between two treatment groups. More specifically, the difference in performance between the context filter groups can be traced back to the difference between the location-based room filter (LORF) treatment which performed best, and the semacode-based object filter (SOF) treatment which performed worst. Thus, more specific information about the learner context does not seem to lead to a higher knowledge gain on the vocabulary-learning task in this study. Rather, as all but one of the room filters perform better than the object filters, the opposite can be inferred: for the described vocabulary-learning task learners benefit from a more generic context filter, giving them an overview of the content present in the room.

Hypothesis two is only partially supported by the results. A significant difference has been reported between the semacode-based and location-based selection methods. According to our predictions though, both the location-based as the semacode-based groups, by the amount of effort required to access the information, would have to outperform

the other groups for the hypothesis to hold. Thus, while the location-based treatment outperforms all other treatments, as we expected, the semacode-based approaches perform worse than expected.

The results become clearer if we look at the combination of the context filter and selection method. Table 3 presents the mean number of actions the learners needed to carry out to access all the learning content available in a room; hence, table 3 shows the combined effort needed in the authentic context and user interface to access all vocabulary in the room. It can be clearly seen that for the room filters the learners have to carry out fewer actions to access the learning content than those using an object filter. Apparently, this result is also reflected in the measured usability as the room-based filters outperformed the object-based filters (see figure 2). In addition, three of the room filter treatments have a higher knowledge gain than the object filter treatments. In particular, the location-based room filter (LORF) required least actions of all the treatments, was rated highest on pragmatic quality (PQ) in the usability test ($M = 1.60$, $SD = .85$), and outperformed all other treatments in terms of knowledge gain. It can be concluded that learners using a treatment (NRF, LRF, LORF) that requires fewer actions in the authentic context and in the interaction with the mobile device will have a higher knowledge gain (KG); the semacode-based room filter (SRF) is the exception. Since the other context filters outperform the semacode-based filters in their class (= row), we expected another effect influencing the results. The desirability interviews with the participants made clear that software did not detect the semacodes correctly all the time, and therefore the number of actions needed to access the learning content increased beyond that which was reported in table 3. In addition, this increased effort led to frustration with software for some participants, and therefore a lesser knowledge gain on the vocabulary task in this study. Had the semacode-based filters worked correctly, we would expect all room filters to have outperformed the object-based filters.

These results raise three questions. First, we expected a more specific object filter to lead to a more specific learning experience, and thus a higher knowledge gain. However, the results led to believe the opposite to be true: a more general room context led to higher learner performance. Obviously the vocabulary-learning task in the study did not benefit from more specific context information. Therefore, an interesting question that remains is when a more specific context filter does lead to a better learner performance and especially if there are differences in terms of learner transfer and retention in comparison with more general filters.

Second, the influence of the selection method on the learner performance is not entirely clear. While the group performing the fewest number of actions performed best, still the knowledge gain seemed quite resilient to the amount of actions performed: the number-based and list-based object filters did not perform significantly worse than the room filter treatments.

Third, it is important to consider to what extent the learner task directly influences the effectiveness and efficiency of the context filters. The learning task plays an important role in the cost of accessing learning content and the benefits that arise from it. The authenticity of the task might influence the impact of this cost/benefit balance; learners using the phrasebook in explorative way in the real-world might be satisfied with a higher cost because the benefit is also influenced by the authentic task at hand. Moreover, the benefit in authentic environments may arise from different causes than the vocabulary-learning task in this study. Thus, an important question is when this cost/benefit balance is optimal for learner performance. For the vocabulary-learning task presented in this study, a room filter was more efficient because it gave more information in comparison to the actions needed by the learner. Besides that, the benefit of the learning tool for people with object-filter approaches did not outweigh the effort necessary. An interesting question is how to keep the cost/benefit balance similar for learners with different granularities of context filters: if more effort is required, the return value for this effort should be worthwhile. Especially, in shortly lived information access in a mobile scenario, the cost/benefit balance will influence the learner performance. Further research should find out the influence of the selection method and context filters on this balance.

The questions lead to several suggestions and recommendations for future research and future mobile learning applications. First, to be able to measure the effects on learning performance of the more specific object-based filters versus the room filters the cost and benefits of using those filters should be the same. If learners can access the same amount of learning content with a similar effort, the effects measured can be really attributed to the specificity of the context filter used. In this respect, the learners suggested a history of recently accessed learning content to simplify repetition of language content. Moreover, they thought that accessing objects in the same category as the one currently accessed would benefit their learning. Both suggestions will simplify the access of learning content (reduce the cost) and make it faster to learn more the vocabulary (improve the benefit).

Second and related to that, it would be interesting to further investigate how context specificity influences learning. Does a more specific learning context result in a more specific, thus deeper learning experience and a better retention? And what situations would require which type of specificity? Moreover, how can results from a specific authentic learning context be transferred to a more general one? In that respect, an investigation into combination of specific and more general learning contexts becomes worth considering.

Third, the effects of categories or semantic context in mobile language learning need to be looked at in more detail. Most learners indicated that they benefitted from the implicit categories that the objects in a room belonged to and would like to see these categories more explicitly presented in the user interface. The effects of further ordering the information on learner control, performance and satisfaction is another fascinating point to consider.

Last, the technology used in this study still had some problems. The participants assigned to semacode-based treatment reported that they often needed to scan the semacodes several times before they were detected. It would be interesting to see the results, if less effort for the semacode approaches was required. In addition, the implementation of fully automatic object detection was not feasible at the moment of this study, and therefore left unconsidered. However, with recent developments in RFID technology it would also be possible to implement this eight scenario and compare it to the other comparisons in the experiment. Another promising opportunity that reduces the effort to access the learning content would be augmented reality: Hindi language content could be overlaid over a camera image of the objects and be instantly accessed by the learners, resulting in a range of new and interesting learning scenarios.

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Appendix A: Pre-test Questionnaire for the Number-based room-filter (NRF) treatment

Welcome to our experiment. The experiment consists of three parts: first, this pre-test, then a learning phase, and finally a post-test questionnaire. Following this questionnaire you will receive an iPhone, which you will use to explore the rooms of the CELSTEC Media Lab. Login using the username and password provided below. In each room you will find some posters depicting certain objects. If you enter the current room number in the search field at the top, a selection of the pictures (tap to enlarge), the Hindi words, and Hindi audio (tap the audio icon on the right) for the objects present in the room is presented to you; learn those words and try to remember them. All your activities with the software will be logged. The results of the experiment will be handled anonymous and confidentially. Thank you for participating in this experiment. Before continuing, please first fill out your personal details below.

Personal details

Gender: ☐ Male ☐ Female
Age:
Occupation:
Treatment: **roomsearchfilter**

Username:
Password: **testtest**

Affinity with language learning

In this part we will ask you some general questions about the languages you speak, the level of competence in those languages, and your ability to learn new languages.

Native language:

How many *other* languages do you speak:

Which other languages do you speak (0 = not at all, 4 = native speaker)?

Arabic	0	1	2	3	4
Dutch	0	1	2	3	4
English	0	1	2	3	4
French	0	1	2	3	4
German	0	1	2	3	4
Hindi-Urdu	0	1	2	3	4
Italian	0	1	2	3	4
Spanish	0	1	2	3	4
Chinese (Mandarin/Cantonese)	0	1	2	3	4
Portuguese	0	1	2	3	4
Russian	0	1	2	3	4

Other languages not mentioned:

How well do you know Hindi?

0 1 2 3 4 (0 = not at all, 4 = native speaker)

Are you interested in learning new languages?

0 1 2 3 4 (0=not at all, 4 = very interested)

How would you estimate your ability to learn new languages?

0 1 2 3 4 (0 = not good, 4 = very good)

How would you estimate your ability to learn new languages quickly?

0 1 2 3 4 (0 = not good, 4 = very good)

Understanding of Hindi

This section will test whether you already have some knowledge of the Hindi language. Please choose the meaning for every of the Hindi words below. It is essential that you give an answer for every question; thus, if you do not know the meaning of a word please take an 'educated guess'.

Almaari ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Angur ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Ainak ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Kamal ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Qalam ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes

Kursee ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Kela ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Cheenee ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Paanee ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Namak ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar

Nal ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Cheh ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Pustak ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Pyaalaa ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Mor ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock

Magar ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Mez ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Lahsun ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Seb ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile
Neela ☐ Garlic ☐ Apple ☐ Blue ☐ Table ☐ Crocodile

Davaa ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Haath ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Sabun ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Ungli ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Kapraa ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger

Mobile Technology & Learning

This part contains some general questions concerning the mobile technology you own, the mobile learning technology you have already used, and your opinion on using mobile technology to learn.

Do you own a mobile phone?

☐ yes ☐ no

If so:

Does this phone have built-in camera?

☐ yes ☐ no ☐ Don't know

How often do you use the camera?

0 1 2 3 4 (0 = never, 4 = on a daily basis)

Does this phone have built-in GPS?

☐ yes ☐ no ☐ Don't know

How often do you use GPS/location-based services?

0 1 2 3 4 (0 = never, 4 = on a daily basis)

Do you own any other mobile technology?

☐ yes ☐ no

If so, what kind of mobile technology?

☐ iPod Classic ☐ iPod Touch ☐ PDA

☐ GPS receiver ☐ Other Mp3-player ☐ Navigation system ☐ Other:
--

Did you use mobile devices for learning already?

☐ Yes (go to **A**) ☐ No (go to **B**)

A. If yes, how?
B. if not, would you want to use mobile devices for learning? 0 1 2 3 4 (0 = not at all, 4 = very much) If so, any idea how?

Do you think mobile devices are useful for learning?

0 1 2 3 4 (0 = not useful, 4 = very useful)

If you think the devices to be useful, please indicate how important you think the following features, (0 = not useful, 4 = very useful)

<i>Recording audio content for a real-world object to allow other learners to learn from a native peer</i>	0	1	2	3	4
<i>Listening to language podcasts recorded by a native speaker</i>	0	1	2	3	4
<i>Learning, creating, and reviewing flashcards, personalised lists of often used phrases, for continuous rehearsal on handhelds</i>	0	1	2	3	4
<i>Communication with native peers</i>	0	1	2	3	4
<i>Receiving language content based on your current location to support authentic language learning in the real-world</i>	0	1	2	3	4
<i>Receiving language content related to a real-world object, to support authentic language learning in the real-world</i>	0	1	2	3	4
<i>Receiving language content related to your current activity, to support authentic language learning in the real-world</i>	0	1	2	3	4
<i>Receiving language content based on personal preferences, interests each week</i>	0	1	2	3	4
<i>Using the mobile phone to translate a word anywhere & anytime</i>	0	1	2	3	4

Appendix B: Post-test Questionnaire

Thank you for participating in this experiment. In this questionnaire, we would like to ask you some questions regarding your participation in the experiment, test your understanding of Hindi, and ask you some questions about the technology and media. Last, we would like to ask you for possible improvements to the experiment. Before continuing, please again fill out your personal details below.

Personal details

Gender: ☐ Male ☐ Female
Age :
Occupation:

Motivation

Did you like to participate in the experiment?
0 1 2 3 4 (0=not at all, 4 = very much)

Do you like to learn new languages?
0 1 2 3 4 (0=not at all, 4 = very much)

Did the experiment change your opinion about learning new languages?
0 1 2 3 4 (0=not at all, 4 = very much)

Would you be interested to learn more Hindi?
0 1 2 3 4 (0=not at all, 4 = very much)

How would you rate the following scenarios for language learning?

A. Language learning software on a handheld device (for instance a mobile phone) would make it easier for me to learn a new language:

0 1 2 3 4 (0 = not easier, 4 = a lot easier)

Please explain your answer above:

.....
.....

Difficulty of the experiment

How often did you have problems understanding the tasks present in the experiment?
0 1 2 3 4 (0=never, 4=always)

How would you rate the difficulty of the tasks in the experiment?
0 1 2 3 4 (0=not difficult, 4=very difficult)

B. Language learning software on a desktop computer would make it easier for me to learn a new language:

0 1 2 3 4 (0 = not easier, 4 = a lot easier)

Please explain your answer above:

.....
.....

Understanding of Hindi

This section will test whether you gained some knowledge of the Hindi language during the learning phase. Please choose the meaning for every of the Hindi words below.

Almaari ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Angur ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Ainak ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Kamal ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes
Qalam ☐ Spectacles ☐ Cupboard ☐ Lotus ☐ Pen ☐ Grapes

Kursee ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Kelaa ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Cheenee ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Paanee ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar
Namak ☐ Banana ☐ Salt ☐ Water ☐ Chair ☐ Sugar

Nal ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Cheh ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Pustak ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Pyaalaa ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock
Mor ☐ Cup ☐ Six ☐ Tap ☐ Book ☐ Peacock

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Ungli ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger
Kapraa ☐ Soap ☐ Cloth ☐ Hand ☐ Medicine ☐ Finger

Suitability of Technology and Media

The software was easy to understand:

0 1 2 3 4 (0 = do not agree at all, 4 = fully agree)

The objects in the pictures were clearly visible:

0 1 2 3 4 (0 = do not agree at all, 4 = fully agree)

The text was clearly visible:

0 1 2 3 4 (0 = do not agree at all, 4 = fully agree)

The audio quality was clear enough

0 1 2 3 4 (0 = do not agree at all, 4 = fully agree)

How do you estimate the benefit of mobile devices in this learning scenario?

0 1 2 3 4 (0 = not applicable, 4 = highly relevant)

Did the experiment alter your opinion about mobile devices in this learning scenario?

☐yes ☐no

Problems with the technology

Did you experience any technical problems during the experiment?

☐yes ☐no

If so, could you please describe these problems?

.....

.....

.....

.....

Suggestions for improvements

Last, we would like to ask you suggestions, ideas or opinions for future versions of the experiment. Especially, we're interested in how you think we can improve the software to be more effective.

Are there any additions you would like to see in a future version of the software?

.....

.....

.....

.....

Any other (more general) suggestions for improvements?

.....

.....

.....

.....

Were any aspects of the questionnaires unclear to you?

☐yes ☐no

If so, please elaborate so we can try to improve this in later versions:

.....

.....

.....

.....

Your participation in the experiment

Would you like to be informed about the results of the experiment you just participated in?

☐yes ☐no

Would you be willing to participate in a possible follow-up to this experiment?

☐yes ☐no

If you answered yes to at least one of the above questions, please fill out your e-mail address here:

.....

A Learning Assistance Tool for Enhancing ICT Literacy of Elementary School Students

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ABSTRACT

With rapid advances in the development of information technology, information access has become central to life in the 21st century. In recent years, the development of useful learning-assistance systems has become a popular topic in literature. Learners can benefit from guidance provided by a tool that assists learning when a student has trouble using an e-learning platform. An effective learning-assistance tool can reduce teacher workload and increase the time spent giving individual guidance to learners who fall behind. However, few machine-learning techniques have been used as learning-assistance tools in literature to determine learner status or provide feedback to learners and teachers. Therefore, this work employs a learning-assistance tool that uses learning-reinforcement techniques to continuously interact with an environment and provides learners with suitable and timely feedback to guide students through difficulties, inspire them, and help them complete assigned tasks. The learning-assistance tool can promote learners' information and communication technology (ICT) literacy and assist learners in overcoming difficulties. Furthermore, teacher workload is significantly reduced because appropriate hints or feedback are automatically delivered to learners without teacher involvement.

Keywords

Information and communication technology, Learning assistant, Diagnosis, Machine learning, Reinforcement learning

Introduction

Internet learning via e-learning, distance education, remote experimentation, and computerized examination has been extensively used at all education levels. Numerous web-based e-learning platforms and examination systems have been developed. These information and communication technology (ICT)-based systems reduce the time needed for examination-related tasks, such as grading, marking, recording, and analyzing, and provide ubiquitous practice and tests via web browsers.

As students can learn effectively with and be encouraged by a learning-assistance tool that provides useful hints or feedback, this work developed a novel learning-assistance tool that guides learners when they become confused or stalled when using an ICT literacy-assessment platform constructed for elementary school students in Taiwan. Project-based activities are incorporated into the web-based diagnostic and assessment platform. Students are expected to use the application software suite provided by the platform to solve everyday problems. Guidance is offered via a feedback rule construction mechanism. A machine-learning technique, reinforcement learning, is adopted to provide useful hints or feedback to learners based on their learning portfolios, collected during learning activities. To the best of our knowledge, this is the first diagnostic and assessment tool in literature. Use of Asynchronous Java Script and XML (AJAX) technology in this work enhances interactivity, access speed, and usability of the web-based diagnostic and assessment platform, such that problems associated with traditional click-and-wait web applications can be alleviated. That is, via AJAX technology, the web-based diagnostic and assessment platform can respond promptly to ensure timely interaction between the platform and learners. According to

experimental results, the proposed learning-assistance tool effectively assists learners in making progress during continuous assigned projects. The assessment module was confirmed capable of evaluating learner work quality correctly.

The remainder of the paper is organized as follows. Related work in literature is discussed in the next section. Following that, the overall architecture of the proposed ICT learning-assistance tool, how to apply the reinforcement learning mechanism to the learning diagnostic module, and experimental results are discussed in their respective sections. Finally, conclusions and future work directions are given.

Related work

In the late 1990s, many governments increased their investments in ICT in the educational domain. The rapid development of the Internet and the World Wide Web led to the adoption of plans to equip all schools with accessibility to these facilities within a short period. In England, the government launched a six-year project to build an information-technology platform for delivering onscreen tests to all secondary schools. The tests were developed to enable students to apply technologies to solve problems, analyze information, develop ideas, create models, and exchange information (Becta, 2006). A computer-proficiency test developed by Bradlow, Hoch, and Hutchinson (2002) consisted of 27 multiple-choice items measuring student computer knowledge in several domains, such as general computer terminology, file management, spreadsheets, databases, the Internet, and email. However, the test is not specifically designed to test the digital skills needed by primary school students. The items measured factual knowledge of computer terminology and concepts rather than gauging procedural knowledge about how to perform computer tasks. In Taiwan, several ICT-assessment platforms have been constructed to assess the computer knowledge of primary school students via multiple-choice questions. Students typically memorized answers to those multiple-choice questions, such that the multiple-choice questions did not assess student ICT literacy.

A computer-based performance test in which students are assessed via a number of functional computer tasks is undoubtedly more effective for assessing digital skills than a questionnaire. All levels of operation, such as response times, mouse-click sequences, and other user actions, could be automatically recorded in computer-based performance tests. Recorded behaviors facilitate in-depth analysis of student digital skills. Kuhlemeier (2007) demonstrated that computer-based assessment has tremendous potential to learn about what students know across various ICT environments.

After investigating the concepts of ICT-literacy assessment in England and the USA, project-based activities are incorporated into a novel assessment platform to meet the pressing need of Taiwan's nine-year mandatory school program. Students are expected to apply an application software suite provided by the platform to solve daily life problems. Sequentially, the assessment platform grades student outcomes and generates statistics for both teachers and students.

In the last few years, development of useful learning-assistance systems has become a common research topic in literature. ActiveMath, a web-based mathematics learning-assistance system (Melis, Gogvadze, Homik, Libbrecht, Ullrich, & Winterstein, 2006), assists learners in searching for interesting courses or practical examples of mathematics. The system can intelligently analyze learner input and provide appropriate and timely feedback to learners when they make mistakes in completing math problems. The learning-assistance system was helpful in stopping learners from wasting time on unnecessary mistakes, and effectively improved learner achievement. Huang, Chen, Luo, Chen, and Chuang, (2008) incorporated a diagnostic and assessment tool into an e-learning platform developed for programming language courses. The proposed learning diagnosis assessment tools based on text-mining and machine-learning techniques were employed to reduce teacher workload. Moreover, Huang, Chen, and Chen, (2009) proposed an argumentation processing agent for computer-supported cooperative learning. Learners are first assigned to heterogeneous groups based on a questionnaire given directly before they start learning activities on the e-learning platform. The argumentation-processing agent then analyzes the learning portfolio of each learner in an e-learning platform and automatically issues feedback in cases of a poor argument or abnormal behavior.

All of the above-mentioned learning-assistance systems employed machine-learning techniques to provide assistance to learners and teachers. Thus, this work adopted a well-known machine-learning technique, reinforcement learning, to track learner operations and provide suggestions to learners when learners were confused or stalled when using a

previously developed ICT-literacy assessment platform. The AJAX technique is employed to ensure timely interaction between a user and the platform. One key advantage of using AJAX is that web standards in AJAX are well defined and supported by all major browsers.

In recent years, many developers have built web applications using AJAX technology. Expedia added features such as pop-up calendars on its travel site using AJAX (Paulson, 2005). Google worked with AJAX to construct applications such as Gmail and Google Groups, a community and discussion service. Flickr utilized AJAX on some of its websites, allows users to add and view photos (Patrick, 2006). Additionally, AJAX-based Google Maps allows users to hold down the left mouse button and slide the cursor over an image to retrieve part of a map not shown on the screen. Updates occur smoothly and images move and change immediately. With typical web applications, users must wait for entire pages to reload, even when image changes are small (Wang, & Bian, 2007). A synchronous learning environment, called the Synchronous Learning Environment with Web 2.0 (SLEW) (Lin, Chi, Chang, Cheng, & Huang, 2007), has a course agent, clear user interface, and an interaction mechanism for teachers and learners developed using AJAX technology. SLEW can support teachers and students who are participating in synchronous learning via poor network bandwidth. Furthermore, AJAX technology is employed in SLEW to retain learning materials, such that learners can review their materials during learning processes. The most important feature of SLEW is that AJAX technology is applied to partially update a web page rather than re-loading all page content.

Reinforcement learning is to study how animals and artificial systems learn to optimize their behavior when provided with rewards and punishments. Reinforcement learning algorithms have been developed that are closely related to dynamic programming methods, which are general approaches to optimize control. Reinforcement learning is a novel approach to systems management that differs radically from conventional model-building approaches. Van Vliet, Kletke, and Chakraborty, (1994) developed a reinforcement learning agent that can learn to play the Othello game without using knowledge from human experts. Their experiments demonstrated that a player employing reinforcement learning agents to learn how to play Othello outperformed players using basic strategies. To the best of our knowledge, a reinforcement learning technique has never been applied to the design of an intelligent e-learning platform.

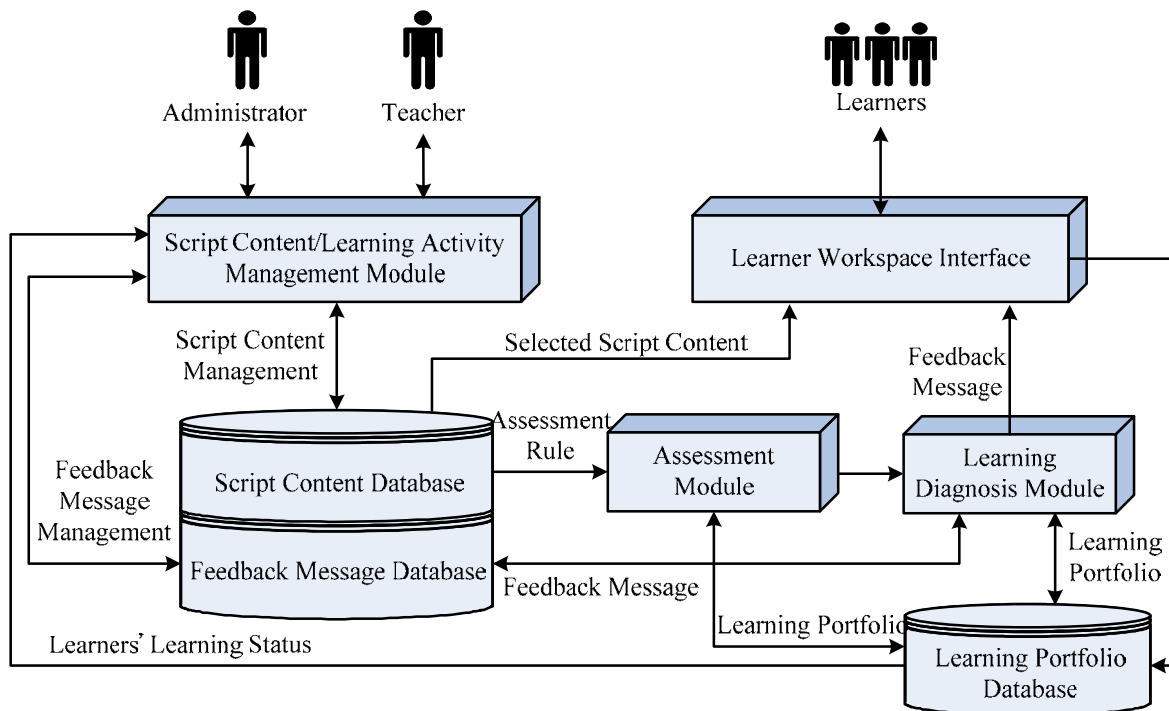


Figure 1. Architecture of learning assistance tool

Architecture of learning-assistance tool

Figure 1 shows the architecture of the learning-assistance tool in this work. The e-learning platform has four main components — a script content/learning activity-management module, learner workspace interface, a learning diagnostic module, and an assessment module. The script content/learning activity-management module is used by teachers to construct and modify script content for students using the learning-assistance platform. The student workspace interface has a system control area that provides such functionalities as login/logout and calling for help. Step-by-step instructions and hint messages can be displayed for students. Five application software module selection buttons and a software workspace are also in the student workspace interface. The five application software modules developed in this work possess functions similar and compatible to those in file browsers, Word, Excel, and PowerPoint. Three open-source software modules are modified to mimic the functions provided by the Microsoft application suite — Word, Excel, and PowerPoint. Furthermore, two additional tools, a built-in search engine and an email manager, are also developed.

The inputs for the learning diagnostic module are obtained from learner portfolios updated during online learning activities on the e-learning platform. Learner portfolios include an assessment of each learner, provided by the teacher based on learning records and response times on the e-learning platform. The diagnostic module monitors learning status and provides timely assistance to students who require help. The assessment module evaluates student learning outcomes using learning portfolios and transfers final reports to teachers and students.

The assessment module

The automatic assessment module has two main components, an expected result generator and a comparison unit. The expected result generator assists the teacher who designed a project to generate an expected result after each step. The expected results are converted into tags and saved in the database. The comparison unit merely compares student answers with expected answers saved in the database.

For instance, a teacher may expect that students can use the network search engine to search for information of the habitual records of the animals. The teacher is asked to design related web pages and upload them to the system before class to limit the material students can search and to ensure the quality of automatic assessment. Students are required to collect and organize information associated with an animal's special habits from the web using the word-processing module. Each learner then assigns a file name to her/his file, which is defined by the script content, and sends it to the teacher as an email attachment. The entire process can determine whether students can use the network search engine and word-processing software and send attachments by email. This script can assess whether students are capable of extracting information from websites and indicate whether the material source is abiding by copyright laws. The automatic assessment system designed in this work examines learner achievements for this example via the following steps:

- Determine whether students can use the search engine to search the website and access the specific website related to assigned task.
- Compare the file edited by learners using the word-processing module with the expected answer given by an expert to determine if learners pass this assessment.
- Examine whether students are capable of sending email attachments.

The learning diagnosis module

A feedback guidance mechanism is developed to continually give learners timely adaptive feedback messages to enhance learning achievement according to learning portfolios. The learning diagnostic module, which is embedded in the reinforcement learning mechanism, offers appropriate feedback to enhance learning outcomes. The learning diagnostic module provides a reference for teachers or the proposed system and gives the necessary assistance to students when they encounter a problem during a specific step. As the reward value is lower than a preset threshold, the learning-assistance mechanism gives appropriate feedback based on the environment and reward setting. Notably, the threshold is first determined by several experienced elementary school teachers who are familiar with student information literacy levels, based on the complexity of the experiment script and time limitation to finish the

test. The threshold can be adjusted during the prototype phase to reduce any gap between teacher expectations and student performance.

Application of reinforcement learning mechanism to learning diagnosis module

Reinforcement learning is learning how to take appropriate actions such that a numerical reward is maximized. Trial-and-error search and the reward value are important features of a reinforcement learning mechanism. An agent must develop what it knows to obtain a reward, and explore to make superior action choices in the future. With the reinforcement learning mechanism, a learning agent can improve its performance using feedback from the environment. Environmental feedback is called the reward signal. Reinforcement learning differs from supervised learning in how an output error is treated. Feedback with supervised learning shows information needed for an exact output, whereas feedback with reinforcement learning merely contains information about the quality of output.

Notably, Q-learning (Rahimiyan & Mashhadi, 2008) is a recent form of the reinforcement learning technique and is primarily concerned with estimating an evaluation of performing specific actions at each state. Thus, Q-learning has many successful applications, such as bidding in a power market, mapping and navigating the surface of Mars, clearing hazardous waste, and conducting rescue missions following earthquakes. Since Q-learning is a model-free algorithm that can be implemented easily, it is modified as the Q-learning algorithm in this work to enhance decision-making for the learning diagnostic module.

Figure 2 shows the normal operation of reinforcement learning. An agent learns effective decision-making policies via an online trial-and-error process in which the agent interacts with an environment. Each interaction consists of the following:

- Observing an environment's current state $s_t \in S$ at time t , where S is the set of possible states
- Performing some legal action at state s_t
- Receiving a reward r_t , which is a numerical value a user would like to maximize, followed by an observed transition to a new state, $s_t + 1$

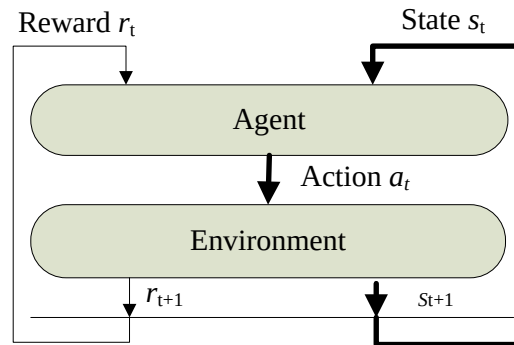


Figure 1. Reinforcement learning mechanism

Figure 2 shows the framework of reinforcement learning mechanism, which is flexible and can be applied in different ways. For example, time steps do not need to refer to fixed time intervals. They can, rather, refer to arbitrary successive stages of decision-making and acting. Actions can be low-level controls, such as voltage applied to the motors for a robotic arm, or high-level decisions, such as the decision of whether or not to have lunch. Therefore, actions can be any decision in which a learner attempts to learn how to make a decision, and states can be anything learners know that may be useful when making decisions.

Traditional Q-learning algorithm

The aim of the Q-learning agent is to learn an optimal policy, that is, a mapping from a state to an action that maximizes expected discounted future reward, represented as a Q-function, which can be calculated recursively.

Thus, Q -learning algorithms work by estimating the values of state-action pairs. The value $Q(s, a)$ is defined as the expected discounted sum of future payoffs obtained by taking action a from state s and following the current optimal policy thereafter. Once these values are learned, the optimal action from any state yields the result with the highest Q -value, as shown in Figure 3. The values for the state-action pairs are learned using the following Q -learning rule:

$$1. \quad \hat{Q}(s_t, a_t) = Q(s_t, a_t) + \eta[r_t + \gamma \max_a Q(s_{t+1}, a_{t+1}) - Q(s_t, a_t)],$$

where $Q(s_t, a_t)$ is a value function defined for a state-action pair (s_t, a_t) at time t ; η and γ are learning rate and discount factor, respectively; and r_t is a reward received as a result of taking action a_t in state s_t .

For all states $s_t \in S$ and all actions $a_t \in A$ at time t ,
 initialize $\hat{Q}(s_t, a_t)$ to an arbitrary value
 Repeat (for each trial)
 Initialize the current state s_t
 Repeat (for each step of trial)
 Observe the current state s_t
 Select an action a_t using a policy
 Execute action a_t
 Receive an immediate reward r_t
 Observe the resulting new state s_t'
 Update $\hat{Q}(s_t, a_t)$ according to Eq. (1)
 Until s_t is a terminal state

Figure 3. Q -learning algorithm

An extended Q -learning algorithm

An extension to the original Q -learning algorithm is proposed. First, an R -function is defined to represent the evaluation of state-action as follows:

$$R = \sum_{k=1}^n \gamma^k \times r_k,$$

where R is the general reinforcement learning value function. This function sets the probability of each path learners choose as γ , and reward r is multiplied by γ . Additionally, k is the step number of the path probability.

The probability of a user choosing an action from j actions in the z th state is

$$p_{i,j} = \frac{n_j}{n_i},$$

where n_i is the total number of users at the i th state, and n_j is the number of users choosing the j th action.

A threshold is set to determine whether a learner can finish an action within an expected time interval. If a learner fails to finish this mission within the expected time interval, a time reward is sent to the learner as follows:

$$t_{reward} = \begin{cases} 0 & , \text{if } t < t_{timeout} \\ t \times r & , \text{if } t > t_{timeout} \end{cases},$$

where $t_{timeout}$ is a preset timeout, t is elapsed time after a timeout, and r is a time reward given by experts.

Total reward, defined as the selection of the best way to proceed, is expressed by

$$R = \left(\sum_{i=1}^n \left(\prod_{j=1}^m \max(p_{i,j}) \right) \times \text{reward}_{i,j} \right) - t_{\text{reward}}$$

where $\max(p_{i,j})$ represents the most likely action, which is indexed by j , selected during the i th stage; $\text{reward}_{i,j}$ is the reward given by experts for each action node on a path; t_{reward} is subtracted per unit time in this equation because the probability of completing the mission decreases over time. When the total reward, as given by Equation 5, is smaller than the preset threshold determined by experts, a hint or suggestion is issued by the learning diagnostic module to guide learners. Three levels of hints or suggestions, including weak, moderate and strong, are provided. For example, in the mission that requires a learner to use the email module to send mail, a weak hint or suggestion, as shown in Figure 4, is issued to guide the learner when the learner gets stuck at an action node on an unexpected path for the first time. A moderate hint or suggestion, as given in Figure 5, is provided when the learner cannot get back on the right track after receiving a small hint. Finally, a strong hint that gives a direct instruction, as shown in Figure 6, is used to prompt learners when they continually go astray from expected paths.



Figure 4. An example of weak hint



Figure 5. An example of moderate hint



Figure 6. An example of strong hint

Figure 7 shows a diagram of the expected solution path for the example of sending email; the reward value of each action node defined by experts is included. In this example, the mission goal is to use the email module to send mail and receive a reply. Thus, the black action nodes along the middle path in Figure 7 should be chosen to complete the task. If a learner walks along the correct path in Figure 7, the system will give the student a positive reward provided by an expert based on the importance of action nodes to complete the mission. For example,

1. If learners launch the email module during the first stage, a learner likely grasps the key information or concept needed to solve the problem because launching the email module is the key to choosing the correct path to complete the mission. The learner can then receive a high positive reward value of, say, 15, accordingly. However, if the learner chooses other application modules, such as any of the blue nodes in Figure 7, the learner has no chance of completing the assigned task. The learner then receives a negative reward value of, say, -3.
2. When the learners choose the correct path during the first stage, they will be led to the second stage. In the example shown in Figure 8, learner selection of the path during the second stage includes receiving a new email, sending email, replying, deleting, backing up the mail folder, and using the trash folder. If a learner chooses the right path during this stage, which is to send new email, the learner will receive a reward valued of 10. Other choices will give learners a negative reward value of -1.
3. The reward values for nodes at other stages are assigned in a similar manner.

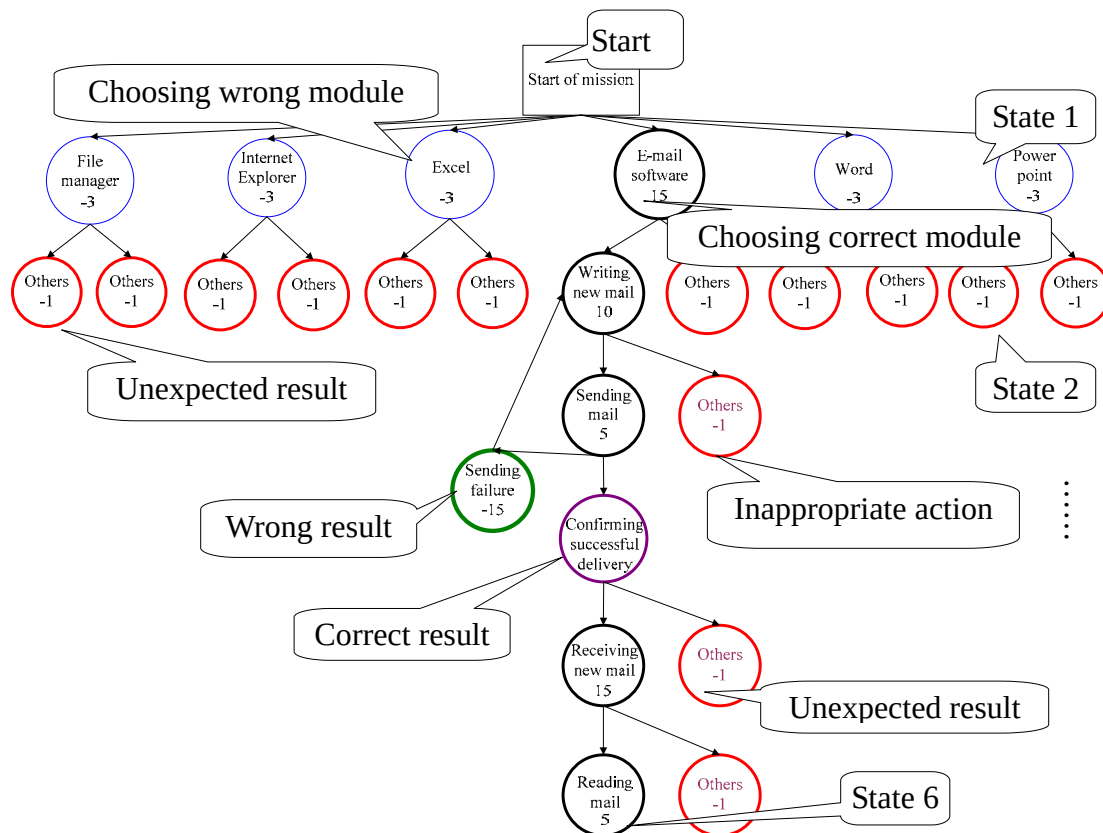


Figure 2. Illustration of expected solving paths for an email sending example

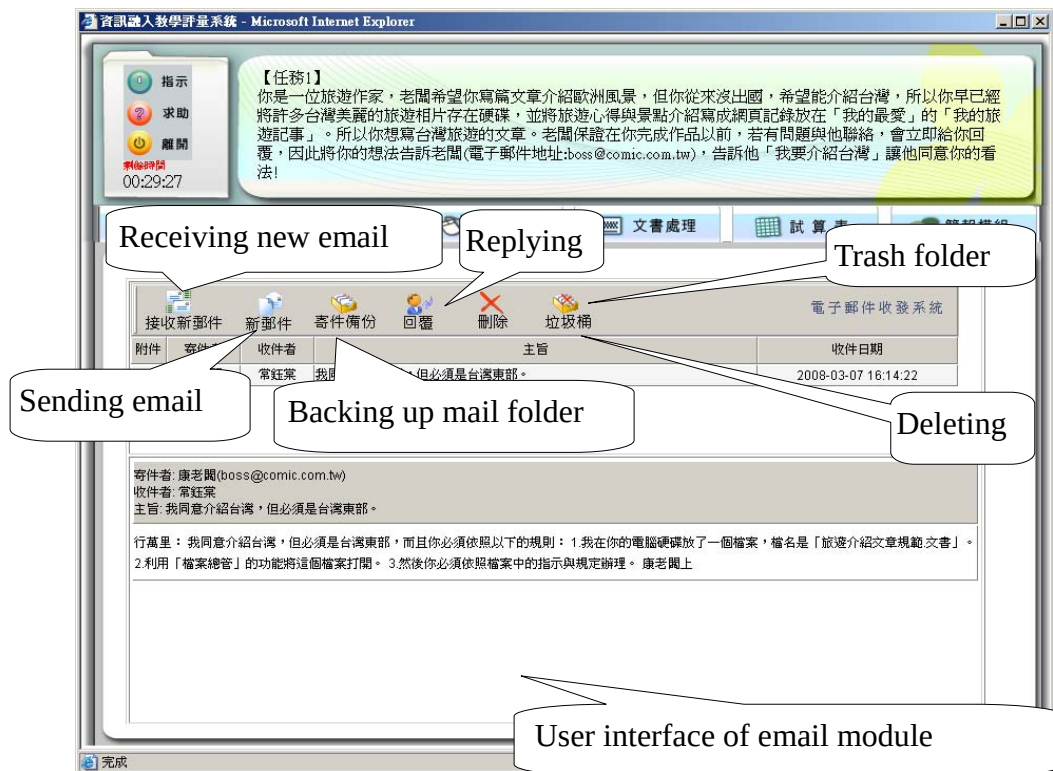


Figure 3. Workspace interface of email module

If a learner successfully solves the problem without following the expected paths designated by a teacher, the learner's recorded operating sequence for the assigned project will be reported to the teacher to obtain teacher approval. The teacher will then specify the reward values for each action node on the solution paths constructed by the learner.

Experimental results and analyses

To verify the effectiveness of the reinforcement learning mechanism in the proposed learning-assistance platform, an operation script and two situation mission scripts were developed for elementary school students. An experimental group and control group were constructed, each consisting of 29 Grade 5 students. A pretest was given to all participants in the two groups to determine whether these students have the capabilities for file management, email, using an Internet browser, presentation, and word processing. Both the experimental group and the control group were given three tests. After being given the story background, students freely decided how to interact with the system to solve the assigned problems. No learning-assistance mechanism was provided to the control group during the assessment. The students in the control group were expected to find useful information on the assessment platform to complete the mission. Conversely, the experimental group was aided by the learning-assistance tool such that they were prompted with timely and appropriate hints or feedback. Furthermore, a post-test was given to both groups using the assessment platform without the learning-assistance tool.

Table 1 through 6 show *t*-test results of the pretest for the high-, medium-, and low-achievement categories in the experimental and control groups, respectively. Table 1 lists the means and standard deviations for the 10 students in the high-achievement category in the experimental and control groups, followed by differences between means. The mean and standard deviation for the 10 students in the high-achievement category in the experimental group were 97 and 4.83, respectively, while those for the 10 students in the control group were 95.5 and 4.97, respectively. Table 2 is used to determine whether the null hypothesis — no significant difference between mean scores for the two groups — can be accepted. The interpretation of the independent sample *t*-test of pretest is a two-stage process. The first stage involves examining the homogeneity of the variance between the two groups. The independent sample *t*-test analysis examines whether equal variances in the two compared groups can be assumed by using Levene's test for equality of variances at the second stage. SPSS is adopted to compute both the *F*-statistic and *p*-value (Sig.). If Sig. is less than 0.05 ($p < 0.05$), the Levene's test indicates that the variances between the two groups are not equal. If Sig. is larger than 0.05 ($p > 0.05$), the Levene's test indicates that equal variances can be assumed. Notably, Table 2 shows $F = 0.151$ and Sig. $p = 0.702$, which indicates that $p > 0.05$ and equal variances can be assumed. Thus, the null hypothesis — no significant difference between mean scores for the high-achievement category in the two groups — was tested using the *t*-test. The two-tailed significance (*p*-value) was 0.503. Hence, the difference between mean scores for the high-achievement category in two groups was not significant at $p > 0.05$; thus, the null hypothesis is accepted. Since mean scores for the high-achievement category in the experimental group and control group were not significantly different, we infer that students in the high-achievement category in both groups have similar computer skills.

Table 1. Group statistics of pretest for the students in high-achievement category

Group	N	Mean	Std. Deviation	Std. Error Mean
The experimental group	10	97	4.83	1.52
The control group	10	95.5	4.97	1.57

Table 2. Independent sample *t*-test of pretest for the students in high-achievement category

<i>F</i>	<i>Sig.</i>	<i>t</i>	<i>df</i>	<i>Sig.</i> (2-tailed)	Mean	95% CI	
					Difference	Lower	Upper
0.151	0.702	0.684	18	0.503	1.5	-3.10	6.10

CI = Confidence Interval, *df* = degrees of freedom

Table 3 lists the means and standard deviations for the 10 students in medium-achievement category in both groups, followed by difference between means. The mean and standard deviation for the 10 students in the experimental group were 81 and 5.16, respectively, while those for the 10 students in the control group were 79 and 5.16, respectively.

Table 4 shows $F = 0.443$ and Sig. $p = 0.514$, indicating that $p > 0.05$ and equal variances can be assumed. Thus, the null hypothesis of no significant difference between the mean scores for the two groups was tested using the t -test. Independent sample t -test outcomes have a two-tailed significance (p -value) of 0.398, indicating that no significant difference existed between pretest scores of the two groups. Thus, we infer that students in the medium-achievement category in the two groups have similar computer skills.

Table 3. Group statistics of pretest for the students in medium-achievement category

Group	N	Mean	Std. Deviation	Std. Error Mean
The experimental group	10	81	5.16	1.63
The control group	10	79	5.16	1.63

Table 4. Independent sample t -test of pretest for the students in medium-achievement category

F	Sig.	t	df	Sig. (two-tailed)	Mean Difference	95% CI	
						Lower	Upper
0.443	0.514	0.866	18	0.398	2	-2.85	6.85

CI = Confidence Interval, df = degrees of freedom

Table 5 lists the means and standard deviations for the nine students in low-achievement category in both groups, followed by the difference between means. The mean and standard deviation for the nine students in the experimental group were 58.88 and 12.19, respectively, while those for the nine students in the control group were 60.55 and 12.85, respectively. Table 6 shows $F = 0.066$ and Sig. $p = 0.801$, which indicates that $p > 0.05$ and equal variances can be assumed. Thus, the null hypothesis of no significant difference between mean scores for the two groups was tested using the t -test. Independent sample t -test outcomes show two-tailed significance (p -value) was 0.781, indicating that no significant difference exists between pretest scores of the two groups. Accordingly, we infer that students in the low-achievement category of the two groups have similar basic computer skills.

Table 5. Group statistics of pretest for the students in low-achievement category

Group	N	Mean	Std. Deviation	Std. Error Mean
The experimental group	9	58.88	12.19	4.06
The control group	9	60.55	12.85	4.28

Table 6. Independent sample t -test of pretest for the students in low-achievement category

F	Sig.	t	df	Sig. (two-tailed)	Mean Difference	95% CI	
						Lower	Upper
0.066	0.801	-0.282	16	0.781	-1.66	-14.18	10.85

CI = Confidence Interval, df = degrees of freedom

Table 7 through 12 show t -test results of the post-test between the high-, medium-, and low-achievement categories in the experimental and control groups, respectively. The mean and standard deviation for the 10 students in the high-achievement category in the experimental group were 82 and 20.44, respectively, while those for the 10 students in the control group were 59 and 26.854, respectively, as given in Table 7.

Table 8 also exhibits $F = 0.858$ and Sig. $p = 0.367$, demonstrating that $p > 0.05$ and equal variances can be assumed. Thus, the null hypothesis of no significant difference between the mean scores for the students in the high-achievement category in both groups was tested. It can be seen from Table 8 that the t -value was 2.155, the degrees of freedom were 18, the two-tailed significance (p -value) was 0.045, and the difference between two means was significant at $p < 0.05$. Therefore, we infer that mean scores in the high-achievement category in the experimental group and control group have obvious differences. The students in the high-achievement category in the experimental group improved their ability to retrieve and analyze information when guided by the learning-assistance module.

Table 7. Group statistics of post-test for the students in high-achievement category

Group	N	Mean	Std. Deviation	Std. Error Mean
The experimental group	10	82.00	20.440	6.464
The control group	10	59.00	26.854	8.492

Table 8. Independent sample *t*-test of post-test for the students in high-achievement category

<i>F</i>	Sig.	<i>t</i>	<i>df</i>	Sig. (2-tailed)	Mean Difference	95% CI	
						Lower	Upper
0.858	0.367	2.155	18	0.045	23.000	0.579	45.421

CI = Confidence Interval, *df* = degrees of freedom

Table 9 and 10 list the post-test statistics for students in the medium-achievement category. The mean and standard deviation for the 10 students in the medium-achievement category of the experimental group were 59 and 24.244, respectively, while those for students in the control group were 51 and 15.239, respectively, as shown in Table 9.

Table 10 shows $F = 5.038$ and Sig. $p = 0.038$, implying that $p < 0.05$ and unequal variances can be assumed. Thus, the null hypothesis of no significant difference between mean scores for students in the medium-achievement category in both groups was tested. Test results show that the *t*-value was 0.883, the degrees of freedom were 15.151, the two-tailed significance (*p*-value) was 0.391, and the difference between two means was insignificant at $p > 0.05$. That is, no obvious difference existed between the experimental group and control group in the medium-achievement category. Only a small number of students had satisfactory ICT application capabilities in the medium-achievement category; thus, their performance could be improved with assistance from the learning diagnostic module.

Table 9. Group statistics of post-test for the students in medium-achievement category

Group	<i>N</i>	Mean	Std. Deviation	Std. Error Mean
Experimental group	10	59.00	24.244	7.667
Control group	10	51.00	15.239	4.819

Table 10. Independent sample *t*-test of post-test for the students in medium-achievement category

<i>F</i>	Sig.	<i>t</i>	<i>df</i>	Sig. (2-tailed)	Mean Difference	95% CI	
						Lower	Upper
5.038	0.038	0.883	15.151	0.391	8.000	-11.284	27.284

CI = Confidence Interval, *df* = degrees of freedom

Table 11 and Table 12 list the post-test statistics for students in the low-achievement category. Table 11 lists the means and standard deviations. The mean and standard deviation for the nine students in the experimental group were 36.67 and 20.616, while those for the nine students in the control group were 41.11 and 20.883, respectively.

Table 12 shows that $F = 0.063$ and Sig. $p = 0.806$, suggesting that $p > 0.05$ and equal variances can be assumed. Thus, the null hypothesis of no significant difference between mean scores was tested. The test results show that the *t*-value was -0.454 , the degrees of freedom were 16, and the two-tailed significance (*p*-value) was 0.656. We conclude that the difference between two means was insignificant at $p > 0.05$, and no obvious difference existed between the experimental group and control group in the low-achievement category.

Table 11. Group statistics of post-test for the students in low-achievement category

Group	<i>N</i>	Mean	Std. Deviation	Std. Error Mean
Experimental group	9	36.67	20.616	6.872
Control group	9	41.11	20.883	6.961

Table 12. Independent sample *t*-test of post-test for the students in low-achievement category

<i>F</i>	Sig.	<i>t</i>	<i>df</i>	Sig. (two-tailed)	Mean Difference	95% CI	
						Lower	Upper
0.063	0.806	-0.454	16	0.656	-4.444	-25.180	16.292

CI = Confidence Interval, *df* = degrees of freedom

Based on *t*-test results of the pretest, it was observed that students in each achievement category in the experimental group and control group had similar basic computer skills. The students in the high-achievement category in the experimental group performed significantly better when using the learning-assistance system because students in the high-achievement category typically had a strong ability to analyze information. The performance of most students in the medium- and low-achievement categories did not improve when the students were assisted by the learning

diagnostic module because these students lacked basic ICT application capabilities and had difficulty using the application software suite provided by the platform. We thus infer that the proposed learning-assistance tool proved helpful to students with basic computer skills.

Additionally, the teacher observed that students in elementary school are typically impatient with text information given by the assessment platform. We believe this phenomenon is strongly correlated with recent advancements in multimedia information technology. Students are accustomed to accessing multimedia information, such as audio, video, and still images in daily life, such that they tend to lack skill in concentrating and analyzing text information. By receiving timely feedback from the learning-assistance tool, students were guided to learn how to collect, analyze, and integrate information, and solve daily life problems using their computer skills.

To verify whether hints or feedback provided by the learning-assistance tool were appropriate, a short questionnaire was given to students in the experimental group that included the question “Is the learning system able to provide you with appropriate hints or feedback?” Among the 29 participants, 23 believed that the hints or suggestions were useful when they went in the wrong direction during the assigned projects. Furthermore, the teacher who participated in this study was asked to manually check whether the system offered useful and timely feedback that guided students when they encountered a problem. Table 13 lists the accuracy of feedback. Most feedback or hints were beneficial for students in determining the next step.

Table 14 shows the number of feedback messages at three levels provided to students in the three achievement categories when they encountered a problem. Students in the high-achievement category use software frequently, and most completed the mission with only weak hints provided by the system. Conversely, most students in the low- and medium-achievement categories needed moderate and strong hints because they were unfamiliar with using the software. However, they still had difficulty using the software after receiving the hints or suggestions as a result of their poor ICT application capabilities. Accordingly, these students needed to spend considerable time making progress during the assigned projects. Therefore, their post-test outcomes were often poor because they failed to complete the assigned projects before the end of the assessment period, although most students believed that the hints or suggestions provided by the system were useful. In order to help the students in the low- and medium-achievement categories effectively when they use the proposed learning-assistance platform, teachers need to spend more time to help students be familiar with using application software suite provided by the platform prior to participating in the assessment. Meanwhile, the scale of the project can be reduced to allow the students in the low- and medium-achievement categories to have enough time to complete the assigned projects at the end of the assessment.

Table 13. Accuracy of feedback provided by the system

Feedback	Correct	Incorrect	Total
Count	203	29	232
Percentage	87.5%	12.5%	100%

Table 14. The number of feedback messages in three levels provided for the students in three achievement categories

Number of feedback messages in three levels	Weak hint	Moderate hint	Strong hint
High-achievement category	13	3	0
Medium-achievement category	4	16	30
Low-achievement category	2	40	124

Conclusions and future work

Project-based activities were incorporated into a novel assessment platform to meet the pressing needs of primary school students in Taiwan. Students were expected to the apply application software suite provided by the platform to solve daily life problems. The assessment module evaluated student learning outcomes using learning portfolios and provided the teacher and students with final reports. A well-known machine-learning technique, reinforcement learning, was used to track learner operations and provide suggestions to learners when they were confused or stalled when using the ICT literacy assessment platform. To verify the effectiveness of the reinforcement learning

mechanism in the learning-assistance platform, 58 Grade 5 students from two classes participated in the experiment. Experimental results reveal that students in the high-achievement category in the experimental group performed better after using the learning-assistance system. Most students in the low- and medium-achievement categories had difficulty using the software due to their poor ICT application capability. Accordingly, they spent additional time making progress during the continuous assigned projects. Therefore, their post-test outcomes were often poor because they failed to complete the assigned projects before the end of the assessment period. Furthermore, teaching loads were significantly reduced because appropriate hints or feedback were automatically provided to learners without teacher involvement. In future work, student learning portfolios will be used and additional appropriate machine-learning techniques will be adopted to establish a probability model for each action node on the path toward completion of the assigned task and to automatically determine the reward value at each node, which is currently set by domain experts.

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Development and Evaluation of an Interactive WebQuest Environment: “Web Macerasi”

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ABSTRACT

This study was conducted to develop a web-based interactive system, Web Macerasi, for teaching-learning and evaluation purposes, and to find out the possible effects of this system. The study has two stages. In the first stage, a WebQuest site was designed as an interactive system in which various Internet and web technologies were used for infusion of technology into teaching and learning process. The Web Macerasi site was used for project work by 92 prospective students who attended different courses in different years. For collecting the students’ perceptions about the implementations of the system, a questionnaire of WebQuest effectiveness and a focus group interview guide were developed. Next, the first phase of the study was concluded, and the WebQuest system was updated based on the data gathered from students. In the second phase, 27 students from a different course used the system, and their perceptions were collected through the questionnaire and analyzed. It was found that the students favored the technology-supported media, were more willing to collaborate, found the feedback very useful, and agreed on the positive contribution of planned works. Consequently, the Web Macerasi site was found to be successful and to have been used effectively in terms of its aims. Further studies should be carried out for diffusion of this technology into the teaching-learning processes.

Keywords

Technology integration, Media in education

Introduction

Technology is used in education for two main reasons: as a tool for increasing the effectiveness of instruction and to integrate technology into the curriculum. Researchers are trying to answer the questions of how technology should be integrated and what the effect of this process will be on various dimensions of the teaching-learning process. One possible answer to this question is WebQuest. WebQuests are inquiry-based activities through which students interact with resources on the Internet (Dodge, 1995). They are structures that aim to support student works based on application with technology. The many reasons to use WebQuests include the construction of collaborative activities, the improvement of critical-thinking skills, the enhancement of motivation, the development of social skills, and the chance of concrete, hands-on experience (Leahy & Twomey, 2005). March (1998) reported that WebQuests were designed to bring together the most effective instructional practices into one integrated student activity. Many studies have been conducted to explore the benefits of using WebQuest in theoretical terms. Zheng and his colleagues (2005) concluded that WebQuests have four constructs: critical thinking, knowledge application, social skills, and scaffolded learning. On the other hand, March (1998) grouped these constructs under just three headings: student motivation and authenticity, developing thinking skills, and cooperative learning.

WebQuest, which makes students access the web to complete a task or solve a problem, elicits higher-order thinking rather than simple information searching and recall. These tasks should involve problem solving, judgment, synthesis, and analysis of information. Perkins and McKnight (2005) explained one of the benefits in the following words: “In the process of problem solving, students learn skills in an interactive, involved manner rather than in isolation” (p. 124). Moreover, Abu-Elwan (2007) added that, in order to develop students’ skills, WebQuests provide an authentic, technology-rich environment for problem solving. March (1998) stated that a WebQuest forces students to transform information into something else: a cluster that maps out the main issues, a comparison, a hypothesis, a solution, etc. Vidoni and Maddux (2002) stated, “WebQuests challenge students’ intellectual and academic ability rather than Web searching skills” (p. 104). Regarding the finding of valid resources, Perkins and McKnight (2005) explained, “Students have to evaluate the sites that are used for useful information while eliminating misinformation. This helps students develop their critical-thinking skills” (p. 124).

March (1998) explained that “By running several WebQuest groups in the same class, students will also see that different solutions were chosen by each team because of the quality of the group members’ research and

argumentation skills” (p. 15). In addition, Kundu and Bain (2006) stated, “While, as a group, students who undertake a WebQuest interact and work together, each group member carries out a specific, meaningful role” (p. 7). As Lightner, Bober, and Willi (2007) mentioned, “Member responsibilities are social, not merely academic, such as providing support, encouragement, and assistance in completing assignments and meeting course requirements” (p. 13). Moreover, Lacina (2007) added that “WebQuest allows students to work cooperatively to learn and exchange new information while using technology that provides the multiple forms of information needed to understand a new topic” (p. 251).

WebQuests are the right choice for implementing problem-based and inquiry-based instructional activities because of the fact that project-based learning promotes engaging instructional methods to make students active constructors of knowledge (Grant, 2002). Projects may or may not be problem-based or inquiry-based (Lowry & Turner, 2005), but in any case WebQuests are eligible platforms for carrying out the projects.

An interactive WebQuest environment: “Web Macerasi”

Generally, teachers have been designing static WebQuests that contain web pages but no interaction for directing both short-term and long-term projects. However, by taking advantage of technology, it is possible to use these kinds of platforms more functionally and provide an interactive environment for the process of guiding a project in order to manage the quests. The core of this study, which began with a question about how to use WebQuests more effectively, is to design, develop, and put into practice interactive WebQuests for teachers and students (Gülbahar & Madran, 2006). By using this interactive environment, teachers can perform operations such as creating WebQuests, updating existing WebQuests, evaluating the performance of students who enrolled in any WebQuests, and accessing other, previously published WebQuests. The flowchart of this interactive environment is shown, without going into detail, in Figure 1.

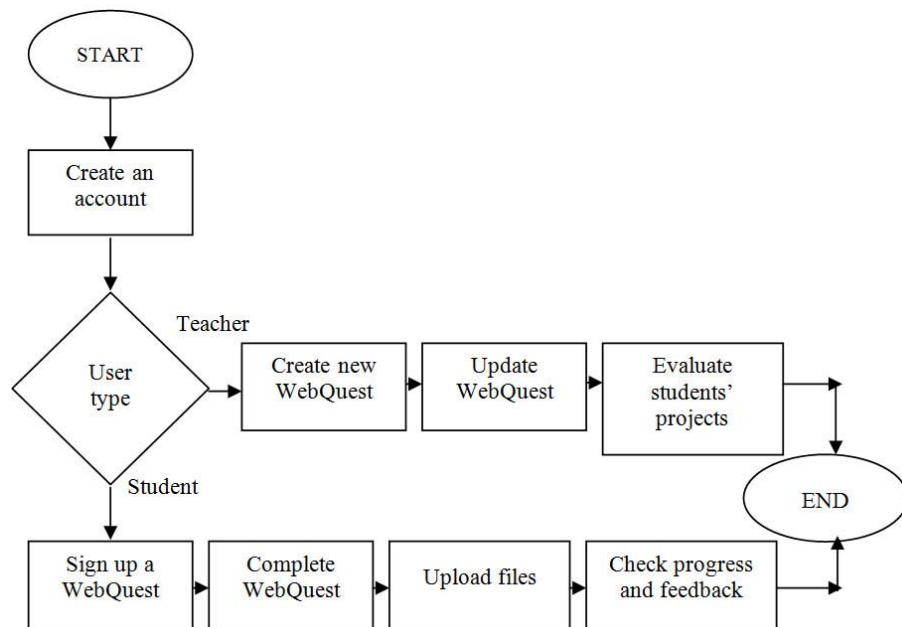


Figure 1. Flowchart of interactive WebQuest

These web pages were organized to write WebQuests steps (introduction, task, resources, process, evaluation, and conclusion) and other details (task type, evaluation preferences, creating rubrics and deadlines for each step, etc.) (Dodge, 1997; Kundu & Bain, 2006). In this approach, PHP and MySQL technologies were used to introduce interactivity to WebQuests. The WebQuest system (<http://webmacerasi.midas.baskent.edu.tr/>), including detailed documents and examples about WebQuests called Things to Learn about WebQuests, Join WebQuest (for students entering WebQuests) and Create WebQuests (for instructors creating WebQuests) can be accessed from the first page of the system. Users can write their questions and comments through the “central office.”

To join a WebQuest and to create a WebQuest, students and instructors have to start the procedure of getting a “passport” by filling out an application form. After the site administrator has approved their application for a passport, they can enter the site by supplying a user name and password. The navigation bar on the top right side of the WebQuest system includes all operations for WebQuest (Figure 2).



Figure 2. WebQuest navigation bar

With the Create WebQuest option, instructors can create WebQuests for students to follow their own projects step by step. Instructors can write the steps of the WebQuests in a text editor, providing detailed options to the users. After completing all the steps of the WebQuests, instructors can define each task in the Process part so that while students follow the due date of their homework and upload their files, instructors can access the files, grade homework, and provide feedback. It is also possible to provide students with the ability to create WebQuests through the Create WebQuest option base upon user restrictions.

Students can enroll active WebQuests in the system by clicking Join WebQuest. Moreover, the Communication option allows students to send messages to each other and to the instructors. Users of the system can perform detailed searches with the Search option. The Information option allows users to change, update, and view their passport information, upload avatars, and change passwords. Help provides information on the various buttons' functions, and Exit will log users out of the system.

This research study was conducted in order to design and develop the previously mentioned interactive WebQuest environment called Web Macerasi, which can be used for both instructional and evaluation purposes, and to evaluate its effectiveness upon implementation.

Research method

The purpose of this study was to develop a system, Web Macerasi, for bringing interactivity to the WebQuest approach and to evaluate the system both quantitatively and qualitatively. For this reason the study was carried out in four main steps: analysis and design, development, implementation, and evaluation. The last two steps, implementation and evaluation, have been repeated and the research is completed. Thus, the study will be presented in two phases.

The convenience sampling method was used, as random sampling was not convenient for this research (Fraenkel & Wallen, 2006). That is, users were selected in terms of their availability and therefore this study is a case study.

The study investigated the following questions:

1. What is the level of participants' agreement on the Likert-type scale about the WebQuest site design in terms of general design, grammar, navigation, and technical problems?
2. What is the level of participants' agreement on the Likert-type scale about the steps of WebQuest project in terms of introduction, task, process, resources, evaluation, and conclusion?
3. What are the perceptions of participants towards working with WebQuest projects in terms of planning skills, problems faced, implementation, real-life experience, popular and unpopular features, suggestions, and integration ideas?

Procedure

In the first phase, analysis and design steps were completed. In other words, the content of the Web Macerasi was determined and prepared, a detailed literature review of projects was conducted, and flowcharts and storyboards for the system were completed. Parallel to this work, supplementary documents and sample project ideas that would serve as guides for the WebQuest approach, descriptions of the WebQuest approach, sample projects, and instructions for system usage were created. After creating the content, the interactive WebQuest system, Web

Macerasi, was developed. The system was used to carry out projects in different classes. In order to create a difference between the projects, durations ranged from one week to three weeks, and the number of tasks ranged from two to six (Gülbahar, Kalelioğlu, & Madran, 2008a). After implementation of the system, the Effectiveness of WebQuest Application Questionnaire was administered to the participants, and focus group interviews were conducted according to the interview guide.

Regarding the students' views on improving the system, a few amendments were made in the system. The demands of the students relating to the aims of the site were taken into consideration. Firstly, visual modifications were made as the students mostly focused on visual messages. Secondly, a visual message was included as an alert that shows the finished tasks. In addition, a link that shows a "hint for detail" was placed on the site in order to increase accessibility of support documents. After that, the modified system was implemented with another group, and the Effectiveness of WebQuest Application Questionnaire was administered again as the second phase of the study.

Sampling

The first phase of the study was conducted in three courses from two different departments in the educational faculty of a private university. These courses were Computer Programming I, offered by the Secondary Science and Math Education Department (SSME) for freshmen; Applications of Authoring Languages in an Internet Environment, offered for juniors by the Computer Education and Instructional Technologies Department (CEIT); and Design, Development, and Evaluation of Educational Software, offered by the same department for seniors. For each course, different projects related to the course content were provided.

In total, 92 pre-service teachers, including 59 women (64%) and 33 men (36%) participated in the first phase of the study. Thirty-two (35%) of these were freshmen, 38 (41%) were juniors, and 22 (24%) were seniors. In terms of departments, 59 students (64%) were from the CEIT, and 33 students (36%) were from the SSME. The students varied in age between 17 and 30, and the students' mean age was 22.06. All but one of the students had a computer at home. Of the participants, 69 (75%) had used computers for more than four years, 15 (16%) had used computers for three to four years, 7 (8%) had used computers for one to two years, and one (1%) had used computers for less than a year. While 69 (75%) of the participants had not completed any WebQuest project before, 23 (25%) of the participants had.

The second phase of the study was conducted in a sophomore course called Teaching Principles and Methods, offered by CEIT. Twenty-seven students, 12 women and 15 men, enrolled in this course. Completion of a four-week WebQuest project called "How learning occurs?" was required for students in this course.

Instruments

Both qualitative and quantitative measures were established for the research project. For collecting data relating to WebQuest, the Effectiveness of WebQuest Application Questionnaire was used. Analyses were made after piloting validity and reliability. Content validity was ensured through obtaining views of three experts. After taking the concerns of the experts, we modified the questionnaire and sent it back to the experts until the last version was achieved. In order to reveal the different dimensions of the research process and its outcomes, focus group interview guides were prepared.

The Effectiveness of WebQuest Application Questionnaire (EWAQ)

The Effectiveness of WebQuest Application Questionnaire (EWAQ), which was composed of four main parts and 72 questions, was developed and used to collect quantitative data for this study. This questionnaire was developed by the researcher according to the items used in the previous research studies about website evaluation instruments and WebQuest evaluation rubrics (Dodge, 2001; March, 2002; Lara & Repáraz, 2005; Vanguri, Sunal, Wilson & Wright, 2004). For the content validity, three expert opinions were taken into consideration.

The first part of the questionnaire consisted of nine items for eliciting demographic data about participants. The second part of the questionnaire consisted of 22 items concerning the general design of the WebQuest site, in which

there were ten items for general design ($\alpha = 0.85$), four items for grammar ($\alpha = 0.56$), four items for navigation ($\alpha = 0.66$), and four items for technical issues ($\alpha = 0.78$). The third part of the questionnaire consisted of 19 items concerning the steps of the WebQuest project, in which there were four items for the introduction ($\alpha = 0.73$), four items for task ($\alpha = 0.72$), four items for process ($\alpha = 0.61$), four items for resources ($\alpha = 0.71$), four items for evaluation ($\alpha = 0.65$), and three items for the conclusion ($\alpha = 0.67$). There were 18 items in the last part of the questionnaire, addressing general thoughts about working individually and in a group on WebQuest projects ($\alpha = 0.93$). All the items in this questionnaire used a five-point, Likert-type scale, where 5 was coded as strongly agree, 4 as agree, 3 as neutral, 2 as disagree and 1 as strongly disagree. Item 14 was reverse-scaled before going through the steps of the analyses. The reliability coefficient was calculated as 0.95 overall for the questionnaire.

Focus group interview guide

To obtain detailed data and the personal views of participants relating to WebQuest, structured focus group sessions were conducted. For the interviews, juniors were selected due to their large number. The focus group sessions last between 40 and 60 minutes with four to five participants in each session. The interview guide consisted of eight questions, as follows:

1. In what way has WebQuest affected your working in a planned and regular manner? Please describe.
2. Have you encountered any problems in carrying out WebQuest projects? If so, please specify.
3. Do you think you will make WebQuest projects in the future? If so, please list the reasons why.
4. To what extent could this project help you to solve similar problems you might meet in real life? Why and how?
5. List three characteristics of WebQuest that you like.
6. List three characteristics of WebQuest that you do not like.
7. Which items could be included in the WebQuest site to contribute to effective usage of WebQuest? Please write your recommendations.
8. Please express your opinions related to the use of WebQuest to support project-based teaching (a. In terms of contributions to instruction; b. Other).

Data analysis

The quantitative data were analyzed by descriptive analysis methods, and the qualitative data were analyzed by content analysis. The aim of content analysis is to discover concepts and relations that may explain the data. Therefore it is necessary to find themes that define the data, and to conceptualize and organize them in a logical manner (Yildirim & Şimşek, 2000). An inductive approach is used for determining the concepts and relations that explain the data. Regarding all these facts, the data were analyzed in 4 phases: (1) coding data, (2) finding out themes, (3) organizing and defining data according to themes, and (4) interpreting results (Yıldirim & Şimşek, 2000). In addition, the data were changed into figures for making comparisons among the themes in the analysis of the qualitative data (Yıldirim & Şimşek, 2000). The themes were analyzed according to their significance levels. The figured data were used in the presentation of the data.

Results

Perceptions about the design of the website

There were items that inquired into the general design, spelling, navigation, and technical problems of the WebQuest. The results of the questionnaires for both the first and the second phase are presented in Table 1.

The mean of satisfaction with WebQuest for both groups is about 4.00, which mean that both groups were satisfied with WebQuest. There is no significant difference between the two groups' means, but the group that participated in the second phase seems to have scored a little lower than did the first group. This difference might be due to the number of participants.

Table 1. Perceptions about the design of website

	PHASE I (N = 92)		PHASE II (N = 27)	
	Mean	St. Dev	Mean	St. Dev
GENERAL DESIGN (Please answer according to the pages existing in the website.)				
Screen design is visually appealing.	4.30	0.69	4.04	0.94
Visuals are consistent with content.	4.47	0.60	4.26	0.71
Visuals give cues to users.	4.40	0.66	4.11	0.85
Screen is used in an effective manner.	4.46	0.68	4.04	1.02
Colors used within the pages are in harmony.	4.58	0.65	4.11	0.97
Web pages are designed according to visual design principles.	4.45	0.60	4.15	0.77
No readability problem within the pages.	4.67	0.59	4.33	0.73
Page elements are aligned appropriately.	4.58	0.73	4.48	0.58
Elements are distributed in the pages in a balanced way.	4.52	0.58	4.30	0.72
Clickable areas gain attention.	4.17	0.88	3.89	1.12
GRAMMAR (Please answer according to the <u>content</u> presented in the website.)				
No spelling mistakes exist.	4.27	1.01	4.11	1.05
No grammar mistakes exist.	4.43	0.78	4.11	0.97
Language used is understandable.	4.28	1.11	4.26	0.94
Technical expressions, which are difficult to understand, are used.	2.30	1.29	2.74	1.45
NAVIGATION (Please answer according to the pages existing in the website.)				
No broken links exist.	4.33	1.02	4.15	1.23
Links open in separate pages.	3.51	1.38	3.96	1.09
Navigation options are used consistently within the pages.	4.30	0.84	4.37	0.79
Site navigation is easy.	4.47	0.83	4.33	0.78
TECHNICAL PROBLEMS (Please answer according to the pages existing in the website)				
Pages download quickly.	4.24	0.81	3.81	1.39
Pages can be used without additional plug-ins.	4.45	0.80	4.26	0.81
Files upload without any problems.	4.43	0.88	3.93	1.23
Pages operate without any errors.	4.50	0.85	4.19	1.00

Perceptions about steps of the WebQuest project

In order to collect their views on the steps of their projects in terms of WebQuest, we asked participants questions that inquired into every step. The means and SD are presented in Table 2. It is normal to obtain different results for the theme, period, and steps of the projects that were delivered to every group. But most of the means are about 4.00, which is significant. There is no significant difference between the processing and progressing steps. The students who participated in the second phase had difficulty with resources. One of the important problems the students met was inadequacy of Turkish web resources in the implementation of the project, as the searches recommended foreign resources. There are no significant differences between groups with regard to results and evaluation. We conclude that almost all of the students' attitudes were positive.

Table 2. Perceptions about steps of the WebQuest project

	PHASE I (N = 92)		PHASE II (N = 27)	
	Mean	St. Dev	Mean	St. Dev
INTRODUCTION				
Introduction presents goal of project.	4.21	0.91	4.07	0.78
Topic of project is appealing.	3.84	1.26	3.04	0.98
Introduction gives enough concrete information about the project.	3.98	0.89	3.89	1.01
Project's scope is consistent with learning outcomes of the course.	4.23	0.85	3.89	0.93
TASK				
In the task section, project expectations are clearly explained.	4.16	0.90	4.19	0.83
Project requires interpreting knowledge in various forms.	4.29	0.87	3.81	0.83
Developing a creative product is expected for completing the project.	4.11	0.98	4.00	0.83
The roles and tasks within the project necessitate different points of view.	4.22	0.85	3.89	0.89
PROCESS				
Stages of the process are organized so that they can be accomplished	3.87	1.19	3.93	1.07

during the allocated time period.				
Each stage is explained in a clear and definite manner.	4.02	1.08	4.00	1.24
Students can request help from the instructors when they face a problem during the process.	4.41	0.82	4.07	1.14
Stages of the process are organized according to various levels of Blooms' taxonomy.	4.22	0.90	4.30	0.72
INFORMATION SOURCES				
Enough information is provided to complete the project.	4.13	0.93	2.89	1.15
Web addresses are given with extra information that defines site.	4.30	0.86	3.89	0.97
Information sources are consistent with project topic.	4.51	0.60	4.07	0.87
Information sources are appropriate for target students.	4.26	0.82	3.22	1.22
EVALUATION				
Grading of each task was clearly defined.	4.53	0.80	4.48	0.64
Grading was consistent with difficulty level of each task.	4.04	1.01	4.19	0.83
Students have the chance to get feedback and performance reports.	4.46	0.77	4.26	1.02
Evaluation criteria are consistent with course objectives in terms of information and skills.	4.27	0.75	4.15	1.02
CONCLUSION				
Conclusion summarizes students' experiences during the process.	4.32	0.82	4.19	0.78
Messages in conclusion aim to prepare students for real-life situations.	3.91	0.91	3.63	1.04
Messages in conclusion give clear explanations to students about how they are expected to succeed when they finished the project.	4.20	0.82	4.04	0.98

Perceptions about WebQuest project

A five-point Likert-type scale was administered to participants to find out what they experienced during the project. The results showed that the students preferred collaborative activities. The students merely indicated that they showed "respect to other participants' thoughts during completing the project" ($M = 4,64$ and $M = 4,63$).

The "I have not encountered any problems with finishing my project" response had the lowest value ($M = 3,25$) among participants of the first phase, whereas "WebQuest contributed to my desire to collaborate with others" had the lowest value ($M = 3.15$) among participants of the second phase (See Table 3). This means that the first group had a timing problem while the second group had a collaboration problem.

Table 3. Perceptions about the "WebQuest" project

	PHASE I (N = 92)		PHASE II (N = 27)	
	Mean	St. Dev	Mean	St. Dev
This project oriented me to research.	4.08	0.99	4.07	1.07
I didn't have problems due to time limitations while completing the project.	3.25	1.50	3.63	1.36
I think I am suitable for group work.	4.17	1.09	3.89	1.25
I didn't need any help from the instructor during the project.	3.35	1.36	3.52	1.31
I valued the contribution of members of the WebQuest project.	4.36	0.77	4.11	0.80
I shared information with other participants.	4.20	1.06	3.85	1.06
I showed respect for other participants' opinions during the project.	4.64	0.52	4.63	0.49
I generated creative ideas during the project.	4.32	0.85	4.04	0.64
I helped other participants find their mistakes.	3.79	1.16	3.37	1.04
I completed the WebQuest project easily.	3.78	1.18	3.59	1.24
The WebQuest project encouraged me to collaborate with other participants.	3.83	0.97	3.15	1.26
The WebQuest project made me use my imagination.	3.85	1.18	3.37	1.33
WebQuest increased my skills in applying recently learned concepts to my profession.	3.82	1.14	3.37	1.04
Contributing to WebQuest increased my motivation in the course.	3.80	1.19	3.67	1.11
WebQuest supported my understanding of course-related topics.	3.71	1.12	3.81	0.88

WebQuest was effective for reaching the goals of the course.	4.08	1.01	3.89	0.93
Project-based learning is more efficient than individual work.	4.10	1.09	3.59	1.08
I liked having web support for this course project.	4.35	0.95	4.19	0.74

Focus group interviews

Focus group interviews were conducted with junior students of the Department of Computer Education and Instructional Technologies, since there were problems in terms of accessibility to senior students. Interviews were conducted with 34 of 36 students. The perceptions of the students are presented in the same order as that of the questions.

Perceptions about working on the WebQuest project in a planned and guided way

At first, the participants were asked about how they were affected by working on the WebQuest project in a planned and guided way. Nineteen participants expressed that the planned step-by-step progression characteristics of the project created an appropriate approach and that that was beneficial for them in some respects. Concerning the topic, one of the participants said, "Segmented time is definitely better." Another participant explained that clearly disclosing the project's requirement and goals prevents it from being sophisticated, and another participant stated his opinion that "if it is somehow planned, it gives us relief." Yet another participant stated that if they do not study in a planned way, the project is deferred to the last day of submission, details are omitted, and there are deficiencies in the final product.

The participants stated that, in general, they did not study in a planned and disciplined manner. Hence, for this study, they had to have a schedule imposed on them. Even though students in higher education are expected to be more intrinsically motivated, their need to be extrinsically motivated can be interpreted as a reflection of their unawareness of their vocational careers. To conclude, even at a higher education level, it is correct to carry out project-based instruction over a long period divided into processes based on days and weeks, bound to the calendar.

Perceptions about the problems participants encountered during the execution of their WebQuest project

The second question was related to difficulties participants encountered while conducting their projects. Five themes emerged from the data obtained from this question. These themes were as follows: deficiency of information about the system, difficulties in meeting of groups, time concerns, difficulties related to user login, and difficulties uploading files.

- Giving extra time to allow students to become familiar with the site may solve the first problem. Since students may not have been skilled enough in the application, and since there were time constraints, students were confused.
- Concerning the second problem, examination of the data revealed that the problem occurred in three different groups. We suppose that the reason for this problem might be lack of extra time for group construction. This problem also occurs in group work in conventional education, as the group members may not get together due to various reasons. Thus, as with the first problem, giving extra time will probably help solve this problem.
- About scheduling, some participants stated that they had difficulties because the projects for other courses were mostly conducted at the end of the semester, whereas some pointed to the limited time between the phases of the project. Separation of project stages into longer time intervals and planning long-term projects may help overcome this obstacle and may enhance the quality of the product.
- Entrance into the system, registration, and confirmation were the problems collected under the title of problems about user logins. After asking additional questions and further investigating the system, we saw that time limitations and hurrying resulted in some typing errors, which caused the students to encounter these problems.
- Lastly, the problems mentioned by the participants related to uploading assignments were as follows: (i) uploading only zip files, (ii) erasing previous files when a more recent one was uploaded for the same task, (iii) not showing the deadline of the task, and (iv) not noticing that the last uploaded file was an updated version of a previous file. At this point, allowing various file formats to be uploaded onto the system and assigning version features to the uploaded files may cause similar problems.

Perceptions about designing WebQuest projects in the teaching profession

With regard to the question of whether or not participants want to use WebQuest in their future profession, 32 participants expressed that they wanted to use it for different purposes whereas four did not want to use it. Although participants gave different responses, the reasons for usage were as follows:

- to encourage students to study systematically and on time
- as an alternative method for considering the interests of students
- to encourage the use of computers and technology
- for assessment
- to encourage group work
- to inform and provide feedback to students related to their homework and assignments
- to collect all the assignments together in the same space

Generally, we found that most of the participants were in favor of using WebQuest in their teaching profession. The fact that participants wanted to use the system in their future profession might be seen as an indicator of a positive attitude toward the system. However, availability and suitability of technical features of Web Macerasi were found to be crucially important for the use of this system.

Perceptions about the contribution of the WebQuest project to real-life problems that may be encountered

When the participants were asked about the project's contribution to their lives, we realized that they could not use foresight to establish a connection between their experience and their real lives. Six of the participants stated that they gained new perspectives and could empathize with other participants by the help of the roles given. Hence, dealing with the same problem by looking at it from different perspectives enhanced students' views while approaching and creating solutions to the problems they face. One student said, "at least it enables us to think from multiple perspectives...we can think differently from all aspects." Another said, "We could understand how things differ according to different people during this WebQuest project." In addition, one participant emphasized this situation by summarizing the fact that "when we put ourselves in each role, we actually noticed the difference. This will enable us to examine things from multiple perspectives when we encounter a problem in our daily lives." Moreover, one explained its contribution in terms of supply and demand, as it enabled empathy to understand the expectations of different people. Two participants stated that they now have knowledge that will be useful when they encounter similar situations in their lives, and four stated that they gained experience in design and evaluation. Based on these results, we can conclude that the roles in WebQuests can yield positive outcomes and that time restrictions can lead students to learn how to plan their studies.

The top three features of the WebQuest site and project

When the participants were asked which three features of the system they most favored, the results showed that both the design and the WebQuest method itself were favored by the students. Seventeen participants stated that they liked the colors, content and usability of the website. One said, "For me, the design was great, attracting my interest and emphasizing the purpose as research." Sixteen students valued the representation of objectives, availability of sources, the step-by-step procedure for the project, and deadlines for assignments. Some participants (12 students) stated that uploading files and receiving feedback from their assignments was very useful. Nine participants also stated that the roles helped them to empathize with others and increased their creativity. One said, "The representation of the grades was very good, as also was the registration process." Another said, "The formation was very good. WebQuest attracted our interest. I mean, the name was really attractive." Based on the fact that students valued both the content and the system, we can conclude that the interactive WebQuest approach is a good approach.

The three least-favored features of the WebQuest site and project

Few opinions emerged when the participants were asked for their three least-favored features of the system. Moreover, it can be said that there were no big problems, so the system does not need a major change. However, some minor changes might be implemented in order to increase the effectiveness of the system. Seven participants

explained the need for deadline extension for the tasks, six participants stated the need for clearer directions, and four participants emphasized the need for a platform for interaction with others. As there were few answers on this topic in the study, it might be said that the system was generally valued.

Suggestions to improve the effectiveness of the WebQuest site

Participants were asked to share their suggestions about making the system more effective, and numerous demands were noted. Since this study is a case study and user preferences were important, all suggestions made were taken into consideration, even if stated by only one participant. The suggestions made by the participants are listed along with the number of participants who made the suggestion:

- present communication tools (forum, chat, etc.) (14)
- add illustrations, graphics, and animation (12)
- provide an information system via email (such as “evaluation completed,” “files uploaded,” etc.) (5)
- present detailed help and add a video introducing the system (4)
- provide opportunities to change colors on page, project, or task (4)
- support different file extensions (such as .zip and .rar) (4)
- provide opportunities to share uploaded files (4)
- provide information about completion of tasks (3)
- allow instant confirmation of applications (2)
- use visual effects for unused buttons (2)

These data showed that all suggestions were about technical features that could contribute to the effectiveness of the system. Thus, the system could be enhanced by taking these concerns into consideration.

Perceptions about supporting a project-based teaching method via the web

In general, participants expressed positive thoughts about supporting a project-based teaching method in a web environment. Concerning the WebQuest approach to providing Internet resources, seven participants said that they felt confident when resources were provided by the instructor, and that they were prevented from getting lost in the Internet environment while researching and directed to research. Five of the participants stated that the points offered for the projects affected the time allocated for working on the project and the quality of the products created, respectively. Three participants emphasized the need for more Turkish resources. The fact that submitting the project in a web environment decreases cost was found favorable by two participants. One participant stated, “In my opinion, I can access the directions 7 days a week, 24 hours a day. This is a big advantage. Which task will be completed is clear. Very good.” Providing project content from the web environment and offering use of web resources were favorable results.

Discussion

WebQuest, which is an alternative assessment tool in higher education, provides a base that makes it possible to implement a project-based instruction method and helps teachers to integrate technology into the curriculum. Web Macerasi aimed to make the system interactive and easily usable for students and academic staff. The study attempted to develop a WebQuest system for use in different courses and to evaluate its results.

The study was carried out in two phases and was implemented in two terms, starting in the 2006–2007 spring term and finishing in the 2007–2008 fall term. As a limitation to this study, the sample size of the second phase was very small. The findings of the study were very positive. Participants considered the design, grammar, navigation, and technical problems adequate. Participants assessed the content and the steps of WebQuest projects positively. The comments of the students on process demonstrated that they preferred collaborative activities.

Regarding the topic and duration of each project, participants stated different views. However, when we distinguish between the project content and the interactivity of the web-based approach, we found that when the right choices of project topic were made and enough resources were supplied, participants were pleased to use such a technology-rich

environment in order to carry out their projects. Many students asked for the repetition of similar projects and agreed to continue with those projects. Thus, the way technology was integrated into the curriculum can be said to have been effective (Gülbahar, Kalelioglu, & Madran, 2008a). Furthermore, the usability evaluations were carried out through a heuristic walkthrough method by help of five students and five academics and revealed that both two groups finished the process with a success rate of 75%. Hence, suggestions for enhancing usability were as follows: informing the users on a theoretical basis, using different concepts for some processes, and providing extra links relating to some procedures (Gülbahar, Kalelioglu, & Madran, 2008b).

Conclusion

The results of this study that contributed to the effective usage and integration of technology into education were as follows:

- The project-based method encouraged students to finish their obligations on time and make them work in a planned way.
- The Internet and web technology-supported project-based method has a positive impact on students.
- Carrying out projects using a web-based system provides the students with learning-by-doing activities and constitutes examples in technology integration.
- Supporting project-based teaching by Internet and web technologies makes the academic staff organize assessment schemes and realize objective assessment.

The results of this study, whose overall sample was 119 students, proved that different technology-based methods should be used extensively in education. Ordinary use of technology is insufficient for students, but systems like Web Macerasi allow students to perceive technology differently. Furthermore, these media facilitate different collaborations among virtual groups and the strict timing of the projects makes students take responsibility.

The next phase of this project should focus on effective usage and on broadening the project's scope. Different approaches to technology-based instruction and assessment should be studied. Possible study themes are as follows:

- the potential impact of WebQuest projects on elementary and secondary education
- evaluating different approaches to WebQuest; for instance, similar systems for electronic portfolios might be developed and studied.
- the potential enrichment of technology-based implementations for different instructional methods. Collaborative learning activities might be carried out by technological infrastructure; students' attitudes towards these systems could be studied.
- the impact of the interactive WebQuest on students' study habits or on their success rates

In addition, the following questions can also be considered for further research:

- What is the impact of the instructional methods that were supported by the interactive WebQuest environment on the study and research skills of the students?
- What is the impact of the instructional methods that were supported by the interactive WebQuest environment on the study on the retention rate?
- To what extent does Web Macerasi contribute to the promotion of social skills and critical thinking in students?
- What are the perceptions of the instructors who use Web Macerasi?
- What are the effects of completing a Web Macerasi project on students' higher level thinking skills?
- What are the effects of completing a Web Macerasi project on students' interaction, group work and cooperative learning?

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Using a Multimodal Learning System to Support Music Instruction

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ABSTRACT

This paper describes a multimodality approach that helps primary-school students improve their learning performance during music instruction. Multimedia instruction is an effective way to help learners create meaningful knowledge and to make referential connections between mental representations. This paper proposes a multimodal, dual-channel, multimedia learning (DML) system that provides efficient control over several multimedia objects such as Word files, PowerPoint files, web pages, images, films, and real-time videos. The multimodal DML system was applied in an experiment in which 32 fourth-grade students were assigned to the experimental group, where they received twelve 40-minute music lessons using multimodal presentation over a period of eight weeks. The control group consisted of 32 fourth-grade students who received the same twelve 40-minute lessons, but with musical notations. The results reveal that students in the experimental group showed a higher level of learning achievement and motivation than those in the conventional group. The conclusion was that multimodal presentations are helpful to scaffold learning.

Keywords

Elementary education, Improving classroom teaching, Media in education, Multimedia system, Music instruction

Introduction

Modern music notation is a system for marking notes, using musical symbols, on a set of five horizontal lines called a staff. Therefore, music can be written down as notation to represent the relative duration and pitch of sounds (Flowers, 1998). However, students may not readily understand music notation because the symbols are abstract, especially when the student is unfamiliar with music-notation symbols and the pitch of the notes (Rogers, 1996). Generally speaking, teachers use lecturing, metaphors, providing practical examples, or imitation activities to teach music notation to their students. When it comes to the higher level skills of the music elements, such as timbre, dynamics, rhythm, melody, harmony, structure, and texture, pupils who are unfamiliar with music notation often take only tiny, unsure steps forward (Kyme, 1960). This situation often results in students no longer being interested in learning music, or it may limit their music awareness and cognition. Therefore, the music teacher should teach students how to recognize and comprehend music notation when designing an instructional activity.

Although music and painting are different, the creation of music and painting has been linked for a long time, and their artistic concepts have some things in common. For example, in Kandinsky's (1866–1944) painting production, *Sketch for Composition II* (1909–1910), he used music as a creative subject to finish the painting. He found that vivid lines and clear color can represent the beauty of the rhythm in music. Yellow could represent the loudspeaker, green could represent the violin, and red could express the army. Modest Mussorgsky, a Russian musician (1839–1881), took inspiration from painted pictures to compose music while visiting his friend's painting exhibition. In education, for using painting in teaching music, Hair (1987) found that pupils from kindergarten to sixth grade who attend music class for 30 minutes a week are superior in their verbal descriptions, when answering a music-elements test using visuals, such as the select-a-picture method. Flowers (1998) showed that children could easily describe music elements in the visual mode, but not in the verbal mode. Cassidy (2001) took 68 university students as a sample and found that 51 students who did not major in music education could be affected by the instructional method using the abstract and conceptual listening map, but the other 17 students who majored in music education were not significantly affected. Gromko and Russell (2002) tested 41 second- and third-grade pupils in Iowa and found that through the assistance of a music map, the children could listen to and distinguish music elements as well as read notes in detail. Tan and Kelly (2004) stated that music can assist a student's creative and thinking ability while painting. It seems that painting can improve students' motivation and promote their learning effect while lecturing music.

Recently, multimodal learning has been used in the construction of learning environments. A multimodal learning environment uses two different modes, verbal (e.g., printed words, spoken words) non-verbal (e.g., illustrations, photos, video, and animation), to represent the content knowledge (Moreno & Mayer, 2007). Multimodality is proven to enhance learning in many fields. This article supports that argument and therefore tries to provide teachers who prefer an exclusively text-based pedagogy with a multimodal presentation. Moreover, the explosive progress of computer technology has encouraged the trend of presenting teaching materials by means of projectors and laptops. Lectures combined with multimedia can be better for some students, allowing them to construct meaningful knowledge and make referential connections of mental representation (Mayer, 2001; Paivio, 1986). The materials available come in many forms, such as PowerPoint, Word, Adobe Acrobat, video, and more. It is important for teachers to integrate those multimedia materials in their lessons. Teachers should use the richest possible medium to ensure a range of activities that extend the scope and range of learning opportunities available to students in the classroom (Trevino, Lengel, & Daft, 1987). Therefore, teachers need to smoothly manage and control the presentation of teaching materials to improve students' learning performance (Guttormsen Schär & Zimmermann, 2007). Recently, the multimodal mode is being employed in the construction of a learning environment for presentation (Tan, Gergle, Scupelli, & Pausch, 2006). The multimodal mode presents more visible information to the students as well as makes reading more comfortable due to sufficient display space. Students can easily view two or more different documents in a side-by-side fashion. Tyndiuk, Lespinet-Najib, Thomas, and Schlick (2004) examined an experiment with 40 high-school students and found that the multimodal mode provides effective assistance for difficult interaction tasks. Therefore, the multimodal representation is an important part of the instruction (Tan & Kelly, 2004). This paper proposes the DML system to support a multimodal presentation during instruction. Using the DML system, teachers can easily arrange various instructional materials with different media formats to enhance students' learning performance in a multimedia learning environment. Furthermore, an exploratory study was conducted to examine the effects of the proposed system with 64 fourth-grade students in a rural elementary school.

The remainder of this paper is organized as follows. Section 2 briefly reviews the literature. Section 3 describes the DML system. Section 4 describes the experiment and its result, and Section 5 is our conclusion.

Literature review

Multimedia instruction

Multimedia instruction presents multiple modalities of information that are intended to foster learning, including speech, printed text, static graphic, animation, and video (Baddeley, 2002; Mayer & Moreno, 2003; Moreno & Mayer, 2007). Mayer (2001) defined multimedia as the presentation of material using both visual and verbal methods. The cognitive theory of multimedia learning, proposed by Mayer (1997), provides empirical guidelines to promote instructional design for achieving meaningful learning. The theory is based on the following assumptions: dual channel, limited capacity, and active processing (Moreno & Mayer, 2000). The human information-processing procedure can be separated into multimedia presentation, sensory memory, working memory, and long-term memory. Words and pictures represent the teaching materials designed by instructional designers. Atkinson and Shiffrin (1968) define words as teaching materials presented in verbal form, such as using speech or printed text, and they define pictures as teaching material presented in pictorial form, such as using static graphics or dynamic graphics. Sensory memory is a short-term sensory buffer. Before we cognitively process the sensory information at the higher levels, sensory memory retains an exact and accurate copy of what is seen or heard in a verbal or pictorial form for a short-time sense (Atkinson & Shiffrin, 1968). The process of stimulus from multimedia presentation to sensory memory represents the word or picture to be registered by the eyes or ears. Several pieces of verbal or pictorial information could be organized and integrated (Sorden, 2005). The dual-channel theory suggests that students learn best when both channels are processed together. For this reason, our intention is to design a teaching-aided system that supports the verbal and pictorial form based on the multimedia formats while presenting and providing multiple multimedia formats.

Mayer presents seven principles that should be used in ways that are consistent with the cognitive theory of multimedia learning (Moreno & Mayer, 2000; Moreno & Duran, 2004).

- Multimedia principle: Students learn more effectively from words and pictures than from words alone.
- Spatial contiguity principle: Students learn more effectively when corresponding words and pictures are presented next to each other rather than far from each other on the screen.

- Temporal contiguity principle: Students learn more effectively when corresponding words and pictures are presented at the same time rather than when they are presented separately.
- Coherence principle: Students learn more effectively when extraneous words, illustrations, sounds, video, and animation are excluded rather than included.
- Modality principle: Students learn more effectively when multimedia material combines animation and narration rather than animation and on-screen text.
- Redundancy principle: Students learn more effectively from animation and narration than from animation, narration, and on-screen text.
- Individual differences principle: Students with low knowledge have stronger design effects than those with high knowledge, but the effects are stronger for high-spatial learners than for low-spatial learners.

Listening map

A listening map is a pictorial or graphic representation of sound that symbolizes the musical features of a musical selection in a visual format (Cassidy, 2001; Gromko & Russell, 2002). It is a valuable teaching aid for the music-listening lesson because it represents exactly where musical events take place and enables children to easily understand musical form, texture, and melodic structure, especially regarding balance and contrast (Kassner, 2007; Miller, 1986). For example, long or short lines express the difference in duration of the rhythm, large or small pictures express the power of the dynamics, high or low pictures express the melody, different pictures stand for different musical instrument sounds, and the writing symbols or the composition of the pictures can represent the musical elements (Shockley, 1997). Land and Vaughan (1978) hoped that students would be able to write pitch with simple figures and use their body to present musical creativity (Figure 1a). Newman (1994) was of the opinion that children are often confused regarding volume and pitch because they believe that singing louder will produce a higher pitch. Therefore, teachers must teach student to distinguish the level of sound through some form of visual assistance. He found that by following rising or dropping lines, children can distinguish the level of a sound and sing it out (Figure 1b). Gromko and Russell (2002) also used the listening map to teach. They found that the listening map can help students distinguish music elements and read notes. In summary, teachers can scaffold students by using multimodal representation to construct students' coherent mental representations and therefore promote their learning effects.

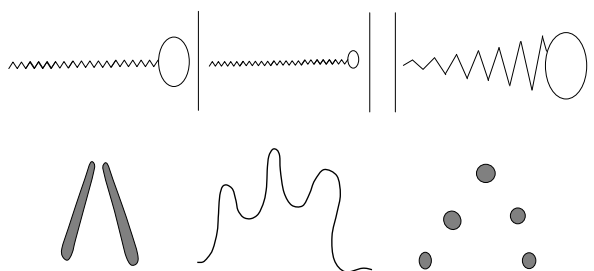


Figure 1a. The graphic image

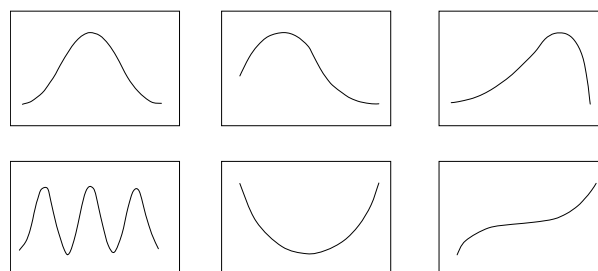


Figure 1b. the curved line

Multi-monitor display

For reconstructing the teaching materials, a desktop monitor does not provide sufficient space to display the needed information. Most users are multitasking more than ever and feel that a single monitor offers a limited display surface (Grudin, 2001). A greater display surface increases the amount of information that is visible to the user at any given moment, in addition to providing a more comfortable reading space. Several screens allow for several documents to be presented simultaneously. Therefore, users can easily read several documents placed on different monitors (Rodgers, Mandryk, & Inkpen, 2006). Multiple monitors improve the performance of multitasking (Czerwinski, Robertson, Meyers, Smith, Robbins, & Tan, 2006).

The topology of multi-monitors is available in Microsoft Windows, called a virtual screen (MSDN, 2006). Windows 98, Windows 2000, and Windows XP all support multiple monitors on a single system. The multi-monitors architecture enables the operating system to use the display area from two or more monitors to construct a logical

desktop (MSDN, 2006). To use the multiple-monitor supporting feature, an AGP or PCI display adapter is needed for each monitor or a specific display adapter to drive two or more monitors. A comparison for single-channel presentation and the dual-channel presentation is shown in Table 1.

Table 1. A comparison for the single-channel presentation and dual-channel presentation

Presentation	Single channel	Dual channel
Presentation method	single	dual
Presentation time period	short	long
Note-taking time period	short	long
Thinking time period	short	long
Coherent reference	middle	good

The structure and application of the multimodal DML system

The DML system integrates and presents instruction materials side by side simultaneously, which can produce a vivid instructional presentation in a dual-presentation environment.

The structure of the DML system

The DML system has seven modules. The object container module, which is designed by using the object linking and embedding (OLE) technology, controls the contents and functions of existing application programs, such as PowerPoint (PPT), Word, Excel, Internet browsers, or Adobe Acrobat formats. The multi-presenting manager module detects the number of monitors for users to select and displays the windows to the assigned screen. The Windows manager module control Windows taskbar items, deploys the authoring tools, and calls them back to the current monitor. The video-recording module records learning activities, such as students' singing or acting, by using digital video in the classroom. The PPT duplicate module is used to put a real PowerPoint application in one projector and duplicate a PowerPoint application in the other projector. A limit of traditional systems is that only one PowerPoint application can manage the PowerPoint presentation. Teachers use the PPT duplicate module to simultaneously present two individual PowerPoint files. The image-copying module can copy the image from one screen and add it to programs such as PowerPoint on the other screen. The presenting position module changes the location or changes the presenting area of the object container materials.

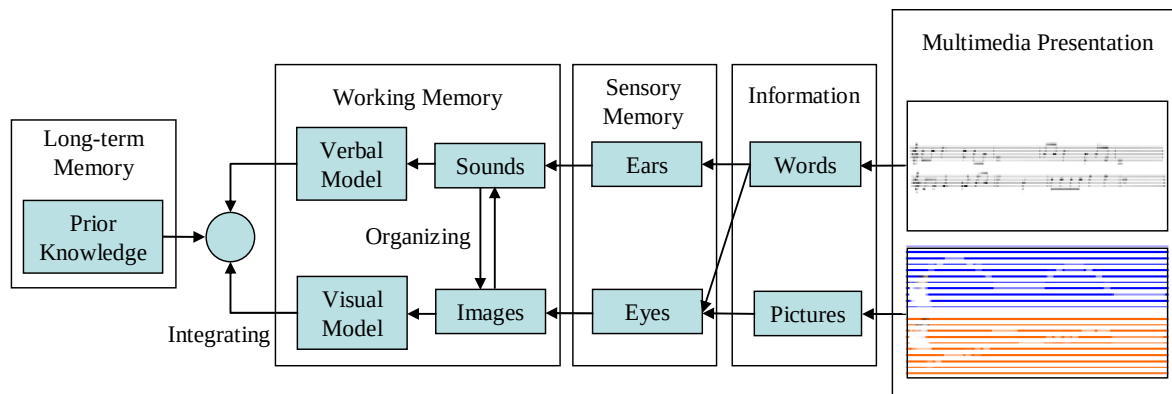


Figure 2. The dual-presenting mechanism in the DML system

Application of the DML system

Students usually do not build referential connections of mental representations when teachers teach them music elements, because it's difficult for students to make sense of the elements if they are altered in any way. Accordingly, many students simply ignore music notation or study through rote practice during music education. According to the cognitive theory of multimedia learning (Mayer, 2001), the synchronized mechanism of the

multimodal presenting approach plays an important role in helping learners build referential connections. By doing so, learners can readily infer the music elements rather than memorize them. Figure 2 shows the dual channels of the presenting mechanism in the DML system. It shows that a textual representation and a pictorial representation are shown on different monitors by the multi-presenting manager module. From the segmented curve lines of the listening map of a multimedia presentation, students can clearly observe the change in the melody. By using the DML system, students simultaneously obtain two stimuli, one is music notations (texts) and the other is listening maps (pictures).

The instructional process of music education using the DML system is described as follows:

1. In the preparation phase, the teacher sets up the DML system and prepares the learning materials with Word, PowerPoint, or video files. S/he uses devices such as a notebook, projector, digital camera, or interactive whiteboard for instruction.
2. In the warm-up phase, in order to increase the students' learning motivation, the teacher plays a short video to introduce the learning content.
3. In the developing-activity phase:
 - 3.1 The teacher plays the piano or tape and then lectures about the content.
 - 3.2 After singing, the teacher teaches music notation and the corresponding listening map by using the DML system.
 - 3.3 The teacher discusses the music elements with the students.
 - 3.4 The teacher shows the students how to make body movements using the Dalcroze Eurhythmics method and records the activities.
 - 3.5 The teacher then displays the recorded video on one monitor and, on the other monitor, takes a sequence of practice snapshots on which to comment.
4. Before ending the class, learning sheets are displayed on one monitor. Comments or hints for the learning sheets are presented on the other monitor.

Methods

In this section, we describe a teaching and learning experiment to show the learning achievement while using the DML system to present teaching materials in music instruction.

Participants

The test to determine the effects of the DML system on student learning achievement was carried out in a remote elementary school near the geographical center of Taiwan. All children at the school received music instruction from one specific music teacher. The participants were 64 students (with a mean age of 9.6 years) selected from a population of fourth-graders who did not receive private instructions in playing the piano or other musical instruments. Of the sample, 53% ($n = 34$) were girls and 47% ($n = 30$) were boys. The participants were randomly assigned to the experimental group ($n = 32$) or the control group ($n = 32$). In fact, in the more remote elementary schools in Taiwan, teachers teach all subjects, including Mandarin Chinese, science, mathematics, social studies, music, and other subjects. Thus, they are not experts in teaching any of these subjects, especially music.

Instructional design

Appreciation is an integrated behavior for music learning. Instruction in music appreciation leads students into the world of appreciating music rather than their originally unconscious hearing. This instruction allows students to learn and understand musical rhythm, melody, form, and more. In this study, the experimental group adopted the DML system to present the listening map to assist them in their music appreciation instruction. The experiment consisted of twelve 40-minute classes for eight weeks. The selected teaching materials were mainly classical music such as "*Introduction et Marche Royale du Lion*," "*Fossils*," "*Les Toreadors*," "*In a Persian Market*," and "*In the Hall of the Mountain King*." The instructional strategies include a brief introduction, music appreciation, and eurhythmics. The control group was treated similarly to the experimental group, but only used PowerPoint to present music notation and did not use the DML system to present additional visual auxiliary materials, such as the listening map.

Brief introduction

The teacher briefly introduces the composer's life story and then plays the music.

Music appreciation

For the experimental group, the teacher plays the music and uses the DML system to simultaneously present the words and the pictures, such as music notation and the listening map, in order to show the characteristics of music appreciation. For example, Figure 3 represents the cognitive model of multimedia learning combined with the multi-presenting presentation of the DML system. The various instructional materials presented by the teacher are blended with multimedia learning on the different projection screens. The top portion in Figure 3 shows part of Ketèlbey's "In a Persian Market (The princess segment)." The teacher uses the DML system to present PowerPoint documents and pictures simultaneously. Projection Screen 1 on the left shows the music notation, while Projection Screen 2 on the right shows the listening map. In the listening map, the flute and some musical instruments are represented by a butterflies, stars, and flowers. The down ladder represents the downward slant of the melody (Zhou, 1999). The teacher can explain the notations with geometric figures to make referential connections between them for the learners. The students also absorb learning information through the referential connection of various teaching materials.

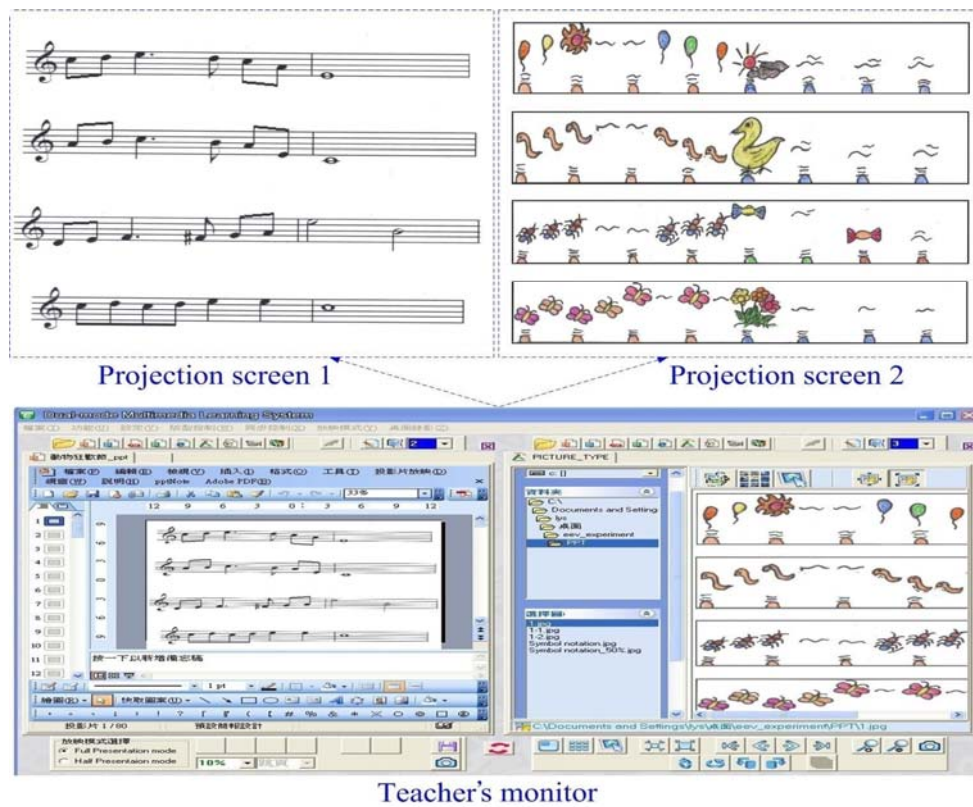


Figure 3. Blending the cognitive theory of multimedia learning into the DML system

For the timbre of "Les Toreadors" (Lin & Xu, 2004), the round red icon represents the sound of the brass instruments, the big red bomb icon represents the sound of the cymbals, and the flower icon represents the sound of the brass instruments (see Figure 4). In this figure, similar dynamics is indicated by same size of bomb icon; the position of the accent is expressed by the bigger, brighter, red bomb icons. For the rhythm, the small round red icon expresses the regular beat of the brass instrument; the large red bomb icon represents the position of the cymbal; the flower icon represents the playing of the bass part of the brass instrument. For melody, the level of high or low and

the colorful curved lines represent the melody. Moreover, teacher can also depict a simpler listening map (e.g., line) for students (Figure 4b) (Liao, 2007).

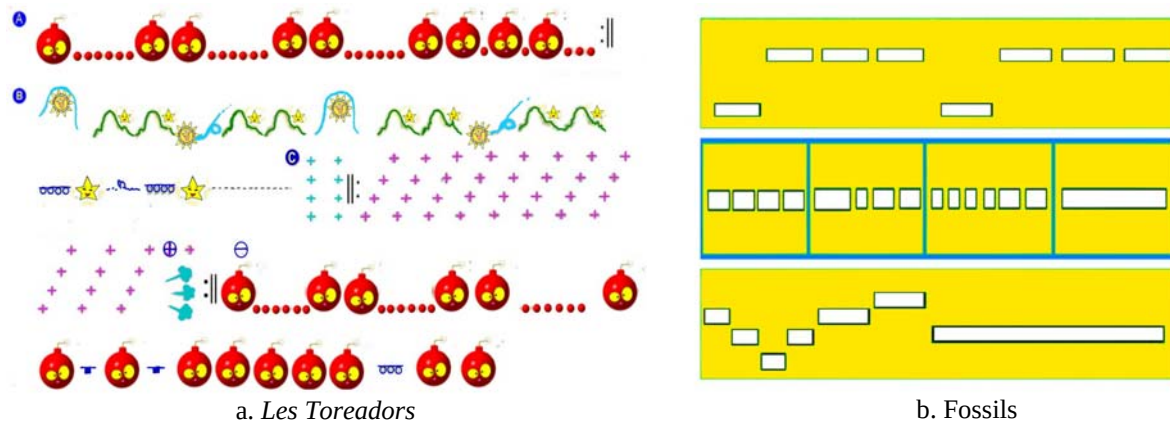


Figure 4. The listening map

Eurhythmics

Cognitive and affective behaviors have a major impact on creating the latent energy of creativity (Williams, 1982). The teacher adopts eurhythmics, the playing of a musical instrument, drama, and creativity to perform a situated story. Therefore, students express the music they hear and move their hands, limbs, and bodies to show their own feeling in various eurhythmic ways (Reimer, 1989).

Materials

Learning achievement

The learning achievement in this study is in terms of the scores of the students for the timbre, dynamics, rhythm, and melody. The timbre is the essence of a sound produced by different musical instruments or a voice. Dynamics expresses the power of the sound, including sustained loudness, sustained softness, stronger and stronger, weaker and weaker, etcetera. Rhythm is the length of music notations. Melody expresses the level of the sound, contingent upon the number of times it vibrates (Kamien, 2004). In the test method, students listen to 10 pieces of music, such as Saint-Saens, Bizet, and Dukas, and more. Each piece of music lasts about 30 seconds and is played twice to test if the students can distinguish the following: (1) the theme trend of the music, (2) the type of musical instrument, (3) if the dynamics get stronger and stronger, weaker and weaker, or do not change, (4) if the rhythm is long or short. Each musical element has 10 points, for a total of 40 points. The higher the score, the more the student has learned; the lower the score, the less a student has learned.

Learning motivation

Learning motivation means that the teacher leads students to carry out an activity, maintains the activity, and makes the activity reach the goal that the teacher has set up (Pintrich, Smith, Garcia, & McKeachie, 1993). In this study, the learning motivation questionnaire, containing value, expectancy, and affection, was modified by the motivated learning strategies from (Keller & Keller, 1991; Pintrich & Schunk, 2002; Teoh & Neo, 2007) and written in Chinese to satisfy the students. There were six items and two open-ended questions in the questionnaire (see Table 3). The answers were scored using a Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The higher score shows the stronger learning motivation; the lower score indicates the opposite motivation. The internal consistency (Cronbach's α) was .83. The two open-ended questions were "Do you feel that this music-teaching method is helpful to you, and why?" and "Do you need the teacher to use the DML system, and why?"

Multimedia presentation

Learners often select contents presented to them based on individual need and cognitive awareness (Teoh & Neo, 2007). The multimedia presentation questionnaire included seven items that were modified from (Teoh & Neo, 2007) and written in Chinese to accommodate the students (see Table 4). For example, “I found that there was just the right amount of information presented on the screen,” “I found the texts and graphics that were presented to be clear, structured and appealing”. The higher the score, the better the multimedia presentation. The answers were scored using a five-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The internal consistency (Cronbach’s α) was .89.

四年五班 12 號 姓名

親愛的小朋友：

仔細聆聽老師播放的音樂，[老師播放第一段音樂並說明]這是 A 段音樂；[老師播放第二段音樂並說明]這是 B 段音樂；[老師播放第三段音樂並說明]這是 C 段音樂。現在請小朋友再聽一次這三段音樂，運用想像力在下面框格中畫出 A、B、C 三段的圖畫（音畫）。

A 段圖畫

B 段圖畫

C 段圖畫

現在請小朋友聆聽整首音樂曲子，並將全曲音樂順序（曲式）用 ABC 段落寫出來

A → B → A → C → A

這樣的曲式，我們稱它為：輪旋曲式

Student's data

A brief explanation of the music sheet: listening and drawing

Drawing and coloring

The musical form

Figure 5. Student's worksheet

Results

Learning achievement

Table 2 shows that the learning achievement of the experimental group was more effective regarding timbre and melody than that of the control group, $t(62) = 2.388$; $p < .05$; $t(62) = 2.100$; $p < .05$, respectively. However, results did not differ from the control group with respect to dynamics and rhythm, $t(62) = 0.810$; $p > .05$; $t(62) = 0.361$; $p > .05$, respectively. The experimental group ($M = 23.31$, $SD = 4.22$) significantly outperformed the control group ($M = 20.66$, $SD = 5.30$) in learning achievement, $t(62) = 2.219$, $p < .05$. The average scores of the experimental group were slightly higher than those of the control group. This means that the experimental group gained more in learning achievement than did the control group. Gromko and Russell (2002) also found that painting can assist elementary

children when listening to European classical music. The results showed that using visual materials can assist music learning and promote learning.

Table 2. Summary of means (M), standard deviations (SD), and t-test (t) results for learning achievement

Variables	Points	Experimental group (n = 32)		Control group (n = 32)		t
		M	SD	M	SD	
timbre	10	5.97	1.45	4.97	1.87	2.388 *
dynamics	10	6.78	2.71	6.28	2.20	0.810 <i>ns</i>
melody	10	5.38	1.88	4.38	1.93	2.100 *
rhythm	10	5.19	1.51	5.03	1.93	0.361 <i>ns</i>
total	40	23.31	4.22	20.66	5.30	2.219 *

* $p < .05$; ** $p < .01$; *ns* = no significant

The results showed that using the DML system to present the listening map can assist music instruction and music appreciation and that it can effectively improve learning achievement in timbre and melody. In general, the human ear is tuned to the sound and size of a voice (Tsur, 2006). However, the listening map is easily recognized for pupils (see Figure 5). The painted elements expressed in the listening map are better adapted to the visual characteristics in timbre and melody. For example, different figures or images express the timbre for different musical instruments. The level of the lines, high or low, expresses the melody of the sound. Therefore, the experimental group was superior in controlling the timbre and the melody after having been taught how to do it.

Motivation

Table 3 shows that the experimental group ($M = 21.66$, $SD = 2.79$) significantly outperformed the control group ($M = 19.97$, $SD = 2.73$) in learning motivation, $t(62) = 2.446$, $p < .05$. The average scores of the experimental group were higher than those of the control group. Students in the experimental group thought learning was interesting and engaging. This indicates that multimedia can increase learning motivation, and that computer-assisted learning is useful for learning. The results also showed that if the music teacher used the DML system then the students achieved better results in motivation than when the teacher used the traditional method.

Table 3. Summary of means (M), standard deviations (SD), and t-test (t) results for learning motivation

Item	Experimental group		Control group		t
	M	SD	M	SD	
I find learning is interesting and engaging.	3.78	0.61	3.31	0.69	2.876 **
I find that computer-assisted learning is useful for learning.	3.78	0.66	3.47	0.51	2.126 *
I know now more about the subject.	3.72	0.63	3.41	0.80	1.735 <i>ns</i>
Multimedia increases my motivation to learn.	3.38	0.66	3.13	0.59	2.189 *
The learning content is just right, not too easy and not too hard.	3.56	0.67	3.25	0.84	1.643 <i>ns</i>
I believe I can learn the subject well.	3.43	0.72	3.50	0.57	-0.387 <i>ns</i>
Total	21.66	2.79	19.97	2.73	2.446 *

* $p < .05$; ** $p < .01$; *ns* = no significant

The facilities of the product may stimulate the study of the effectiveness of those different representations. Some findings are obtained during music instruction by asking students their opinion, using open-ended questions. The following feedback to these open-ended questions was provided by the students in the experimental group:

- It is easy to listen to and distinguish the melody.
- I find I can show the rhythm of the notes with short or long lines.
- The music lesson becomes more interesting and pleasant.
- I can learn the music in different ways.
- I can understand the element of the music through the listening map.
- I find that the images express the different note types.

The questionnaire includes the open-ended question “Do you need the teacher to use the DML system, and why?” Some students’ answers were as follows:

- I need the DML system because I think the teacher can teach us in different ways.

- I need it, because these past weeks, I have found the “listening map” to be very helpful.

Accordingly, applying the DML system to music instruction can capture the interest of the students and prompt their awareness of music elements.

Multimedia presentation

Table 4 shows the experimental group as being more effective in multimedia presentation than the control group, $t(62) = 2.047$; $p < .05$. The average scores of the experimental group ($M = 24.91$, $SD = 3.17$) were higher than those of the control group ($M = 23.34$, $SD = 2.94$). The result showed that the DML system combined with visual materials such as pictures and texts can assist in music learning. From Table 4, we found that students in the experimental group thought the use of texts and graphics to be clear, structured, and appealing and the materials presented were visualized.

Table 4. Summary of means (M), standard deviations (SD), and t-test (t) results for the multimedia presentation

Item	Experimental group		Control group		<i>t</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
I found that					
there was just the right amount of information on the screen.	3.31	0.82	3.19	0.69	0.658 ^{ns}
the texts and graphics presented were clear, structured, and appealing.	3.66	0.83	3.22	0.75	2.215 [*]
the texts and graphics presented allowed me to easily identify the important information and key concepts.	3.47	0.80	3.56	0.62	-0.523 ^{ns}
the texts and graphics presented were helpful in learning the music elements.	3.66	0.75	3.25	0.92	1.946 ^{ns}
the presented texts and graphics help me to connect the knowledge that I have learned.	3.69	0.59	3.53	0.67	0.987 ^{ns}
the texts and graphics presented help me to better visualize the content.	3.72	0.77	3.31	0.64	2.285 [*]
the graphics and examples presented help me to pay attention to the subject.	3.41	0.71	3.28	0.99	0.579 ^{ns}
Total	24.92	3.17	23.34	2.94	2.047 [*]

* $p < .05$; ns = not significant

Conclusions

This paper represents a step towards multimodal representations applied in the educational process. In this study, the multimodal DML system has been proposed to assist pupils in performing during their music lessons. The DML system allows a teacher to project teaching materials on two screens to students while instructing them in music appreciation. One screen presents the musical notation as a musician would see it and the other screen presents a pictorial representation of the music involving the use of small graphics that would appeal to children to represent various aspects of the music such as timbre, dynamics, rhythm, and melody. The DML system was used in an experiment with 32 children (grade 4) assigned to the experimental group who received twelve 40-minute lessons for eight weeks. Experimental results showed statistically better learning results for the experimental group on two musical elements. Positive effects were also indicated for learner motivation and attitudes toward instruction for the experimental group.

Multimodality is proven to enhance learning in many fields. This study supports that argument, and is therefore potentially persuasive to provide teachers who cling to an exclusively text-based pedagogy with multimodality presentation. The DML system introduced a breakthrough in software enhancement for multimedia learning that is designed to streamline the procedure of presentation by refining the presenting tool. The instructor utilized the DML system to simultaneously provide dual-channel presentation with music notation and its corresponding listening map. The teaching method resulted in students' responding better to the music learning. The listening maps are used to

describe the basic features of the music notation. They are colorful, easy to understand, and helpful for students to concentrate on the comparatively complicated music notation and music elements (Clark & Paivio, 1991). They also can be concise and figurative to provide simple and summary description about the music notation. Together with graphic presentation, the listening maps form the basis of virtual representation of music notes. Based on Keller's learning motivation theory (Keller, 1987), this study employs multimedia such as pictures and texts to draw students' attention. Accordingly, the learning activity becomes meaningful, interesting, and easily understood. Future research might investigate application for teaching grammar, the parts of speech, or the organization and emphasis of an argument, etc. We also urge future research to examine if the system works well cross-culturally. Moreover, the application of descriptive images for learning is also an important issue for future research.

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Development and Evaluation of a Confidence-Weighting Computerized Adaptive Testing

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ABSTRACT

The purpose of this study was to examine whether the efficiency, precision, and validity of computerized adaptive testing (CAT) could be improved by assessing confidence differences in knowledge that examinees possessed. We proposed a novel polytomous CAT model called the confidence-weighting computerized adaptive testing (CWCAT), which combined a confidence-weighting scoring scheme with the graded response model (GRM). The CWCAT provided a more interactive testing environment by focusing on the examinees' confidence in their responses. An experiment was conducted to evaluate the comparison between the CWCAT and conventional CAT in terms of efficiency, precision, and validity. As expected, the polytomous method provided better discrimination among individual differences in the confidence in knowledge and required fewer items per examinee. Results also showed that CWCAT yielded ability estimates that were higher and better correlated to examinees' performance in English learning. Furthermore, the ability measured by CWCAT was not as likely to be affected by guessing as on conventional CAT, and, therefore, was more consisted with examinees' true ability.

Keywords

Confidence-weighting, Guessing, Computerized adaptive testing, Graded response model

Introduction

Multiple-choice questions (MCQs) have been widely used as an assessment method for decades due to their versatility in assessing a wide range of objectives, high reliability, and easy scoring. By the time one graduates from high school, one has undergone numerous MCQ tests administered by the schools. However, the general acceptance of the MCQs did not imply that the merits of this testing technique were optimal. Compared with other test formats, the MCQ test results were easily affected by guessing since examinees were not penalized for wrong answers. The fact that an examinee who knew nothing still had a one-out-of-four chance to choose the correct answer renders one's test scores not equivalent with his/her ability. Furthermore, additional problems could arise in testing if such guessing behaviors were not random but systematically tied to knowledge levels (Bruno, 1986). Another problem of MCQ testing was derived from its all-or-none scoring system. The underlying assumption of the dichotomous scoring method assumed that an examinee would check the correct answer if he/she had complete knowledge; otherwise, he/she would either omit the question, or guess randomly (Lord, 1975; Rowley & Traub, 1977). In fact, examinees who did not know the correct response always selected an answer based on different levels of knowledge (Jackson, 1955; Lord, 1975). In the conventional dichotomous scoring scheme, distinguishing correct answers based on knowledge from those obtained by guessing was impossible.

Various solutions have been proposed to cope with these problems. Scoring schemes for MCQs, such as order-of-preference schemes, answer-until-correct procedures, and confidence-weighting assessment, attempted to decrease the influence of guessing and assess the different knowledge levels of examinees. However, these solutions were designed for conventional paper-and-pencil (P&P) or computer-based testing (CBT). Few studies have investigated the impact of guessing and confidence in knowledge on computerized adaptive testing (CAT). In contrast to the conventional P&P testing with fixed items, CAT, based on item response theory (IRT), could be tailored to the ability of each examinee (Ho, 2000). By adaptively selecting items for examinees, CAT could improve the accuracy of testing, save testing time, and require fewer items per examinee (Weiss, 1982; Wainer et al., 2000). A number of large-scale testing programs, such as the Graduate Record Examination (GRE) and the Test of English as a Foreign Language (TOEFL), were switching from the conventional P&P version to CAT for the sake of efficiency and effectiveness. However, the guessing problem was either ignored or dealt with from an item perspective instead of from an examinee-dependent perspective on conventional CAT.

The aim of this study was to propose a novel polytomous CAT model called confidence-weighting computerized adaptive testing (CWCAT), which combined the confidence-weighting scoring scheme with the graded response model (GRM) (Samejima, 1970) and to test whether the efficiency, precision, and validity of conventional CAT could be improved by assessing confidence differences in knowledge. To remove the effect of guessing and assess the level of confidence examinees have in their knowledge, the CWCAT provided a more individualized approach by focusing on the examinees' confidence in their response. An experiment was conducted to compare the examinee performance on CWCAT with their performance on conventional CAT; the test length (i.e., the number of items administered in a test) was used as an indicator of efficiency, while the standard error of estimation (SE) was considered as a precision indicator. These two indicators were the main reasons why CAT was better than P&P testing (Lord, 1970; Owen, 1975; Weiss, 1982; McBride & Martin, 1983; Wainer et al., 2000). Furthermore, the effect of assessing examinees' confidence in knowledge on the validity of CAT and the correlation between examinees' confidence in knowledge and their self-awareness were also investigated.

Guessing and confidence-weighting test

The goal of assessment was to accurately measure students' true ability. For most MCQ tests, however, error variance resulting from guessing could exceed error variance from other sources (Zimmerman & Williams, 2003). Since guessing answers to MCQs added random error to the variance of test scores and decreased reliability, guessing behavior was a main factor to consider when attempting improving MCQ tests.

Guessing could run the gamut from so-called wild or random guessing, where all options were chosen with equal probability, to partial knowledge or partial uncertainty, where the test-taker's probability of choosing some options might be higher or lower than that of choosing other options (Bar-Hillel, Budescu, & Attali, 2005). As a consequence of the guessing problem, the test-maker could not distinguish between correct answers based on knowledge versus those derived from a lucky guess. Hence, examinees with different knowledge could end up with the same score, and the examinees with the same knowledge could end up with different scores.

For an examinee, a guess was a gamble, but under number-right scoring it was a gain-only gamble. Formula scoring, a common method used to decrease the effects of guessing by deduction of marks for wrong answers, might engender more problems than it solved. Voluminous theoretical and empirical literature was developed to investigate issues such as the impact of test directions on testing scores (Votaw, 1936; Diamond & Evans, 1973; Lord, 1975; Rowley & Traub, 1977), test reliability and validity under formula scoring (Diamond & Evans, 1973; Lord, 1975; Bliss, 1980; Alnabhan, 2002; Burton, 2002; Zimmerman & Williams, 2003; Burton, 2004, 2005), and the differential tendencies to guess as a function of personality traits and lingual-cultural backgrounds (Rowley & Traub, 1977; Gafni & Melamed, 1994). Many of these problems were rooted in the dichotomous nature of MCQ tests. Under dichotomous scoring, an examinee was assumed to have complete knowledge when the correct answer was chosen; otherwise, guessing was at work. However, an examinee's understanding of a learning task might reside between the two extremes, that is, partial knowledge (Jackson, 1955; Coombs & Womer, 1956; Lord, 1975; Hammond, McIndoe, Sansone, & Spargo, 1998; Burton, 2002, 2005; Gardner-Medwin & Gahan, 2003; Bar-Hillel, Budescu, & Attali, 2005).

Partial knowledge either implied possession of incomplete information that could increase the likelihood of a successful guess, or indicated a lack of confidence in knowledge. One representative example came from Diamond and Forrester (1983), who defined knowledge as asking the question "What do you know?" followed by the meta-question "How sure are you of the answer to the question about what you know?" Knowledge was one important prerequisite that facilitates the adjustment to new conditions. From the perspective of learning, "partial" frequently referred more to uncertainty than to incompleteness, since unreliable knowledge could be a huge handicap to further learning (Gardner-Medwin, 1995). Besides, low confidence in one's knowledge might motivate the search and validation of the prevailing situation by further information acquisition (Chaiken, Liberman, & Eagly, 1989).

Confidence-weighting is a model of assessing partial knowledge based on the degree of examinees' confidence in their answer. In a confidence-weighting test, examinees were given a question along with a number of possible answers, and then asked to rate their confidence in the accuracy of their answer for each item. The number of the confidence level varied from test to test, and an examinee's rating of his/her confidence in an answer was taken into account in the marking of the answer. Since a confidence level described in language terms such as "very sure,"

“uncertain,” etc., might mean different things to different people, the levels were always described in terms of the marks awarded (Gardner-Medwin & Gahan, 2003). In this situation, examinees should discriminate between responses based on sound knowledge and those for which a significant risk of error existed. In a confidence-weighting test, therefore, confidence could be seen as an estimate of the probability that an answer will turn out to be correct (Gardner-Medwin, 1995).

Confidence testing was first tried as a method for increasing the amount of information in objective tests during the 1930s (Echternacht, 1971). Hevner (1932) was one of the first to evaluate this method for true/false tests in music appreciation and art judgment (Holmes, 2002). After comparing the four scoring methods (number-right scoring, formula scoring, confidence-weighting with and without penalty), she found that confidence-weighted number-right scoring had the highest reliability. In an English vocabulary test that asked examinees to mark on a three-level confidence option (complete confidence, partial knowledge, and random guessing) with each item, Abu-Sayf and Diamond (1976) argued that the internal consistency of scores increased with the confidence in the answers while the validity coefficient was highest when partial knowledge was used in the answering process. Hammond et al. (1998) designed an interactive computer-based MCQ test that consisted of two answer boxes, the traditional, mutually exclusive “True,” “False,” and “I don’t know” and a three-level confidence option (positive, educated guess, wild guess). The result that the probability of a correct response of “educated guess” was up to 74.4% implied the effect of partial knowledge on guessing and the advice “do not guess” to be incorrect. In another study, conducted by Khan, Davies, and Gupta (2001), the level of confidence was divided into five categories: very sure, fairly sure, neutral, unsure, and pure guess. The researchers claimed the test analysis allowed measurement of confidently possessed correct knowledge and identified misinformation.

For a learner, to know his/her own level of knowledge was helpful to control the learning progress. According to Chaiken, Liberman, and Eagly (1989), individuals might perceive their level of confidence to be low. As a result, they might be motivated to process additional information to raise their confidence level. However, if confidence levels were high yet knowledge levels were low, individuals were unlikely to be motivated to acquire new knowledge. Therefore, it was necessary that the level of individuals’ confidence in their own knowledge matched their actual knowledge (Sundblad, Biel, & Gärling, 2009). The aim of confidence-weighting was to encourage reflection, self-awareness, the expression of appropriate levels of confidence (Gardner-Medwin & Gahan, 2003), and enhance understanding and learning (Omirin, 2007). From an educational viewpoint, it was also important to identify the degree to which a student was sure or confident about the correctness of his or her responses (Khan, Davies, & Gupta, 2001). That is why Ahlgren (1969) argued that the value of confidence assessment should be seen primarily in the context of education rather than psychometrics.

From what has been discussed above, while correcting guessing effects on MCQs, some issues should be taken into account:

- For MCQ tests, it was reasonable to assume that the examinees guessed when they were sure that they did not know the correct answer.
- Examinees’ knowledge was not all or nothing but, rather, gradual.
- If an examinee didn’t know the answer, a best guess would be made based on his/her partial knowledge.
- There were individual differences in examinees’ guessing based on the different levels of knowledge they possessed.
- Valuable information might be obtained from the examinees’ guessing process for the estimation of their ability.

Computerized adaptive testing

The rationale of CAT involved a simple assumption: “More information can be obtained from a test item if the item matches the ability level of the examinee” (Assessment Systems Corporation, 1987). To reach this objective, adaptive testing strategy generally used branching or decision rule: “If the examinee answers an item correctly, the next item administered should be more difficult; if he answers it incorrectly, the next item should be easier” (Lord, 1970). Although the various adaptive strategies differed, they generally followed a similar pattern depicted in Figure 1 (Ho, 1989; Hsu & Sadock, 1985; Kreitzberg & Jones, 1980):

1. An initial ability is estimated in some conventional ways (e.g., grade level, age, or other information provided by examinee).
2. Select the item with best measurement at the ability estimated from the calibrated item bank.

3. The item is scored as either correct or incorrect, and the examinee's ability level is reestimated.
4. Refine the estimate by returning to step 2 until the estimate is sufficiently precise (e.g., standard error of estimation) or a pre-specified criterion (e.g., test length) is reached.

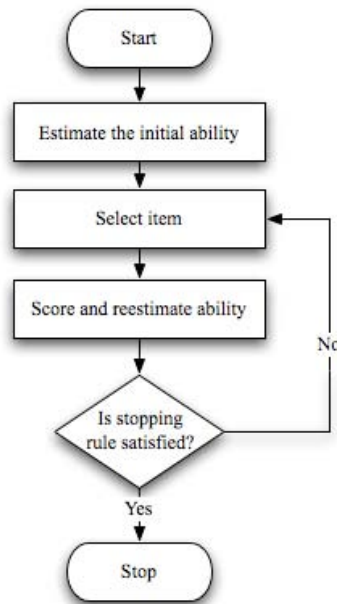


Figure 1. Flowchart of CAT administration

One of the most common dichotomous IRT models was the three parameter logistic (3PL) model introduced by Birnbaum (1968). This model contains three parameters: the difficulty parameter (b), the discrimination parameter (a), and the pseudo-chance-level parameter (c). The mathematical form of the 3PL model could be written as follows (Lord, 1980):

$$P_i(\theta) = c_i + \frac{1 - c_i}{1 + \exp[-Da_i(\theta - b_i)]}, \quad (1)$$

where

$P_i(\theta)$ is the probability that examinee with ability θ can answer a dichotomous item i with difficulty b correctly,
 a_i is the parameter allowing item i to discriminate differently among the examinees,
 c_i is the probability of answering item i correctly by guessing, and
 D is a scaling factor whose value is 1.702.

If $P_i(\theta)$ is plotted as a function of ability θ , the result will be an item characteristic curve (ICC) as shown in Figure 2, in which the x-axis represents an ability continuum and the y-axis the probability of any given choice being selected by an examinee with a given level of ability.

The parameter c , solution of the 3PL IRT for the guessing problem, represents the probability that an examinee with extremely low ability (θ approaching negative infinity) will get the item correct. The c parameter has been referred to as a guessing parameter; but since, for most MCQ, its value is less than the chance probability of random guessing, it is more frequently referred to as a pseudo-guessing parameter. Birnbaum designed the 3PL model to handle the situation in which examinees either guess totally randomly or answer on the basis of their knowledge. That is, the model was viewed as ignoring the common situation of an examinee answering by eliminating one or more of the alternatives and selecting randomly from among the remainder (Birnbaum, 1968; Waller, 1989). In other words, it restricted the guessing parameter to be item dependent instead of allowing this parameter to be person dependent (San Martín, Del Pino, & De Boeck, 2006).

In comparison to dichotomous IRT models, polytomous models facilitated the extraction of additional information about examinees' ability (Donoghue, 1994; Drasgow et al., 1995). Although several IRT models existed for

polytomous item response data, Samejima's GRM (1970) was applied in this study because its ordered categorical responses corresponded perfectly with examinee response types in a confidence-weighting scheme. The GRM was an IRT model appropriate for items having ordered response categories, where higher categories indicated greater ability. Under this model, examinee responses fell in only one of the ordered categories for each item.

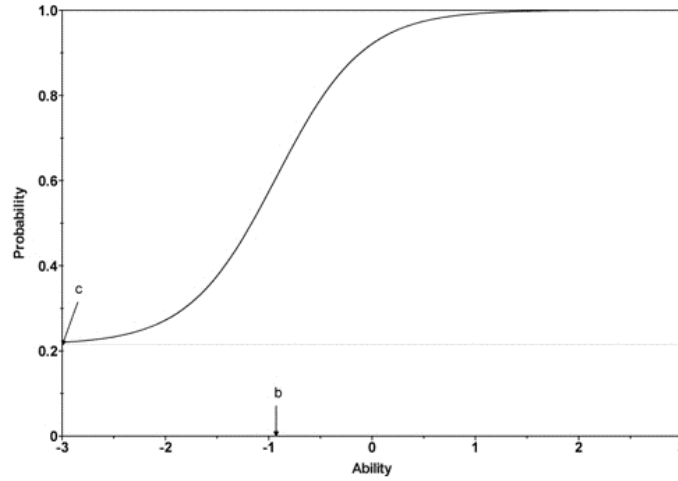


Figure 2. A typical ICC for the 3PL item response model with $b = -.962$, $a = 1.144$, and $c = .196$

A two-stage process was used to obtain the probability that an examinee would receive a given category score on a certain item. In the first stage, the cumulative probability that an individual with a certain trait level would receive a given category score or higher on item i is expressed by

$$P_{ix}^*(\theta) = \frac{\exp[D a_i (\theta - b_{ix})]}{1 + \exp[D a_i (\theta - b_{ix})]} \quad (2)$$

where D is the scaling constant, 1.702, a_i is the discrimination parameter of item i , θ is the trait level, and b_{ix} is the threshold parameter associated with category x for item i . The discrimination parameter a_i varies by item i , but within an item, all response curves share the same discrimination. The threshold parameter b_{ix} varies within item i with the constraint $b_{ix-1} < b_{ix} < b_{ix+1}$. At each value $\theta = b_{ix}$, the respondent has a 50% probability of endorsing the category. One goal of fitting the GRM was to determine the location of these thresholds on the latent trait continuum (Cagnone & Ricci, 2005). Figure 3 presents the ICC for each $P_{ix}^*(\theta)$ function for a four-response category item. The curve representing the probability for any examinee to select response one or any higher category is not presented in Figure 3 because that probability is one.

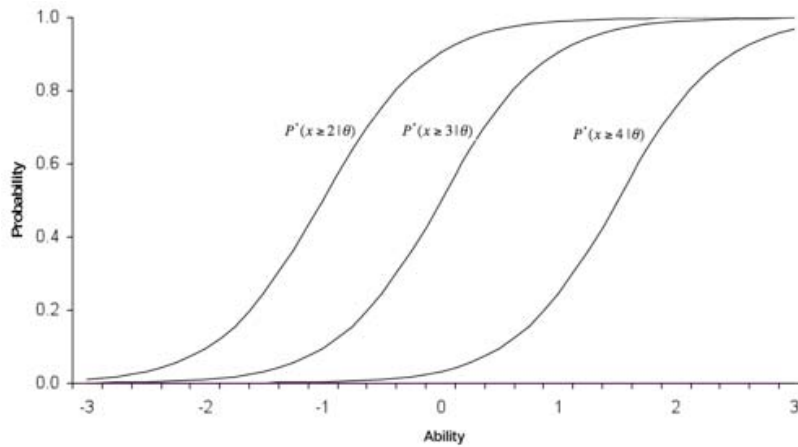


Figure 3. ICC for a four-response category item under the GRM with $a = 2.260$, $b_1 = -1.000$, $b_2 = 0.000$, and $b_3 = 1.500$

The second stage involved obtaining the probability that an individual would respond in a given category. This category probability could be obtained by subtracting adjacent cumulative probabilities conditional on θ , that is

$$P_{ix}(\theta) = P_{ix}^*(\theta) - P_{ix+1}^*(\theta). \quad (3)$$

Figure 4 presents the item category response curves (ICRC) derived from the ICC for the four-response category item presented above.

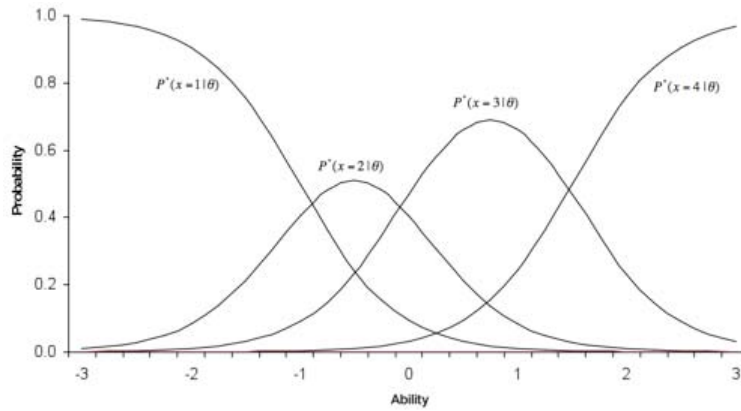


Figure 4. A typical ICRC for a four-response category item with IRT GRM parameters: $a = 2.260$, $b_1 = -1.000$, $b_2 = 0.000$, and $b_3 = 1.500$

Methodology

A two-phase experiment was conducted to assess the study objectives. In experiment phase 1, a computer-based confidence-weighting test (CBCWT) was set up to calibrate item parameters for CWCAT and DCAT. These two CAT versions were administered in experiment phase 2 for the purpose of examining whether the efficiency and precision of CAT could be improved by assessing confidence differences in knowledge. The experiment framework of this study could be viewed in Figure 5 and further described in detail in the following sections.

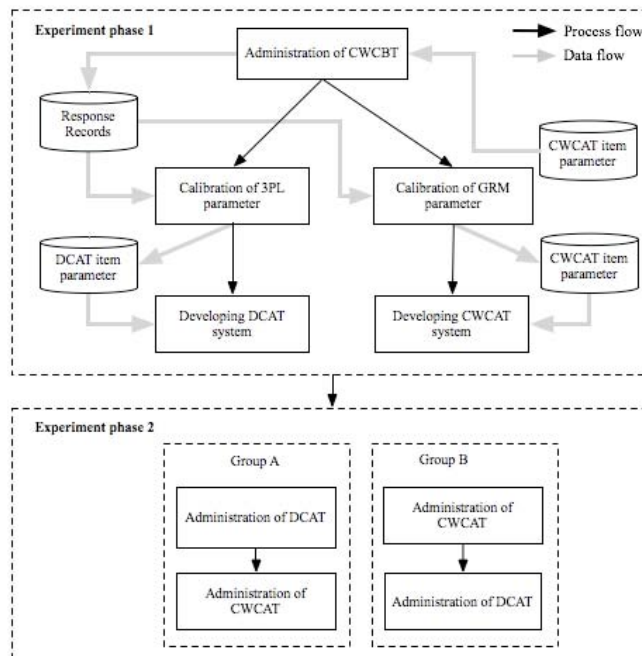


Figure 5. Overview of the study design

Experiment phase 1

During the first phase, a CBCWT was given to 489 third-year senior high school students studying English as a foreign language in Taiwan. All participants were male, within the same age range (17–18) and with similar socio-economic status.

The item bank used consisted of 84 items with four response options drawn from the vocabulary sections in the English Ability Test administered by the College Entrance Examinations Center in Taiwan (Ho & Yen, 2005). In this test, examinees were requested to rate the level of confidence they had ($C = 1, 2$, or 3) for their responses on each item. As Table 1 shows, corresponding marks of 1, 2, or 3 were awarded when their selection was correct; otherwise a score of 0, -2 , or -6 was awarded, respectively. According to Shuford and Brown (1974), the students gave up guessing only when the penalty associated with a wrong answer was larger than $k - 1$, where k was the number of alternatives. The scoring scheme was clearly explained to the participants before the test. This non-linear scheme was in a mathematical sense a “proper” scheme: the way to achieve the highest average score was to have correct insight into the probability of being right and to report this honestly, using level 3 for subjective confidence greater than 80% (odds 4:1), level 2 between 80% and 67% (odds 2:1), and level 1 otherwise (Gardner-Medwin, 1995; Issroff & Gardner-Medwin, 1998).

Table 1. Mapping of the dichotomous response codes onto the polytomous codes

Answer	Dichotomous	Confidence	Polytomous
Correct	1	High ($C = 3$)	3
		Mid ($C = 2$)	2
		Low ($C = 1$)	1
Incorrect	0	Low ($C = 1$)	0
		Mid ($C = 2$)	-2
		High ($C = 3$)	-6

The test results demonstrated that for items answered with high confidence, candidates were correct 81.04% of the time, 50.61% of the time for item with middle confidence and 35.23% of the time for items with low confidence (see Table 2). Table 2 suggests that examinees had an accurate perception of their performance on individual items. The results were consistent with finding of Cooke-Simpson and Voyer (2007).

Table 2. Overall response distribution on the CBCWT

Confidence level	Correct responses	Incorrect responses	Total
High	19,013 (81.04%)	4,448 (18.96%)	23461
Middle	4,349 (50.61%)	4,244 (49.39%)	8593
Low	3,178 (35.23%)	5,844 (64.77%)	9022

Number of responses = 41,076

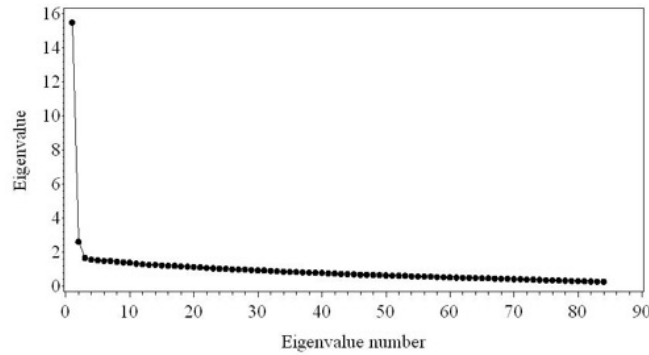
Table 3. Results of the principal components analysis

Item response	Eigenvalue of Factor 1	Eigenvalue of Factor 2	Factor 1 / Factor 2
dichotomous	15.4972	2.6258	5.9019
polytomous	32.7913	3.3251	9.8617

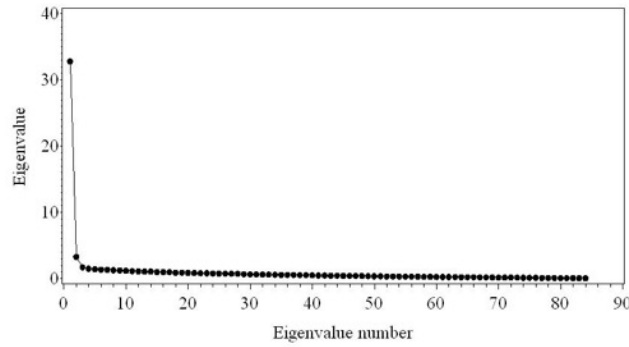
Number of responses = 41,076

Before applying IRT models, it was important to test if the assumption of unidimensionality was met. Unidimensionality represented that test performance was influenced by only one dominant factor. One way to check this assumption was by examining the relative sizes of the eigenvalue associated with a principal components analysis of the item set. As Reckase (1979) reported, the unidimensionality would be met if the eigenvalue of the first factor was more than four times of the other factors. To examine the unidimensionality of both dichotomous and polytomous CAT administered in the following phase, two types of item responses were obtained from the administration of the CBCWT: the dichotomous responses based on response correctness regardless of confidence level and the polytomous responses according to six possible response types (three confidence levels crossed with correct/incorrect feedback). Table 3 shows the factor analysis result for these two kinds of tests. Another way to determine the number of factors was with a scree plot (Cattell, 1966) while the decision about the number of factors

was arrived at based on the point at which the curve of decreasing eigenvalues changes from a rapid, decelerating decline to a flat gradual slope (Orlando, 2004). The scree plots for the data analyzed in Table 3 are presented in Figure 6. Obviously, both factor analysis results of dichotomous and polytomous test met these two criteria.



(a)



(b)

Figure 6. Scree plot with eigenvalue for (a) dichotomous item pool and (b) polytomous item pool

Table 4. Properties of 3PL model item parameters

Parameter	Mean	Std Dev	Minimum	Maximum
b	-.0855	.7678	-1.9306	1.6763
a	1.1022	.3779	.1196	1.8821
c	.2038	.0959	.0012	.5832

Number of items = 84

Table 5. Properties of GRM item parameters

Parameter	Mean	Std Dev	Minimum	Maximum
a	.9338	.3068	.3543	1.5647
b_1	-.9725	.5126	-3.6087	-.3555
b_2	-.4490	.2863	-2.1822	-.1495
b_3	-.0917	.2648	-1.4397	.3845
b_4	.4255	.2896	.1206	2.3491
b_5	1.0878	.6613	.3841	4.8815

Number of items = 84

Two sets of item parameters for CAT administered in phase two were then calibrated with marginal maximum likelihood method of PARSCALE (Muraki & Bock, 1999). The first set of item parameters (see Table 4) was based on the dichotomous responses and was then applied in the DCAT. The second set of parameters (see Table 5) was calibrated for CWCAT according to the polytomous responses. Six categories were classified for each item according to six corresponding response types and, hence, five threshold parameters were calibrated. Support for our

hypothesis regarding that polytomous CAT extracted more information about examinees could be seen in Figure 7, which showed that the CWCAT produced much more test information than DCAT. In the IRT framework, the statistical quality of administration was measured by measurement precision that could be expressed in the form of test information. Higher amount of test information meant better measurement precision or less measurement error.

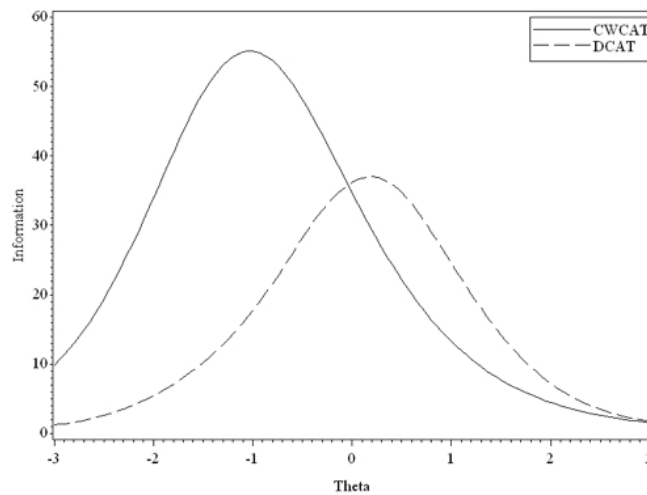


Figure 7. Test information functions for CWCAT and DCAT

Experiment phase 2

In the second phase, 85 participants from the same pool as in phase 1 took both DCAT and CWCAT; 12 of them did not complete the test because of equipment failure or other reasons. Administration of these two CAT versions was counterbalanced to control for possible test order and item pool effects by assigning respondents to two groups: Group A ($n = 39$) students took DCAT first, and Group B ($n = 34$) students took CWCAT first.

Class: 台南一中3年8班	No: 4
Vocabulary Testing	
Item #1	
Almost everybody is a ____ of many different “selves”; we show different faces to different people.	
☐ combination ☐ communication ☐ competition ☐ complication	
Submit	

(a)

Class: 台南一中3年8班	No: 4
Vocabulary Testing	
Item #1	
Almost everybody is a ____ of many different “selves”; we show different faces to different people.	
☐ combination ☐ communication ☐ competition ☐ complication	
Confidence Level: ☐ 1 ☐ 2 ☐ 3	
Submit	

(b)

Figure 8. Administration screen of (a) DCAT version and (b) CWCAT version

The DCAT (Figure 8a) was based on the dichotomous 3PL model, whereas CWCAT (Figure 8b) was based on the GRM. Both CAT versions began with an item of medium difficulty to obtain examinees' initial ability estimated using the maximum information item-selection procedure, and both tests were terminated when a pre-set maximum test length (20 items) was reached or the standard error of estimation (SE) had fallen below .3. After completing both versions of CAT, each participant was asked to predict his/her grade on the approaching English Scholastic Achievement Test (ESAT) as an indicator of self-awareness to his/her English ability.

Results

Experimental results were analyzed to investigate assessments of different levels of knowledge in CWCAT and to examine whether the efficiency and precision of CAT could be improved by dealing with guessing and assessing partial knowledge. The improvement of efficiency meant that fewer items (i.e., the shorter test length) were required to assess examinees with the same degree of accuracy. The precision of CAT was measured in terms of the standard error of estimation, which indicated how the estimated theta reflected the examinees' true ability. A lower SE meant greater precision leading to improved predictive validity. Finally, a predictive validity analysis was conducted to examine whether the CWCAT was a good predictor of examinees' English vocabulary performance. The examinees' English term scores were regarded as external criteria indicating if confidence judgments indeed reflected degrees of knowledge and the estimated ability predicted outcomes.

Assessment of confidence in knowledge

An underlying assumption in this investigation was that discrimination between individual differences in the confidence in knowledge could improve test performance. Thus, analysis of these differences was of prime importance. In CWCAT, examinees' confidence in knowledge regarding vocabulary was expressed by responses falling into one of six possible categories (three confidence levels crossed with correct/incorrect answers). In DCAT, these differences in confidence were ignored and only correct/incorrect responses were considered.

To analyze the response patterns of examinees with different abilities, examinees were classified into three groups (see Table 6 and Figure 9) according to their estimated ability, namely, High (ability > 0.5 SD above the mean), Medium, and Low (ability < 0.5 SD below the mean) groups. The majority of examinees in the High group answered the items with a high confidence; most of their responses were correct. However, most examinees in the Low group had incorrect answers or correct answers with low confidence. The result showed that CWCAT could provide better discrimination among individual differences in examinees' performance by confidence-weighting scoring scheme. Therefore, the assessment of confidence in knowledge might also increase CWCAT precision.

Table 6. Response analysis of CWCAT for three ability groups

Response type	High group (<i>n</i> = 13)		Medium group (<i>n</i> = 34)		Low group (<i>n</i> = 26)	
	Freq.	%	Freq.	%	Freq.	%
1. Incorrect answer with high confidence	32	5.34	33	5.51	52	8.68
2. Incorrect answer with middle confidence	18	3.01	28	4.67	84	14.02
3. Incorrect answer with low confidence	22	3.67	15	2.50	56	9.35
4. Correct answer with low confidence	19	3.17	16	2.67	40	6.68
5. Correct answer with middle confidence	11	1.84	34	5.68	1	0.17
6. Correct answer with high confidence	77	12.85	53	8.85	8	1.34

Number of 73 examinees' responses = 599

Precision and efficiency

Table 7 presents descriptive statistic for ability estimation with normal distribution, time used per item (in seconds), and test length (number of items) in DCAT and CWCAT. The mean ability estimated for CWCAT (.3157) was slightly higher than that for DCAT (.2119). Standard error of estimation for CWCAT (.2827) was lower than that for DCAT (.2966). Mean time per item in CWCAT (24.4717) was marginally longer than that in DCAT (23.8525). As expected, the test length of CWCAT (5.4109) was significantly less than that of DCAT (11.9863). Table 7 also

illustrates the differences between estimated ability (.1038), time used (.6192), and number of items administered (6.5753) between DCAT and CWCAT. Since all participants took both DCAT and CWCAT in the second phase, a paired *t*-test was utilized to determine whether two means were significantly different. For estimated ability, standard error of estimation, and items used, the differences between the two CAT versions, they were statistically significant. However, no statistically significant difference existed among mean time used per item for the two CAT versions.

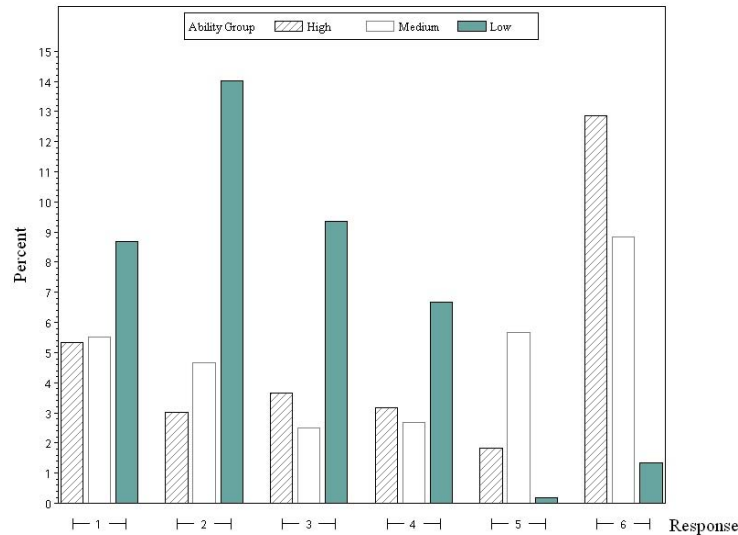


Figure 9. Response distributions of CWCAT for three ability groups

Table 7. Performance statistics of two CAT versions

Variable	Mean	SD of Mean	Means of differences	SD of differences	<i>t</i> value
Ability estimated by CWCAT	.3157	.6228	.1038	.4249	*2.09
Ability estimated by DCAT	.2119	.7199			
SE of CWCAT	.2827	.0018	.0139	.0028	***-5.00
SE of DCAT	.2966	.0023			
Time used per item in CWCAT	24.4717	.9726	.6192	1.0035	.62
Time used per item in DCAT	23.8525	.9472			
Test length of CWCAT	5.4109	.3797	6.5753	.5862	***-11.22
Test length of DCAT	11.9863	.4240			

Number of examinees = 73. Note. * $p < .05$, *** $p < .001$.

Validity and examinees' self-awareness

To investigate if the CWCAT scores truly reflected proficiency of the content, a comparison of validity between the abilities estimated from two CATs was performed. Two kinds of scores in English language (Final_Eng) and English composition (Final_Comp) of the school term were used as indicators. Table 8 presents the statistical distributions of these two factors. The correlations of the two indicators and abilities estimated by two CATs are listed in Table 9.

Table 8. Properties of two scores as criteria for validity

Scores	Mean	Std Dev	Minimum	Maximum
Final_Eng	72.8904	11.0549	36	97
Final_Comp	74.9178	8.2357	55	95

Number of examinees = 73

As seen in Table 9, Pearson correlations between abilities estimated by both CAT and two criteria were all statistically significant. It was found that in both cases, the CWCAT correlations were higher than the DCAT correlations (0.7200 vs. 0.6905 and 0.4013 vs. 0.3622, respectively).

Table 9. Pearson correlations between ability estimated by two CATs and two criteria

	Final_Eng	Final_Comp
Ability estimated by CWCAT	0.7200***	0.4013***
Ability estimated by DCAT	0.6905***	0.3622**

Number of examinees = 73. Note. ** $p < .01$, *** $p < .001$

An additional statistical method, based on examinees' self-estimated ESAT grade point after the administration of both versions of the test in experiment phase 2, was used to examine the correlation between students' English abilities and their self-awareness regarding English ability. As a practical measurement of the students' self-awareness, we defined the self-awareness index by

$$SI = 15 - |SEGP - ESAT_Grade|, \quad (4)$$

where SEGP was the examinee's self-estimated ESAT grade point, and ESAT_Grade was the true ESAT grade he/she received.

In equation 4, the value of SI was translated into 15 scales as the SEGP and ESAT_Grade did. The results indicated that the higher the SI, the more aware an examinee was of his/her English ability. Thirty-eight students gave their estimation for their grades on the approaching ESAT. Gamma correlation was used to determine the degree of relationship between SI and ability. The mean gamma correlation between SI and ability estimated from CWCAT was 0.3936 (ASE = 0.1062), which was significantly greater than zero. In the DCAT condition, the SI and ability gamma correlation was 0.0922 (ASE = 0.1320), which was not significantly different from zero. This result indicated that there exists correlation between students' ability in CWCAT and their self-awareness of English ability.

Conclusion

From the perspective of unidimensionality, the factor analysis result implied that the DCAT was not measuring something different from the CWCAT. As expected, examinee performance increased significantly for CWCAT. This substantial performance increased, as indicated by CWCAT results, could be attributed to the assessment of confidence in knowledge examinees possessed. Since CWCAT measured examinee knowledge by confidence-weighting, individual differences in abilities could be considered as differences in confidence, which was not assessed by the DCAT. Consequently, examinees might score higher on the CWCAT than DCAT based on their different degrees of knowledge. With a possible six-point scale for each item rather than the dichotomous conventional DCAT, CWCAT increased test precision, which was indicated by the low standard error of estimation and higher test information. The results were consistent with the findings of Omirin (2007).

The efficiency of CWCAT was assessed by comparing time used per item, and test length with those of conventional DCAT. As expected, CWCAT required fewer items to estimate examinees' ability. Though the additional time (roughly six seconds) required marking each confidence option was not a drawback of CWCAT, the shorter test length of CWCAT obviously reduced total test time needed. The meaning of confidence assessment in CWCAT could be further examined in the context of validity. According to the analysis result of validity, the ability estimated from CWCAT was more equivalent with the examinee's mastery of English vocabulary than the results from DCAT.

Finally, it should be emphasized that the results were based only on the study of senior high students taking the English vocabulary CAT. The results may differ when examinees of a different age are tested or when other domains (e.g., math) are assessed. Another possible limitation of this study was that all participants were male. Though previous research (Stankov & Crawford, 1997; Jonsson & Allwood, 2003; Gardner-Medwin & Gahan, 2003) indicated there was no gender difference within the confidence-based test, the findings and conclusions still must be viewed with caution.

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Cultural Differences in Online Learning: International Student Perceptions

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ABSTRACT

This article reports the findings of a case study that investigated the perceptions of international students regarding the impact of cultural differences on their learning experiences in an online MBA program. The study also revealed that online instructors need to design courses in such a way as to remove potential cultural barriers, including language, communication tool use, plagiarism, time zone differences and a lack of multicultural content, which may affect international students' learning performances. The study indicates that a culturally inclusive learning environment needs to consider diversity in course design in order to ensure full participation by international students.

Keywords

Cultural differences, Online learning, Instruction design, Case-based learning, Diversity

Introduction

The advancement of computer-mediated communication and Internet technology has shaped the landscape of higher education and allowed universities and educational institutes to expand their global outreach through transnational collaboration with multiple institutions. Developing countries in Asia, including China and India, have been the most attractive destinations for offering online degrees because of their rapid rise in economic development and enormous demands for higher education access.

Although modern communication technologies have afforded increasing flexibility that can be used to conduct transnational course design and delivery, concerns exist regarding the social and cultural dimensions of task design, the cultural adaptability of the learning materials and the re-engineering or transformation of courses (Collis, 1999; McLoughlin, & Oliver, 2000).

Existing research suggests that cultural differences can have a negative effect on students' participation in online courses. Shattuck (2005) observed that international online learners felt a "sense of marginalization, or, sometimes even alienation" from the American learner group even in a highly interactive communication learning environment (p. 186). Reeder, Macfadyen and Chase (2004) found that different cultural communication patterns increased miscommunication, and that the greater the perception of cultural differences between the participants in an activity, the greater the incidents of miscommunication.

Interestingly, other studies have indicated that cultural differences may be mitigated in online education through the "external identities" (Walker-Fernandez, 1999) or "cultural negotiation" (Goodfellow & Lamy, 2009) of the online participants.

In general, the growth of cultural concerns in regard to online learning has not been accompanied by a growing number of studies in the field. Although a handful of researchers have begun to explore cultural issues in online education, very few formal studies have been conducted and the results of these studies have been inconclusive. As the Web-based learning market becomes increasingly global, it is important for online education providers to have an understanding of the different educational values and cultural expectations of the participants as well as the impact of those differences on learning in order to maintain a competitive advantage in today's e-learning world. As such, there is a need to develop new theories and conduct empirical studies in order to provide guidance for the successful design and delivery of cross-cultural online courses.

The purpose of this case study is to examine the perceptions of international students in an online MBA program regarding their transnational learning experiences. Given the limited research in the cross-cultural design of online

education, such a study is important in order to identify potential cultural barriers that may affect the performance and satisfaction of the international student population. Three questions were addressed in this study:

- Do international students perceive cultural differences in their online learning courses?
- How do the international students perceive the impact of cultural difference on their learning?
- What features do international students prefer in the design and delivery of an engaging global course?

Literature

Hofstede's Cultural Dimensions

One of most widely used frameworks for studying cross-cultural communications is based on work conducted by Hofstede (1986). Hofstede developed a four-dimensional model of cultural differences, which can be used to characterize cultural behaviors that originate from different societies. A detailed description of each dimension is displayed in Table 1.

He further stated that many perplexities could arise when teachers and students come from different cultures. These perplexities can occur due to differences in the social positions of teachers and students in the two societies, relevance of the curriculum within each of the societies, profiles of cognitive abilities between the populations of the two societies and expected teacher/student and student/student interactions (Hofstede, 1986).

Table 1. Hofstede's 4-dimension culture model

Dimensions	Descriptions
Power Distance (PD)	The degree to which people accept the unequal distribution of power and wealth in a society. In countries with high PD, individuals with high social status exert great power and influence (Gunawardena et al., 2001).
Individualism-collectivism	The tendency of members of a society to act as individuals or members of groups, and to which a culture values individual versus collective achievement or well-being (Mercado, Parboteeah, & Zhao, 2004).
Uncertainty Avoidance (UA)	The degree to which the individuals of a culture feel threatened by uncertain or unknown situations. Individuals from a culture with high UA are uneasy with unstructured ideas and situations. (Hofstede, 1986).
Masculinity-femininity	The degree to which the society prefers distinct gender roles. (Hofstede, 1986; Mercado, Parboteeah, & Zhao, 2004).

According to Hofstede's research, both China and India rank very high on the PD index, while the US has a very low PD. In addition, the U.S. exhibits very high individualism when compared to China.

Despite the popularity of Hofstede's model, his work has been challenged with strong criticism. In addition to challenging the external validity of his work (Shattuck, 2005), other researchers have labeled his work as the "essentialist" models of culture emphasizing fixity of identity over the reality of identity fluidity (Goodfellow & Hewling, 2005, p355). In spite of this criticism, Hofstede's work has proven to be a valid framework for analyzing cultural differences in teaching and learning (Wang, 2007). Therefore, this framework was considered useful when interpreting the findings of the present study.

Design Culturally Inclusive Technology-Mediated Learning Environments

Collis (1999) and Henderson (1996) proposed the "flexible" approach, which suggests that the courses should be flexible enough to cater to diverse cultural perspectives, rather than simply containing pre-determined content. The central notion of the flexible approach is that the key aspects of course design should be contingent on the cultural dimension of the course, and should be flexible enough to allow the students and instructors to choose their own learning and teaching styles as the course progresses.

Reeve (1992) developed a model which consists of 14 pedagogical dimensions of interactive learning. Each of these

dimensions represents a continuum from one extreme to the other (See Figure 1). This model is used in order to evaluate where the instructional practices in a culture are located on a continuum with contrasting values at both ends. However, Reeve's model was criticized for being culturally biased toward the right end of the continuum, meaning that his critics felt that he was assuming that the right end of the continuum was the superior way of learning (Henderson, 1996).

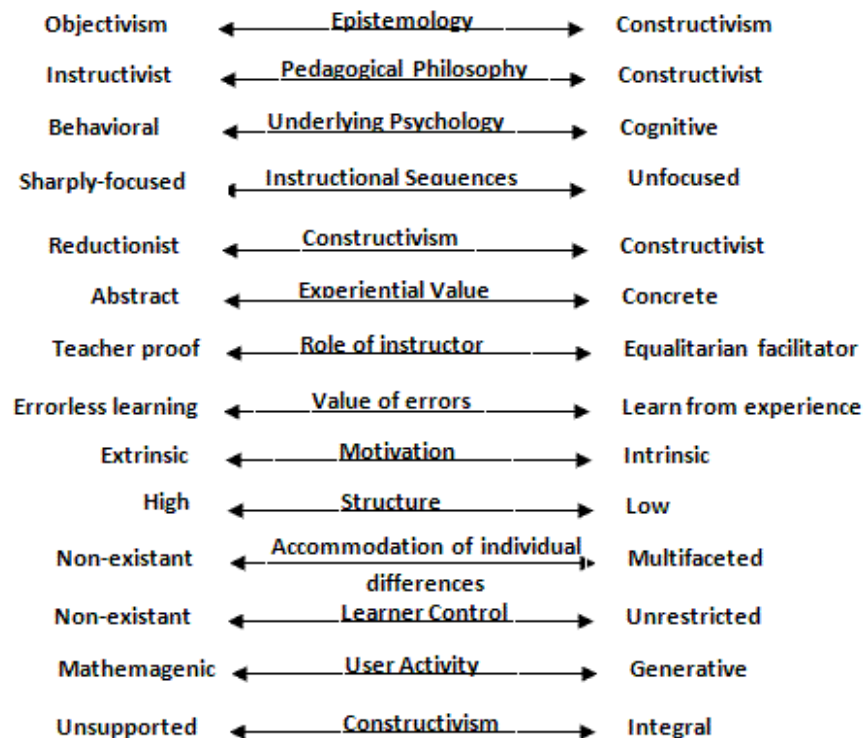


Figure 1. Reeve's 14 Dimensions of Interactive Learning (Reeves, 1992)

In order to overcome the limitations of the existing paradigms, Henderson's (1996) multiple cultural models promote the idea of culture profiling and integrating multiple cultural perspectives into instructional design. He advocates that courses be designed in order to allow variability and flexibility in learning so that the courses can reflect the multicultural realities of society and the multiple ways of teaching and learning. This model requires a deep appreciation of culturally different pedagogical objectives and philosophies as well as the design of multiple learning activities and assessment strategies in order to accommodate cultural diversity (McLoughlin, & Oliver, 2000).

Empirical Research Related to Eastern Culture in Online Learning

Numerous studies that have examined the cultural differences between Western and Eastern education have provided a consistent picture that describes Eastern education as a group-based, teacher-dominated, centrally organized pedagogical culture with examinations as the essential way to define performance and compete for higher social status (Zhang, 2007). In Eastern education, teachers have absolute authority and the students are not encouraged to question or challenge a teacher's knowledge (Biggs & Watkins, 1996). On the other hand, in Western education, to challenge a teacher or tutor is seen as part of the self-development process as dialogue and interaction are encouraged in the learning process (Robinson, 1999).

A number of studies, which have investigated the differences between Eastern and Western cultures in online education, mostly echo the differences found in traditional settings (Liang & McQueen, 1999; Thompson & Ku, 2005). Chinese participants were found to be less critical and opinionated in online discussions than their U.S. peers (Thompson & Ku, 2005) and unwilling to post messages that conflict with the instructor's view (Zhao & McDougall, 2008). Liang and McQueen (1999) observed that the Eastern students preferred to have more direction from their

teachers, even in the interactive online learning environment. In contrast, most of the Western students desired more interactions among the students.

The tendencies of collectivism, uncertainty avoidance and the high power distance of Eastern cultures have been found in online learning environments (Kim & Bonk, 2002; Ku & Lohr, 2003, Wang, 2007;). Bonk and Kim's (2007) study shows the dominance of social interactions among Korean students at the outset of their online collaboration, which demonstrates their cultural inclination toward emphasizing relationships over tasks.

Ku and Lohr (2003) found that the Asian students felt uncomfortable with the nonlinear nature of their online courses, which the researchers attributed to the uncertainty avoidance dimension of Asian cultures. Ku and Lohr's study also found that Chinese and Taiwanese students liked the idea of building an online community among their peers and instructors, which reflects the collectivist-femininity attributes of their cultures.

Language, which mediates an individual's ways of thinking and speaking, is an important cross-cultural variable that is often neglected in existing cultural frameworks. Inadequate language competencies tend to magnify other cultural problems when attempting to complete a Web-based course (Ku & Lohr, 2003). Language barriers for non-native speakers tend to detract from equal participation in computer conferences (Gunawardena et al., 2002). Ku and Lohr's (2003) study indicated that language barriers can be alleviated in an asynchronous online learning environment with the use of written communication as the dominant form of communication.

Methodology

This study was designed as an exploratory study aimed at understanding the emerging cross-cultural issues in transnational online MBA courses. The case study approach is considered appropriate for such exploratory research because it is considered to be the best in regard to explaining "how" and "why" issues in a complex contemporary social phenomenon (Yin, 2002).

Context

The field setting selected was an online MBA program at an accredited business school at a large Midwestern university. This program is designed for professionals who wish to continue their employment while earning their MBA. With the increased competitive domestic MBA market, the program has taken initiatives to explore partnerships with global companies in order to enroll increasing numbers of international students.

Except for the courses offered during the required on-campus visit, most courses were delivered entirely online through the ANGEL course management system.. At the time of the study, approximately half of the courses used CBL and four-fifths used virtual teams. Online asynchronous discussions were used in four-fifths of the courses as well. Email communications, announcements and participation in the asynchronous or synchronous discussions were the methods most often used by the online instructors to communicate with the students.

Data Sources

International students from three global companies were solicited for interviews through email invitations. Table 2 summarizes the profiles of the three companies and the demographics of the interviews.

One-on-one Interviews

Seventeen international students from Nova Engine were solicited to participate in the study. Seven students responded to our invitations and agreed to be interviewed individually. The interviews were conducted via phone, email or face-to-face during the in-residence week as based on the students' preferences. Fifteen semi-structured questions were asked about their perceptions of cultural issues regarding interactions with peers and instructors, instructional design, technology use and globalization of online courses. Each phone or face-to-face interview took approximately 45 – 75 minutes and was recorded with the permission of the interviewee.

Table 2. Profiles of the Companies and Demographics of the Interviewees

Nova Engine	Eastern Container	Xiangjiang Steel Limited
A US company that provides services in design, manufacture and distribution of service engines and related technologies.	Chinese company dedicated to the manufacture and supply of containers, trailers, tank equipment and airport equipment. Has over 100 subsidiaries in China and worldwide.	State-owned Chinese iron making company, which is looking to globalize.
Seven international students (four from India, two from China and one from Russia) were interviewed individually.	Five Chinese students attended the focus group interview.	Seven Chinese students attended the focus group interview.
The students did not have experiences in taking online courses in their home countries.	The students did not have any formal online learning experiences before studying within the MBA program.	
Many students had experiences working with work colleagues from other cultures and/or exposure to other cultures.	Most of the students had experiences communicating with individuals from other cultures through their work.	

Focus Group Interviews

Two focus group interviews were conducted face-to-face with five students from Eastern Container and seven students from Xiangjiang Steel. These interviews used an open, free-flowing interview format. The students were asked to describe their learning experiences in the two-week in-residence program and give their perspectives on the impact of culture-related issues on their learning in their courses. Each interview lasted two to three hours. The interviews were recorded with the consent of each group.

Data Analysis

Although this study does not use a grounded theory approach, Strauss and Corbin's constant comparative method (1990) was used in order to triangulate the data from the different interview transcripts. According to Patton (1990), Strauss and Corbin's constant comparison method was appropriate to be used in the analysis of the different question responses because we cross-case grouped the answers. We followed the below steps when analyzing the interview data.

- Each researcher reviewed the transcripts carefully and made notes of the important patterns, themes and categories that emerged from the data.
- The reviewed transcripts were later analyzed again to compare with previous summaries of key categories and themes. Similar themes or categories were grouped together. The frequencies of each theme or category were marked.
- After each researcher completed their independent analysis, three researchers validated and discussed their coding decisions until a common set of codes based on all of the transcripts was determined.

Findings

The emerging cultural difference themes are summarized in Table 3.

Assessment

In general, the assessment methods used in the courses were perceived by the interviewees as fair, clear and easy to understand. The students noticed the different assessment styles used in the U.S. as compared to their home countries. For example, a student from Russia mentioned that Russia is an exam-oriented culture and, therefore, the students' grades are based mainly on the final exam grade. He noted that in the U.S., the assessment was more

ongoing and process-oriented and that the focus was to sustain the students' continuous involvement. He stated that "in [the program] the instructors assess not only the final exam/test results or assignment grades, but also, the level of the student's participation in discussions. Even if you have good results on the final test, you may get a low final grade if you did not interact enough with your peers during the course." When comparing the assessment methods used in the program with those typically used in schools in China, a few of the Chinese students felt that the assessment methods used in the U.S. are application-oriented as they focus on helping the students to understand and apply the theories while memorization is often the basis of assessment in their schools in China. However, the students still preferred multiple strategies to be used in order to improve both the memorization and application of the theories

Table 3. Summary of Cultural Themes

Dimensions	Cultural Differences	Suggestions for Course Design
Assessment	Exam-oriented vs. process-oriented; Memorization vs. application	Multiple assessment strategies; Structured and flexible assignment schedule
Instruction/Interaction	Lecture vs. conversation; Structured vs. less structured; Deductive vs. inductive (case-based learning)	Incorporate features that accommodate different cultural pedagogy
Asynchronous /Synchronous Communication	Lack of visual cues caused communication barriers in asynchronous communication; Scheduling issue for cross-cultural collaboration in synchronous communication; Time zone differences	Balanced use of asynchronous and synchronous communication
Collaboration	Collectivism and masculinity vs. individualism and femininity; Culture differences visible, but did not negatively affect collaboration	Appreciate cultural differences
Case Learning	Lack of global cases; Lack of a relationship between U.S. case discussion and analysis and local issues of international students; Lack of international experience in regard to the online instructors	Balance the use of local and global cases; Provide more context for culturally specific examples or cases
Academic Conduct	Discrepancies between U.S. and other countries' rules of academic conduct	More education and understanding, rather than pure punishment
Language	Language barriers in reading, writing and communication	More planning and preparation; More audio/visual aids

A few Chinese students noted that a well-defined and predictable course assessment schedule with regularly occurring assessment activities (e.g. weekly discussions or quizzes) was important to sustaining their continuous engagement with the course amid their busy professional lives. However, the students also hoped that future instructors could be more flexible and considerate of the students' cultural contexts in scheduling the assessment activities. A few of the Chinese students mentioned that in Chinese companies, employees sometimes were required to work after regular work hours without much or any notice. The interviewees mentioned that they would try their best to follow the course schedule, but hoped that the professors would understand when such situations occurred, and be flexible.

Instruction and Interaction

The students noted more student involvement in regard to the interactions with the instructors in the U.S. courses compared to those in their home countries. The students mentioned that the major difference between Eastern education and the U.S. education is that U.S. instructors require the students to interact on a regular basis with the peers during the course. Such a teaching method differs from that used in China, Russia and India where the dominant method of teaching is a one-way lecture in which the professor teaches and the students take notes. After the lecture, the students memorize the materials in order to pass the exams at the end of the semester.

The response from the students was positive in regard to the level of interaction between the instructors and students in regard to the more equalized roles of the instructors compared to those in the students' home countries. For example, one student from India noted that "the students talked as much as the instructors, giving their opinions and sharing the experience" during the class discussion.

The Chinese students noted that differences existed in regard to the structure and sequence of the instruction when the U.S. instruction method was compared to that used in China. For example, one Chinese student commented on the highly structured nature of the course content. "In China, the structures are normally clearer, with clear logic, i.e. first is a general briefing, then the content is arranged from the easiest to the hardest, or most important to the least important, etc. While the [program name] courses are more case-based, the cases are not closely linked with the textbooks as [they are] in China."

The conversation style of the online instruction and case-based learning added a level of difficulty to the learning for some of the Chinese students. They acknowledged that the interactions and cases were good ways of teaching, especially when an emphasis was placed on the application of the knowledge skills, but were also concerned with the information overload in the online discussions. For example, one Chinese student stated that, "[i]n China, we are accustomed to the instructors' ways of recapping key points for us. Here, the instructors talk about a lot of things. They should let us know the most important things that we need to grasp in order to understand American laws." She hoped that a combination of both approaches would be used in her future courses.

Synchronous/Asynchronous Communications and Time Zone Differences

The students perceived that advantages and disadvantages existed in regard to asynchronous and synchronous communications in cross-cultural learning environments. On one hand, the students mentioned that one advantage of an asynchronous discussion is that it is "clear, free of the misunderstandings caused by accents and the impact of the time difference is less." However, the delayed text-based communication of an asynchronous discussion is unable to convey the nuances of human interaction and, therefore, the students felt that it was difficult for them to figure out the intentions of the other students during group work due to their different working styles and cultures.

The students felt that the synchronous communications helped them to "get to know each other much better thanks to the live interaction." Nevertheless, this type of communication also presented challenges, especially in scheduling a synchronous conference as the students were spread around the globe in different time zones.

The students mentioned that time zone differences had an impact on their timely participation in the asynchronous discussion forums, as this factor was not usually considered in the course design of most of the courses. In the program, some instructors would post questions requesting the students' answers in a timely manner, and would request that the students not repeat points already made in previous posts. One student noted that "[s]ometimes it would be very difficult to find a question to answer once I woke up in the morning finding that every single question had been answered."

A good balance of both synchronous and asynchronous discussions was regarded as beneficial for international online courses. Many of the students appreciated the instructors' uses of a combination of both types of communication modes in order to balance the communication weaknesses of each type. For example, one student commented that "[in that course], the instructors not only used discussion forums, but also used Breezelive for asking student questions – good balance to have international students in different regions (in a narrow window of time) engaged in the courses."

Collaboration

The students noted different culture patterns in online collaboration and communication but indicated that these differences did not affect their learning in a negative way. For example, one Indian student commented on the independent nature of the U.S. students and the group orientation of the Chinese students, "I would not say the cultural differences affect [the collaboration] in a negative way. Cultural differences are certainly there. Culturally, we like to work more in teams, but the students in the U.S. tend to be more independent. We hesitate a bit in saying

‘No’ to anything even though we know it is of a discomfort to us, but most foreign [the U.S.] students do not [hesitate in saying ‘no’]. We are more sensitive and care for others.”

Another Chinese student mentioned the competitive nature of the U.S. students in comparison to the Chinese students’ politeness which focused on creating harmonious relationships. She commented that the “cultural difference is visible. The U.S. folks are more active, normally hold very strong opinions and can hardly be persuaded. For example, if we have both U.S. and Chinese teammates doing one assignment, the U.S. folks will normally take the lead, set-up the framework and, then, finalize the whole assignment. The Chinese students will be more polite, and may have less of a contribution because of their personalities.”

The students appreciated the diversity brought by the cross-cultural differences. As one Indian student mentioned, “I personally feel that the cross-cultural team helps in bringing a good perspective to the teamwork. The diversity definitely helps, especially in bringing in the experiences that people have in different countries and geographic regions.”

Cases

As a major instructional strategy, many students pointed out the need for more diversified cases in the courses. For example, one student commented that “[the courses need] more global thinking, because they focus on U.S. examples... Sometimes, you think that this case is difficult to apply to my country. They have to think about what is happening in other countries.”

Many students commended one particular course that balanced the use of local and global cases. When asked whether they could give an example of a global course, a student noted, “I would like to suggest Law, as the course structure is very nice and introduces the international students the U.S. legal systems, while comparing [the U.S. legal systems] to different kinds of legal systems worldwide.” The students also noted that such a balance was not only beneficial to the international students, but, also, provided opportunities for the U.S. students to better understand the cultures of other countries.

Several of the Chinese students mentioned that they would like to see more close relationships between the case analyses and practical issues faced by their companies. They stated that they felt that the cases used in the course work were too distant from the reality of the Chinese work environment.

Academic Conduct

Several international students have expressed frustration at being severely punished for their inappropriate citations of others’ work according to the academic rules of the U.S. universities. They felt that the instructors lacked an understanding of the culture differences in regard to educational practices. For example, one student commented on his experiences:

I had not put the reference from where I had taken this information. When the professor pointed [it] out, I immediately expressed my apology for my ignorance and committed to follow it in future ... But I was reprimanded for academic dishonesty, which cost me to lose marks, and finally ended up in a lower grade. I personally feel [that] this would have been treated in a different way in India – probably a warning for [a] future reprimand.

Language Issues

The students reported that language barriers appeared to be the biggest concern for the Chinese students. Although, each student passed the standard graduate admission examinations (i.e., TOEFL, GMAT), the majority of the students still had severe limitations in regard to the English language that hindered them from having the desired level of understanding of the course content, and effective communication of their opinions in the online discussions. For example, one student commented that

For Business Law, we may have had a feeling about it after reading the chapters, but could not express our arguments or perspectives. The law itself was tough to understand. Being able to express it with an in-depth view [was] even more difficult for us.

The students noted that they had to triple their time spent reading when the information was in English rather than in Chinese. To help ease the language barriers, the students suggested that the professors give the course schedule and materials before the start of the course or lessons, so that they can better prepare for the course. The students also appreciated those professors who made efforts in providing audio and video aids, which not only helped the students to understand the course content, but also allowed them to review the content repeatedly in order to overcome the language barriers.

Discussion

Key Cultural Issues

As reflected in the interviews, the Eastern students exhibited modest, face-saving personalities in the group work and preferences for group work, whereas the U.S. students appeared to be independent, assertive and confident with a competitive attitude that dominated the group interaction process. According to Hofstede's study, these findings reflect the collectivism and femininity attributes of Eastern cultures and the individualism and masculinity attributes of Western cultures.

An interesting theme, however, that emerged from the study is that almost all of the students agreed that the cultural differences, which originated from ethnicity, existed, but did not negatively affect their communication or collaboration in learning. The participants seemed ready to accept the differences and looked for the positive aspects that cultural differences bring. There are two possible reasons for these positive perceptions. First, developing countries such as China and India have become increasingly open to new ideas that originated globally. In addition, these countries have also experienced a globalization of their economies and, therefore, cultural diversity has become pervasive in every aspect of their cultures.

Second, the students mainly came from three large global companies that have engaged in or are ready to engage in international business. The students' previous experiences in working with international customers contributed to the heightened level of cultural sensitivity.

The study revealed the cultural differences in regard to instruction styles. The students noted that the U.S. instruction style leaned toward a learner-centered, process-oriented style with a focus on interaction and participation, whereas the Eastern style tended to be lecture-centered with an emphasis on exams. The students also noted that the sequence of instruction was less structured and more inductive in the U.S. (i.e., teaching from examples to general principles), while Eastern education was highly structured and more deductive in its instruction approach (i.e., teaching from general principles to examples). These patterns of cultural differences were consistent with previous discussions regarding the cultural differences between Eastern and Western educational systems (Robinson, 1999; Zhang, 2007).

Although the students were positive in regard to their transition to a more interactive learning style, some of the students felt uncomfortable with the case-based learning method due to the lack of structured instruction content and the absence of strictly guided instruction. These findings were consistent with Hofstede's (1984) results, which showed that individuals in Eastern Asian countries tended to have high uncertainty avoidance and were uneasy with unstructured ideas and situations.

Although the students appreciated the more equalized role of the online instructors in the online courses, their strong preferences for highly structured textbooks and a stronger presence by the online instructor in the discussion forums indicated the authoritative image that they hold of instructors. In China, a textbook represents the finest form of knowledge developed by authorized experts and are the absolute sources for finding the correct answers. According to Hofstede (1986), the heavy reliance on instructors and textbooks are indicators of the high power distance dimension of Asian cultures.

This study shows that language is still a dominant barrier for students who have English as a Second Language (ESL), especially for Chinese students who have rarely been exposed to an English learning environment. This study points out the need for international students to improve their English reading, listening and writing skills beyond the basic TOFEL and GRE requirements before coming to the U.S. in order to be able to complete a smooth transition from their native environment to an intensive English language environment. On the other hand, special assistance or considerations need to be given in online courses attended by international students whose first language is not English, so as to ensure equal student participation.

The issues concerning plagiarism resulted from the students' lack of knowledge of local academic cultures in Western universities. Hayes and Intorna (2005) stated a need for the instructors to develop a broader cultural understanding of how international students were taught and assessed, before imposing rigid categories of judgment upon them that may further alienate them in an already foreign environment. Instructors also need to manage academic misconduct issues by making clear their expectations for the students' academic conduct, explaining how these expectations might differ from those utilized in the students' own countries and providing resources for the students to utilize in order meet these expectations. A culturally sensitive instructor should also give the students opportunities to correct their behaviors when they make their first mistakes rather than harshly punish their course grades as was found to be the case in this study.

Case-based learning plays an important role in online MBA teaching. Online instructors often utilize cases from their traditional counterpart courses in their online courses. Most traditional cases are developed in accordance with the U.S. business context. Therefore, it is not a surprise to find that the international students feel a lack of a connection to the cases used in the program analyzed within this study.

Case development is a complicated process. It might be difficult for online instructors to develop new cases to meet the needs of the international students. However, the instructors can devise innovative ways to increase the international components within their case studies. For example, the instructors can use the sources available on the Internet to design original cases for students to analyze. Students can also be asked to develop cases based on their personal cultural experiences and then share with their peers.

This study raises issues concerning an instructor's cultural competency. As reflected in the interviews, instructors are varied in their sensitivity to cultural issues. A few of the instructors integrated cross-cultural content into their courses. However, many instructors appeared not to have considered cultural dimensions when designing their online courses.

Diversity as a Preference to Cross-cultural Design

The students' preferences for diversity in the assessment strategies, uses of technologies and selection of case materials are aligned with Henderson's (1996) ideas of integrating multiple ways of teaching and learning that "require a global perspective and sensitivity to cultural differences and the numerous ways in which culture influences learning" (McLoughlin, & Oliver, 2000, p. 58). As demonstrated in this study, a lack of diversity in instructional design may put international students at a disadvantage and affect their equal participation in online learning. Students prefer to maintain a sense of continuity by preserving the components of their own culture of learning, but also want to engage in a new cultural way of learning and thinking as part of their goal of learning in an international course. Diversity is the best solution to respecting culturally different ways of learning and ensuring equity among the students participating in a learning community.

McLoughlin and Oliver (2000) argued that a tension may exist between the need to ensure access to learning for a diverse student population and localize instruction design in order to accommodate the learners' particular cultures, cognitive styles and preferences. For example, in this study, the Chinese students requested that the instruction cases be tailored to practical issues in China. Such localization may be accomplished in a course that is specifically designed for Chinese students, but would be difficult to implement in a group with multiple nationalities, without comprising the interests of the students from other nations. A strategy that asks the students to share personal cases from their cultural contexts may be a better way to ensure equal participation in a transnational course. Therefore, in order to balance diversity and localization, instructional designers need to consider both the micro and macro levels of cultural learning and find ways to integrate multiple ways of learning in order to foster intercultural subjectivity (McLoughlin & Oliver, 2000).

Conclusions

The purpose of this study was to identify the emerging issues in cross-cultural online learning environments. In regard to online collaboration, it is encouraging to know that cultural differences which originate from different national cultures do not negatively affect the students' online experiences, but, instead, are seen as a potential factor contributing to more culturally rich learning experiences. Other issues identified in this study, such as language, communication tool use, plagiarism, time zone differences and a lack of diversified cases, may affect a student's learning performance if the instructors do not take into consideration the needs of the international students. This study indicates that a culturally inclusive learning environment needs to consider diversity in course design in order to ensure full participation of the international students.

Implications for Practice

First, the cultural sensitivity of online instructors needs to be addressed in an online MBA program if the program takes the initiative to expand its international boundaries (i.e., intends to build its international student pool). Appropriate cross-cultural training support should be provided at the program level in order to develop the online instructors' cultural competencies.

Second, the findings of this study indicate that online educators need to consider providing scaffolding to the international students in order to support their international learning adventure and reduce cultural language barriers. An initial student orientation to the U.S. culture and academic rules of conduct would be helpful in enhancing the cultural understanding of the international students.

A well-balanced use of diversified activities can alleviate the language barriers as well as allow the students opportunities to improve their English proficiency in a variety of ways. The use of audio and visual aids can be of significant help to international students.

Third, the findings of this study indicate that fostering the principles of flexibility and variability in online courses is essential for a transnational course to effectively address the diversified needs of its international audience. Online instructors can conduct a quick learner analysis in order to get an understanding of the students' expectations and cultural backgrounds so that they may adjust the diversity of the course to address the international audience accordingly.

In summary, as a program-level case study based on a small sample size of participants from several specific ethnic origins, the generalizations of the results in this study should be exercised with caution. However, we believe that the analysis of the emerging cultural issues contributes to the limited extant knowledge of the cross-cultural design of online courses. In addition, the recommendations raised in this study provide valuable information and insights that can be used to assist distance educators and policy makers of similar online MBA programs in designing, practicing, and making policies for students' successful global online learning experiences.

This study opens numerous new avenues for future research. First, the present study can be further extended by including international students from multiple disciplines. Second, each of the emerging cultural factors identified in the study is worthy of a more in-depth investigation. The impact of academic integrity issues on international students' learning experiences is also an important topic of research. The design and development of cases that are culturally inclusive for global learning courses represent a significant area, which contributes to practices of cross-cultural learning.

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Examining the Roles of Blended Learning Approaches in Computer-Supported Collaborative Learning (CSCL) Environments: A Delphi Study

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ABSTRACT

In this study, a Delphi method was used to identify and predict the roles of blended learning approaches in computer-supported collaborative learning (CSCL) environments. The Delphi panel consisted of experts in online learning from different geographic regions of the world. This study discusses findings related to (a) pros and cons of blended learning approaches in CSCL; (b) blended learning for collaboration in various contexts including the narrative accounts of blended learning approaches in CSCL given by the Delphi panelist; and (c) the future of blended learning in CSCL, via three-phases of online survey questions. Implications for design issues and future research into blended learning and CSCL are also included.

Keywords

Blended learning, Computer-supported collaborative learning, e-learning, Delphi study

Introduction

During the past decade, there has been a significant movement toward online and blended formats of learning. This is apparent across educational sectors including K-12 schools as well as adult learning in higher education, the military, government settings, and corporate training environments. One large-scale survey in 2006 showed this increasing acceptance of e-learning practices in higher education. In that study, approximately twenty percent of US higher education students had taken at least one online course. At the same time, however, people across educational sectors have increasingly expressed concerns about the quality and cost-effectiveness of e-learning solutions (Seaman, 2009). For instance, many students who take online courses never complete them (Tyler-Smith, 2006). Faculty members also face new challenges related to the increasing time for course preparation and interaction with students.

Still, many educators suggest that there are positive impacts of e-learning related to changes in pedagogical practices. Unfortunately, despite the increasing adoption of learning technologies, pedagogical changes in online learning have been slow. In fact, many online courses focus on content delivery and tutorial-based instruction. Simply turning classroom lectures into online learning formats does not necessarily provide students with the opportunities for rich interactions arising from engagement in activities that make learning experiences meaningful. Instead, it is important to have deep understandings of *how people learn* as well as *what new technology can provide* for the successful design of technology-integrated learning environments (Bransford, Brown, & Cocking, 2002).

With some concerns and associated dissatisfactions with e-learning approaches, people have searched for other instructional delivery solutions. The term *blended learning*, combining face-to-face and online learning, has been discussed as a promising alternative to traditional instruction and training. While there is a steady movement toward blended learning approaches in education and training sectors, there are myriad questions that need to be examined before fully accepting any promises suggested by blended learning experts. For instance, is blended learning really an effective and efficient approach? What are potential disadvantages of blended learning? How would blended learning change our learning environments? These and other questions must be asked. Towards this end, this study examines the roles of blended learning in higher education. Specifically, this study focuses on blended learning approaches in computer supported collaborative learning (CSCL) environments.

Blended Learning: From Delivery Technology to Learning Technology

Generally, blended learning is defined as learning systems combining face-to-face instruction with technology-mediated instruction (Bonk & Graham, 2006). While there is no doubt that blended learning approaches are increasingly implemented in several learning settings, the emphasis in blended learning so far has been mostly

related to the delivery aspects of technology which concerns access to instruction and information. In fact, relatively little attention has been paid to learning design technology, selecting appropriate modes of interaction, and designing activities based on robust learning theories. Despite the difficulty of choosing the right combination of interaction modes, most companies and universities tend to select instructional delivery methods based on a single criterion—availability.

What is promising, however, in the current trends of blended learning research is the shift of focus from delivery-centered technology to learning technology coupled with pedagogical considerations. The frameworks suggested by Osguthorpe and Graham (2003) and Graham (2006) are particularly useful demonstrating the application of pedagogical approaches in deciding what is blended and what the goals of blending are. Beyond the simple combination of face-to-face and online instruction, they argue that there are different types and levels of mixing in blended learning: activity level blending, course-level blending, and program-level blending. At the activity and course levels, blended learning can be used to design learning activities, interactions among students, and interactions between or with instructors. Program-level blends tend to be more administratively than pedagogically driven. It is further suggested that blended learning environments vary widely according to the following goals: pedagogical richness, access to knowledge, social interaction, personal agency, cost effectiveness, and ease of revision. Some recent research appears to emphasize the complex and dynamic nature of blending learning experiences situated in contexts of learning, learners, and activities. For example, Boyle (2005) examined how to improve a blended learning course from pedagogical design perspectives, and argued that “blended courses that are developed to solve different problems should take different forms, as it is the nature of the problem that determines the form of the blend” (p.222).

Computer-Supported Collaborative Learning: Face-to-Face, Online, or Both?

Koschmann (2002) defines CSCL as “a field centrally concerned with meaning and practices of *meaning-making* in the context of *joint activity* and the ways in which these practices are mediated through designed artifacts” (p.18, emphasis added). Two critical elements in CSCL as the name suggests are collaborative learning and computer-support. In addition, Koschmann suggests that CSCL is concerned with collaborative-meaning making processes that go beyond information sharing among multiple people. Technology such as computers can play a critical role to support or mediate the interactive process of collaborative meaning making in the context of joint activities involving multiple users and multiple modes of interaction. In several contexts, CSCL means blended learning experiences through the mediation of technology rather than being completely online or face-to-face (e.g., Clouder et al., 2006; Koschmann et al., 2005; Michinov & Michinov, 2008; Suthers, 2006).

An important question in blended learning when it is situated in CSCL environments, then, is how to coordinate the two modes of communication (i.e., face-to-face and online) to better support collaboration. In other words, it is important to bring the continuity of learning experiences across multiple time and space to create more holistic and integrated learning experiences. For instance, Ellis, Goodyear, Prosser and O’Hara (2006) argue that blending face-to-face and online discussion has become an important part of the learning experiences for university students, and that it is important to examine how students perceive, approach, and learn from across these two different contexts. In discussion blended learning approaches in CSCL contexts, it is important to know that CSCL does not aim to replace face-to-face interaction, but rather enhances it by providing more resources for learning. Suthers (2006) argues that if we try to replicate face-to-face interaction through the medium of online technology, the goal seems to fail due to the complexity of temporal and spatial factors associated with human interaction. Instead of replication of face-to-face types of interaction, we need to understand what tasks and learning activities online interaction can be better achieved than face-to-face learning. So (2009) echoes the importance of learning experiences integrating online and face-to-face interaction by arguing that there is a need to design CSCL tools to support the effective integration of online and face to-face communication so that critical discourse episodes in face-to-face discussions are not lost and continue to develop online.

The Present Study

This study was designed to examine both the current practices and the future of blended learning approaches in computer supported collaborative learning (CSCL) environments. Toward this goal, this research study used a Web-

based Delphi method to capture the judgment of recognized experts in the field of online learning. The Delphi technique is “a method for the systematic solicitation and collection of judgments on a particular topic through a set of carefully designed sequential questionnaires interspersed with summarized information and feedback of opinions derived from earlier responses” (Delbecq, Van de Ven, & Gustafson, 1975, p. 10). The Delphi technique has been considered as a time- and cost-efficient method to obtain opinions from experts without physically bringing them together for a face-to-face meeting. In addition to flexibility and efficiency, one of the major advantages of the Delphi technique is anonymity which removes common biases occurring in face-to-face group settings (Listone & Turoff, 1975). Delphi study is a method to overcome implicit weaknesses in group communication, such as confrontation, argumentation, or dominance by a few individuals. To minimize such limitations, individuals, who are anonymous and independent, are free to express their own ideas without direct communication with each other. Instead of discussing or debating among individuals, consensus on a certain issue is achieved through a carefully designed series of surveys, facilitated by the researchers conducting the study.

In the area of learning technology, several studies used the Delphi method to (a) identify current practices and perceived obstacles (e.g., Brescia & Miller, ; Buss, 2001; Herring, 2004; Kramer, Walker, & Brill, 2007; Williams, Boone, & Kingsley, 2004), (b) draw consensus on ill-defined problems or constructs (e.g., Brill, Bishop, & Walker, 2006; Soo & Bonk, 1998; Yang, 2000), and (c) forecast future events and trends (e.g., Holden & Wedman, 1993; Pollard & Pollard, 2004-2005). A Delphi study, therefore, was deemed useful in better understanding the uses and implications of blended learning in a collaborative framework.

Methods

Research Design

In the present study, the Delphi technique was used in an online environment to enable researchers to recruit experts from all over the world. The Web-based survey tool used for this particular study was SurveyShare (see <http://www.surveymshare.com/>). A Web-based Delphi technique has been used to overcome limitations in Delphi process using paper-based surveys. We used the steps suggested by Wilhelm (2001) to conduct three rounds of information and consensus gathering as shown in Figure 1.

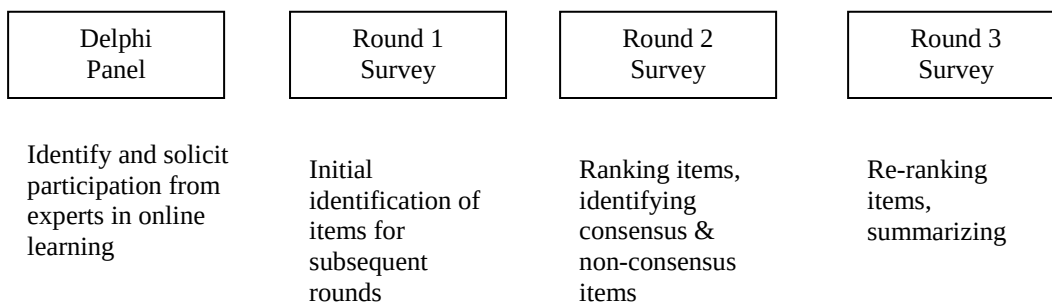


Figure 1: The Delphi study process

Selection of the Delphi Panel Members

Thirty-two experts who had contributed chapters to the *Handbook of Blended Learning* (Bonk & Graham, 2006) were identified as possible members for the Delphi panel. Twelve of them participated in Round 1, though a few others who attempted to complete the survey but did not finish it, were kept in the pool for subsequent rounds. In Round 1, a total of 12 experts responded, thereby giving a response rate of 38%. There are 5 males and 7 females, mostly from university settings. We asked the Round 1 panelists to recommend experts, and two more participants were included in Round 2 (n=14). The Round 2 panel includes 4 from North America, 2 from Europe, 4 from Asia, and 4 from other countries. Since the expertise of the Delphi panelist is considered to be the most important feature

for selection, we asked the panel members to indicate their expertise level of blended learning and CSCL. Thirteen members indicated a high level of expertise in blended learning, and 11 members for CSCL. Again in Round 3, we asked the Delphi panelists to recommend experts, and six more participants were added (n=20).

Procedure and Data Analysis

Round 1

The main purpose of the first round of this study was to identify various emerging issues of blended learning approaches in supporting CSCL environments, which could serve as the basis for the subsequent rounds. All communication between the researchers and panel members was conducted online so as to allow anonymous and confidential responses. This form of communication was also intended to increase the speed of data collection and analysis for subsequent rounds. In addition to some background information (e.g., gender, age, and occupation), the Round 1 online survey included eight open-ended questions to generate common themes which could serve as the basis for the subsequent rounds of the survey. The eight questions were:

1. In general, how can blended learning strategies facilitate collaborative learning activities?
2. How might blended learning hamper or interfere with online collaborative learning activities?
3. How might blended learning foster collaboration among students in a class?
4. How might blended learning foster collaboration among students located in more than one university or region?
5. How might blended learning foster collaboration among instructors?
6. How might blended learning foster collaboration among students and their instructors or tutors?
7. How might blended learning foster collaboration of students and experts?
8. How might online collaboration within blended learning change or be different in 20 years?

The panel members had approximately two weeks to complete and return their responses. Data was then analyzed to generate a list of statements for subsequent rounds. We identified a total of 38 statements from the collected responses. These statements were used as survey items for Rounds 2 and 3.

Round 2

The main goal of this round was to build consensus by identifying areas of agreement or disagreement among the Delphi panel members. Each member was asked to evaluate questions according to the perceived importance they placed on each item. As standard with a Delphi approach, they were required to rate each item without knowledge of who submitted responses. As suggested by Clayton (1997), we employed a five-point Likert scale using zero as a mid point. Such a scale contained both positive and negative values thereby allowing respondents and researchers to easily interpret the level of consensus on each item. For instance, a statement with a mean rating of +1 or above indicates strong consensus among panel members. Below is an example of a Delphi item used in the Round 2:

2. How might blended learning hamper or interfere with online collaborative learning activities?
2.5 There must be a correspondence between face-to-face and online course components:
Strongly Disagree (-2), Disagree (-1), Undecided (0), Agree (1), Strongly Agree (2)

In addition to indicating agreement or disagreement, participants were asked to perform three additional tasks: (1) to rate their expertise level for each question (0=No expertise, 1=Low expertise, 2=Average expertise, 3=High expertise); (2) to rank the statement that they perceived to be the most important for each question; and (3) to provide a brief explanation for their selection of the most important statement. As recommended by Turoff and Hiltz (1995), we asked respondents to indicate confidence in their judgment so that they would not feel obliged to answer items that they did not have expertise. Collecting both numerical rankings and brief descriptions allowed us to capture richer perspectives on problems under consideration, which is often limited in a conventional format of the Delphi method, mainly relying on quantitative statistics-oriented data (Brill et al., 2006).

Since the main goal of Round 2 was to determine the degree of consensus among the Delphi panel members, descriptive statistics were used to calculate central tendency and variability: (1) *mean* (M) as central tendency; and

(2) *standard deviation* (SD) and *quartile deviation* (QD) as variability. Mean is the average of a five-point Likert scale using zero as a mid point, ranging from Strongly Disagree (-2) to Strongly Agree (2). In this study, quartile deviation was used to determine consensus. Quartile deviation refers to the difference between the 25th and 75th percentile in a frequency distribution (QD=Q3-Q1). According to the criteria used by Faherty (1979) as well as Holden and Wedman (1993), items that receive a quartile deviation $\leq .6$ are considered to be high consensus. Items that receive a quartile deviation of greater than .6 but less than or equal to 1.00 indicates moderate consensus. When a quartile deviation is greater than 1.00, items are considered to be low consensus. Generally, through three or more rounds of survey, a mean is expected to increase while standard deviation and quartile deviation are expected to decrease. Frequency counts (*f*) were also calculated to rank items in terms of perceived importance.

Round 3

The main purpose of Round 3 was to achieve a high consensus. In general, the Delphi rounds are terminated when moderate to high convergence (e.g., QD ≤ 1.0) is reached among the panel members. According to the suggestion by Yang (2000), the survey items in this round were presented with descriptive statistics (M and SD next to item statements) and frequency distribution of the experts' ratings (expressed by the number of *) from Round 2. Below is an example of a Delphi item used in the Round 3. This item asks the panel members to re-evaluate whether they agree or disagree that blended learning helps knowledge construction after reviewing the data gathered from Round 2. The number of * in this item indicates that in Round 2, seven panel members strongly agree with the given statement. This format of presentation allows each panel member to visualize how his rating compares with regard to the group ratings.

1. In general, how can blended learning strategies facilitate collaborative learning activities?
- 1.4. Blended learning helps knowledge co-construction. (M=1.21, SD=.98)

(-2) Strongly Disagree	0
(-1) Disagree	* 1
(0) Undecided	** 2
(1) Agree	**** 4
(2) Strongly Agree	***** 7

The Delphi panelists who participated in Round 2 were asked to express agreement or disagreement by rating the same items again. Same as the previous round, descriptive measures about central tendency and variability for each item were calculated. In addition to survey items, we asked the panel to provide a story of how they had fostered collaboration in a blended environment in order to collect more qualitative accounts of their experiences and perspectives about blended learning approaches and CSCL:

Provide a story of how you have fostered collaboration in a blended environment (e.g., Students in Curt Bonk's face-to-face class last year conducted collaborative case analyses with students from the Open University in Malaysia within specially designed discussion forums of a learning management system. Students were paired up across institutions- each team consisted of one student from Indiana University and one from the Open University of Malaysia. Instructors as well as peers could comment on their ideas and solutions.

Thirteen participants responded this item, thereby giving 65% of the response rate.

Results

Overview of Findings

From the open-ended responses in Round 1, we identified 38 themes for the 8 questions and used them for the subsequent rounds. After the third round, 24 items (69%) achieved a mean in the range of 1 (agree) and 2 (strongly

agree), and 35 items (92%) reached a high consensus ($QD \leq .5$). Three items that could not receive high consensus are:

Q: Blended learning interfering collaboration

- Students may feel that there's no need to go online if they can work face-to-face. ($QD=1$)
- Students can equate online activities with self-paced work and face-to-face activities with collaboration. ($QD=1$)

Q: Blended learning fostering collaboration between students and experts

- It is easier to get experts. ($QD=1$)

In order to present data in a more meaningful way, the survey responses are organized into three sections: (1) pros and cons of blended learning approaches in CSCL; (2) blended learning for collaboration in various contexts including the narrative accounts of blended learning approaches in CSCL given by the Delphi panelist; and (3) the future of blended learning in CSCL.

Pros and Cons of Blended Learning Approaches in CSCL

The first two questions asked about how blended learning approaches could facilitate or hamper collaborative learning activities. As shown in Table 1, the panelist responded that blended learning approaches are useful for communication and knowledge co-construction perspectives. Flexibility and time-efficiency appeared often in their responses as advantages of blended learning approaches. Regarding negative aspects of blended learning, there was a high consensus on the item "there must be a correspondence between face-to-face and online course components". Thirteen participants ranked this item the most important. The mean of the item "Students can equate online activities with self-paced work and face-to-face activities with collaboration" was below 0, indicating that the majority of the panel members disagreed with this statement. None of the panel members ranked this item as important.

Table 1. Pros and cons of blended learning approaches in CSCL

Rank	Statement	<i>f</i>	M	SD	QD
<i>In general, how can blended learning strategies facilitate collaborative learning activities?</i>					
1	Blended learning supports flexibility and effectiveness in work and communication.	7	1.30	.57	.5
2	Blended learning helps knowledge co-construction.	6	1.10	.97	.5
3	Blended learning provides the time and flexibility for preparation and follow-up and the time-specific stimulus of a face-to-face session to keep students on track.	5	1.05	.62	.5
4	Blended learning helps relationship building.	2	.90	.72	0
5	Blended learning facilitates project management with online technologies.	0	.85	.75	.5
<i>How might blended learning hamper or interfere with online collaborative learning activities?</i>					
1	There must be a correspondence between face-to-face and online course components.	13	1.35	.75	.5
2	It can interfere when the different blended components are not well connected.	4	1.20	.41	0
3	Lack of access and skills to make effective use of the tools are potential barriers.	2	1.00	.80	.5
4	Students may feel that there's no need to go online if they can work face-to-face.	1	.25	1.02	1
5	Students can equate online activities with self-paced work and face-to-face activities with collaboration.	0	-.11	.88	1

Note. SD= -2, D=-1, U=0, A=1, SA=2

Blended Learning for Collaboration in Various Contexts

Next, we collected the knowledge and opinions held by the Delphi panelist regarding blended learning approaches for collaborative learning in various contexts, including collaboration among students in a class, across different geographical settings, collaboration among instructors, collaboration between students and instructors, and collaboration between students and experts. Table 2 summarizes descriptive measures for these categories. An interesting pattern is found in this set of questions. The majority of the panel members expressed that how blended learning fosters collaboration in various contexts depends on how the course is designed to involve interaction with others, signaling that there was higher consensus on the importance of *design issues* in blended learning and CSCL. Some statements received both low frequencies in ranking and low mean scores, indicating lower importance and higher disagreement. These items include: “Students and instructors can take equivalent roles in the teaching and learning process;” “Students can talk to experts more intensively via online learning;” and “It is easier to get experts.”

Table 2. Blended learning for collaboration in various contexts

Rank	Statement	<i>f</i>	M	SD	QD
<i>How might blended learning foster collaboration among students in a class?</i>					
1	Blended learning can widen access to resources.	6	1.65	.49	.5
1	Online tools can support project management and discussion.	6	1.45	.69	0
2	Students can collaborate online after building a sense of community in a face-to-face context.	4	1.25	.79	.5
2	Online space provides opportunities for students to discuss knowledge and clarify misconceptions.	4	1.20	.41	0
3	Responses can be made either in face-to-face or online environments.	0	1.00	.80	.5
<i>How might blended learning foster collaboration among students located in more than one university or region?</i>					
1	While face-to-face components typically occur within a local university, online collaboration can involve collaboration with students outside an institution.	7	1.25	.44	.5
2	The location of the collaborators does not matter.	6	.85	.75	0
3	The online learning management system (LMS) can be used as a medium to enhance collaboration.	4	1.15	.37	0
4	Online learning results in distributed working on class tasks and reduces travel.	2	.80	.70	.5
<i>How might blended learning foster collaboration among instructors?</i>					
1	It depends on how the learning design involves interactions with others.	12	1.35	.59	.5
2	Instructors in the same department or even across departments can collaborate and learn from each other by sharing resources.	3	1.00	.46	0
2	Blended learning can be used to offer online staff development courses.	3	1.20	.52	.5
3	Blended learning has the potential to develop networks beyond the conference circuit.	1	1.10	.55	.5
3	Blended learning can help instructors maintain their standard curriculum as well as their instructional processes, thereby providing quality controls and learning outcomes assurances.	1	.40	.68	.5
<i>How might blended learning foster collaboration among students and their instructors or tutors?</i>					
1	It depends on how the course is designed.	15	1.70	.47	.5
2	With online technologies, it is possible to have ongoing conversations and collaborations with instructors outside of the traditional learning space.	3	1.45	.51	.5
3	Blended learning can foster open two-way learning and communication.	2	1.11	.57	.5
4	Students and instructors can take equivalent roles in the teaching and learning process.	0	.45	1.05	.5
<i>How might blended learning foster collaboration of students and experts?</i>					
1	It depends on how the learning design involves interactions with others.	13	1.55	.51	.5

2	Students can have instant access to the work of experts, but need to gather, evaluate, and use information in a responsible way.	4	1.30	.57	.5
3	Experts can share their expertise through both online and off-line formats.	2	.90	.45	0
4	Students can talk to experts more intensively via online learning.	0	.65	.99	0
4	It is easier to get experts.	0	.20	.89	1

Note. SD= -2, D=-1, U=0, A=1, SA=2

To further explore design issues of blended learning in CSCL, we asked the Delphi panel members to describe how in practice they had used blended learning approaches to foster collaborative learning in their class (activity or course level) or institutions (program level). Some common themes emerged from the narrative accounts. The most frequently mentioned format of collaborative learning tasks is collaborative writing. That is, students are given a small group task to complete, often in a mandatory participation structure, and a technology medium such as wikis or online discussion forums are used to facilitate the collaborative writing processes. Face-to-face interaction is used for presentation or to continue to work on the group task as shown in the following descriptions:

Students in my course were asked to create a wiki on a topic in pairs; this was then presented to the rest of the class for comments in two forms of a forum and also by encouraging the other class members to add their own ideas. Finally after 2 weeks the original pair wrote up a reflection about the topic for their class assignment. (Panel member #1)

Students in a seminar on design-based research (DBR) on collaborating on the authorship of an edited book about the DBR. The topical outline and writing assignments were worked out face-to-face and the writing is proceeding online with sharing of drafts, etc. (Panel member #2)

Another interesting finding is related to blended learning at the inter-program (residential and distance) and inter-university collaboration (universities in different countries) levels. Three panel members described that their institutions have used blended learning approaches for collaboration across different programs and countries, indicating a macro-level implementation of blended learning.

Students in my blended learning class last year conducted collaborative case analyses with students from the Indiana University...each team consisted of one student from Indiana University and one from the Open University of Malaysia. Instructors as well as peers could comment on their ideas and solutions. (Panel member #14: Inter-University collaboration)

We are researching blended learning across 4 universities: two in Malaysia and two in the UK (Panel member #15: Inter-University collaboration)

Students in an introductory instructional design worked in teams (2 residential and 2 distance students to a team) to complete instructional design projects creating a concept lesson. (Panel member #20: Inter-program collaboration)

Table 3. The future of blended learning in CSCL

Rank	Statement	<i>f</i>	M	SD	QD
	<i>How might online collaboration within <u>blended learning</u> change or be different in 20 years?</i>				
1	There will be no bi-polar classification of online learning and off-line learning. All the learning will be blended learning.	13	1.40	.60	.5
2	More international collaboration will be possible.	2	1.20	.62	.5
2	The technology will change, but the need to collaborate and the basic principles of learning may not.	2	1.15	.49	0
2	Integrated and ubiquitous technologies will provide seamless, fast, and easy access to shared environments.	2	1.11	.57	0
3	Collaborative activities will become more complex, but more resources to support them will be available.	0	1.05	.51	0

Note. SD= -2, D=-1, U=0, A=1, SA=2

The Future of Blended Learning in CSCL

Finally, we asked the Delphi panel member about their projections of the future of blended learning approaches in CSCL environments. As presented in Table 3, all the items in this section reached a high consensus (i.e., $QD \leq .6$). Of particular note in this section was high consensus on the item “There will be no bi-polar classification of online learning and off-line learning. All the learning will be blended learning.” Thirteen of 19 panel members (68%) ranked this item as of highest importance. This may show the Delphi panel member’s positive view on the pervasiveness of blended learning approaches in higher education. Other statements related to the future of blended learning and CSCL include the potential of international collaboration and ubiquitous learning for seamless experiences.

Discussion

In the area of CSCL, issues of blending face-to-face and online interaction have gained increasing interest and attention recently: how much of interaction should take place in face-to-face or online settings? When should we use online versus face-to-face interaction? How can we integrate two modes of interaction in a seamless way to increase continuity of learning experiences? Ultimately, these questions revolve around how to get the right mix. Anderson (2003) points out that “getting the right mix involves a series of tradeoffs, and knowing how one type of interaction can effectively substitute for another, provides an essential decision making skill in the distance educators’ knowledge base” (p.10).

Recognizing the increasing trend of blended learning approaches in higher education settings, this study aimed to collect the knowledge and opinions held by the experts in the field of online learning regarding the current practices and the future projections of blended learning approaches in the context of CSCL. Experts from North America, Asia Pacific, Europe, and other countries participated in the online Delphi study process anonymously. Through three phases of online survey implementations, we inquired about various aspects of collaborative learning such as collaboration among students, instructors, distance peers, experts, etc. In addition, we asked the Delphi panelist to provide narrative accounts about their application of blended learning approaches in practice in order to overcome the limitation of the traditional Delphi method relying on quantitative measures.

Overall, the Delphi panel members reached a high consensus on the most of the 38 items. In terms of ranking, there were a number of items with high consensus. The participants found agreement related to the importance of the design aspects of blended learning approaches to support collaborative learning. They also felt that deciding when to use human interaction or technology-mediated interaction is a complex decision involving several design considerations. Additionally, most of them expressed that the coordination or correspondence between face-to-face and online interaction is a critical factor affecting collaborative learning processes. In narrative accounts of blended learning approaches implemented in their own contexts of teaching and learning, the Delphi panel members described collaborative writing tasks for small group assignments as valuable. In addition, technology components such as wikis and online discussion forums were often mentioned as a tool to facilitate online interaction. It also appeared that some institutions are implanting blended learning at a somewhat macro level by encouraging collaboration across different programs and institutions. Finally, the Delphi panel projected that there would be no bi-polar classification of online learning and off-line learning as all the learning experiences would soon be blended to some extent. This projection is consistent with the research trend in CSCL which emphasizes the seamless integration of face-to-face and online interaction to create rich intersubjective meaning-making endeavors across various settings and time (e.g., Clouder et al., 2006; Olson & Olson, 2000; Suthers, 2006).

The experts in this Delphi study provided a fairly consistent voice. According to them, blended learning offers unique opportunities for international collaboration, knowledge construction and negotiation, and project management. At the same time, the resources available to students for such interactions and collaborations widen the spectrum of learning. As the experts indicated, blended learning also offers greater flexibility and opportunities for community building among students. Equally important, instructors can share their ideas and course materials more readily with each other.

While there are many advantages to a blended course, blended learning is complex. Instructors new to blended learning will need additional training in what it offers for teaching and learning. They will need examples of

international collaboration, expert feedback and collaboration, resource exploration, successful online conversations and negotiations, and online learning communities. As new technologies emerge, such training will be ongoing during the coming decade. They will need to understand not just what blended learning is, but also the models or frameworks that support it (Bonk & Graham, 2006). Instructors could also benefit from seeing examples of common problems in online or Web supplemented learning environments and possible blended learning solutions.

The forms of learning have splintered in the twenty-first century. People now learn from online discussions, listening to podcasts, attending lectures or online Webinars, reflecting on their blogs, browsing websites, and various forms of online collaboration. As this continues to happen, it will be increasingly difficult to differentiate between face-to-face forms of learning and online ones; instead, they will typically include some of both. To say that a course was “off-line” will be just as much of a misnomer as calling another class “online.” Today this overlap between the two areas we typically refer to as blended. It is conceivable that the vast majority of formal as well as informal learning experiences in the future will be blended ones.

So the projection from the experts of this study that there will be no bi-polar classification of online learning and off-line learning and that all learning will, in effect, be blended, seems highly likely. Another alternative is that educators will soon just refer to everything as *learning*, as they used to prior to the emergence of distance and online learning. What is certain is that perceptions of what learning is are changing fast. Terms such as e-learning, online learning, and blended learning may only be temporary concepts that soon evolve or are superseded by other delivery mechanisms.

Concerns and Future Work

It should be noted that the small panel size of this study limits the generalizability of the results. And even though we modified the Delphi process to collect more qualitative data about the participants’ knowledge and opinions, the survey format itself has many limitations related to the depth of participant responses as well as the constraining value of each question. Therefore, this study intends to provide descriptive overviews of the role of blended learning approaches in CSCL environments expressed by the experts in the field of online learning. Further detailed research is needed to have better understandings of some critical questions identified in the present study: the design issues of blended learning approaches to support CSCL and the ways to create a seamless and effective integration of face-to-face and online interaction.

Conclusion

Blended learning is clearly a key part of teaching and learning today and will remain so in the near future. Collaboration and international exchanges will undoubtedly be integral to many of these blended learning efforts. As indicated in this research, instructors who understand the advantages of blended learning can enhance the degree and impact of collaboration within their classes as well as between classes around the world. We are in a global educational world which relies on blended learning in many courses, fields, and disciplines. Advances within the field of CSCL, in fact, will hinge on better understanding and use of blended pedagogical approaches. This research sheds a bit of light on where blended learning experts think such approaches are most valued and beneficial today and tomorrow. However, as noted, additional research and pedagogical experimentations are now needed from both the blended learning experts as well as those more novice to the approach.

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How Epistemic Beliefs Influence e-Learning in Daily Work-life

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ABSTRACT

Epistemic beliefs comprise the individual understanding of the nature of knowledge and the creation of knowledge. Hence, they impact the perception of learning opportunities and professional learning activities. Many enterprises apply computer technology in order to support staff development through e-learning activities. However, a closer look at the practices of e-learning reveals that only rarely the potential of educational technology for professional learning is fully utilised. Frequently it is neglected that employees' subjectivity - in particular their epistemic beliefs - determines their ways of using educational technology for self-directed learning activities. This contribution reports an empirical study of 256 employees of varying hierarchical status and working in companies of different sizes. The investigation aimed at analysing how epistemic beliefs influence e-learning in daily working-life. The findings indicate that epistemic beliefs impact the quality rather than the amount of professional e-learning. The conclusions offer new impulses for the study of knowledge management.

Key words

E-learning, Epistemic beliefs, Knowledge, Professional learning

Introduction

Epistemic beliefs are individuals' basic assumptions about the nature of knowledge and about appropriate ways to develop one's own and others' knowledge (Hofer & Pintrich, 2002; Schommer, 1990). Hence, employees' epistemic beliefs determine the practice of using e-learning opportunities in enterprises. Epistemic beliefs shape individual attributes which influence learning activities, workplaces shape the environmental influence. Latter ones differ in company size and hierarchical status of an individual. Independent from pedagogical considerations and intentions, which may have guided the arrangement of a workplace as a learning environment, employees perceive and interpret their environment by applying their individual beliefs. From a socio-constructivist perspective, one would describe this as a process of construing sense of the world (Billett, 2006; Rogoff, 2003), which is a challenge for implementing knowledge-based tools in general and e-learning opportunities in specific.

Epistemic beliefs have recently received much attention in the fields of educational and psychological research. Whereas psychological approaches focus on the development and stability of epistemic beliefs, educational research focuses on how epistemic beliefs affect teaching activities (Harteis, Gruber, & Lehner, 2006) and learning processes (Bauer, Festner, Gruber, Harteis, & Heid, 2004).

This contribution describes the influence of epistemic beliefs on the practice of work-related e-learning activities. 256 employees from a number of companies voluntarily participated in a study about the relation between epistemic beliefs and e-learning practices. They are differentiated regarding their company size and their hierarchical status. The discussion of the empirical findings focuses on conclusions for knowledge management in companies.

Epistemic beliefs

Epistemic beliefs are individual convictions about knowledge and knowing. Their influence on university students' learning strategies and learning outcomes has been intensively investigated (Schommer, 1993). Little is known, however, about the role of epistemic beliefs for work related learning activities, i.e. how they influence the practices of using e-learning opportunities in the context of daily work-life. It is still unclear how epistemic beliefs contribute to decentralised learning activities, which are emphasized in the contexts of learning organisations (Appelbaum & Gallagher, 2000) and of professional learning (Billett, 2001). Within these approaches, continuous learning – not

necessarily in formal learning settings – is considered to be an instrument of adaptation to rapidly changing market conditions. The claim of continuous learning not only refers to members of the leading hierarchy and white collar workers in enterprises, but also to employees without leading function and blue collar workers. At least according to the programmatic concepts, staff members are supposed to work on complex, holistic tasks as well as to take decision competence and responsibility. This implies the necessity of employees' competence development (Harteis & Gruber, 2004). Recent developments in company training and professional learning tend to focus on self-directed learning processes in order to make inner-firm education more flexible. E-learning is an important component of self-directed learning in companies. For the employees' practices of e-learning, their epistemic beliefs are relevant, because they are likely to influence, how e-learning opportunities are used for meeting individual learning demands. The individual conviction of knowing and learning determines learning strategies and learning purposes.

Theoretical concepts of epistemic beliefs

Epistemic beliefs are considered as a general construct of assumptions about the nature of knowledge and knowing. The most influential theoretical account of epistemic beliefs as a multidimensional construct was developed by Schommer (1990). Initially, she differentiated between five more or less independent dimensions of epistemic beliefs: (a) simplicity of knowledge, (b) authority of knowledge, (c) certainty of knowledge, (d) innate ability, and (e) learning speed. Individuals who are identified as having a high level of agreement on items measuring these dimensions, usually are held to have a less elaborated system of epistemic beliefs. They believe that knowledge is simple, that it is provided by authorities, that it is certain, that humans have stable innate abilities, and that learning happens quickly (or never). In contrast, subjects who reject most of such items are assumed to have an elaborated system of epistemic beliefs: They tend to argue that knowledge is complex in nature, that it is constructed in specific ways within particular communities, and that it is subject of permanent argumentation. It is the terminology of elaboration which clearly indicates that an educational perspective implies the appreciation of developing an elaborated system of epistemic beliefs.

There is a crucial aspect which has not yet been thoroughly considered in research on epistemic beliefs: It is not yet clarified how strictly epistemic beliefs are related to domains. Doubts about the transferability of the dimensions of epistemic beliefs across various domains led to further critical questions (Greene, Azevedo, & Torney-Purta, 2008): Is it plausible to conceptualise epistemic beliefs as a general basic construct? Are epistemic beliefs intrinsically related to domain-specific features (like knowledge)? Can they plausibly be separated from assumptions about one's own and other people's learning processes in their respective fields? Are epistemic beliefs in nature context-bound and thus situated? Is knowledge about knowledge situated? It is plausible to confirm these assumptions – thus leading to most interesting interindividual differences in epistemic beliefs. Most recent research (DeBacker, Crowson, Beesley, Thoma, & Hestevold, 2008; Greene et al., 2008; Muis, 2007) argued that priority of future research should be given to investigations of epistemic beliefs across a number of different domains of practice in order to test these assumptions. The educational relevance of such research easily can be shown by analysing how differences in epistemic beliefs influence employees' practices of using learning opportunities, e.g. e-learning applications.

In this context, learning can be understood as a process of making sense of the world. Piaget (1966) developed the ideas of assimilation and accommodation. Both assimilation (using knowledge for solving the situation) and accommodation (configuration of new knowledge) can be considered as learning processes. Work-life provides opportunities for assimilation as well as for accommodation through involving people both in routines and in challenging new tasks (Billett, 1996). The origin of such an approach is the constructivist idea of learning which manifests the importance of subjectivity. As previous experiences, prejudices, and beliefs influence learning and knowledge, it becomes clear that learning, knowledge, and consciousness are individual entities forming a subjective model of the world – which makes sense for the subject. Thus, subjectivity as the autonomy of an individual's thoughts, views, and assumptions can be seen as the epitome of a person's dispositions and capabilities.

Impact of epistemic beliefs

Epistemic beliefs influence individuals' acting, hence they also affect working and learning. In the past, much emphasis in empirical research was put on analysing the impact of epistemic beliefs on school and university

learning (Demetriadis, Papadopoulos, Stamelos, & Fischer, 2008; Jehng, Johnson, & Anderson, 1993; Whitmire, 2003). Schommer (1998) presented evidence that elaboratedness of a person's system of epistemic beliefs has many substantial implications for learning:

- Students, who believe that learning occurs quickly, tend to read texts more superficially.
- Students, who believe that knowledge is certain, tend to learn facts by heart rather than understanding the meaning of the to-be-learned.
- Students, who believe that learning capabilities are determined by innate abilities, show less interest in activities designed to master complex challenges.
- Students who trust authorities do not tend to challenge the sources of information.

Taken together, students with a less elaborated epistemic belief system tend to be prone to failure if learning requires complex, multi-perspective activities. They are less likely to relate new knowledge with prior knowledge or knowledge gained in different contexts, domains or situations. In contrast, an elaborated system of epistemic beliefs is associated with better learning performance (Hager, 2004).

Even though little research exists in professional fields, it is plausible to assume that employees' learning and working performance analogously is related with the degree of elaboration of their system of epistemic beliefs. That is, the more elaborated employees' systems of epistemic beliefs are, the more they understand their workplace environment as a resource for learning and professional development. Yet, so far little attention was paid to epistemic beliefs in the work context, because such "subjective perspectives" on one's own development are often disregarded.

Epistemic beliefs significantly shape the conceptualisation of problems. This is particularly true when no appropriate heuristics are available and, thus, when demanding innovative solutions are required (Korthagen & Kessels, 1999). Problems, however, are on the one hand often initial points for professional learning activities, on the other hand e-learning devices often integrate problems in their pedagogic approaches.

The impact of epistemic beliefs here is two-fold. First, epistemic beliefs influence the processes proceeding the generation of a solution. Individuals, who believe in the simplicity of knowledge, favour simple coherence between facts and tend to develop a simple solution. In contrast, individuals who are convinced of the complexity of knowledge tend to take into account the fallibility of heuristics. Both views influence the scope of possible solutions – without predetermination of a favoured position. Second, there is an indirect impact on work, because epistemic beliefs influence help-seeking during the process of identifying an appropriate solution for the problem. Individuals with a less elaborated epistemic belief system might trust in information that can quickly be found, and consequently quickly present their final solution. In contrast, subjects with an elaborated system might put more energy into cross-checking new information. Epistemic beliefs thus can be seen as an important component of using e-learning opportunities in companies.

E-learning in companies

In a foresight paper for the European Commission's Joint Research Center, the future of learning in companies as ICT based scenario for experiential learning was described (European Commission, 2006): Learners' activities comprise running simulations, testing assumptions and negotiating sense in virtual or face-to-face communities. E-learning covers all fields of learning in companies. Employees train the operation of new machines and technology with learning software; tools exist to serve individual learning demands from language learning up to the training of communication skills; web-based solutions for knowledge management aim at the distribution of competence and expertise within companies; computer-simulated cases supplement traditional learning and instruction.

Practices of e-learning in companies

Recent studies in German companies showed that about half of the employees have experiences in using e-learning devices (Institut der deutschen Wirtschaft, 2004). Related to these numbers, about half of the enterprises, for example in the metal branch, have implemented e-learning in their companies, whereby especially larger enterprises focus on e-learning opportunities. They mainly use computer-based training software, often in order to learn about

new software and applications. There are similar findings from other countries, too (Slotte & Herbert, 2006; Waight & Stewart, 2005).

Some studies addressed the employees' attitudes about e-learning. For example, Breitwieser, Küpper, and Ponomareva (2002) found that the majority of e-learners appreciate e-learning for a quick approach to new information. Analyses of managers' usage of mobile e-learning devices (e.g. handhelds) indicate that e-learning provides benefit especially for top and middle managers, whereas lower hierarchical levels more often suffer of lacking technical equipment (Maske & Breitner, 2007). However, none of these studies directly addressed epistemic beliefs as influencing factor of e-learning practices.

When e-learning began to develop the hope arose that technological applications would offer cheap, quick, and effective learning opportunities and that – finally – e-learning would substitute traditional learning environments. Meanwhile those hopes are replaced by a more realistic view on e-learning opportunities. The most important role of e-learning in adult education is to supplement regular education – either as blended learning or as preparation or rework of face-to-face trainings (Breitwieser et al., 2002). Recent literature on e-learning frequently refers to constructivist paradigms of learning and instruction (Slevin, 2008) and, thus, emphasizes the focus on individual interpretations and understandings of environmental settings. Thus, the potential of e-learning in the current literature is described as offering opportunities for self-directed learning and social interaction in virtual communities aiming at socially shared construction of meaning. It fosters the joint negotiation of meaning through several individuals, which is supposed to be a crucial mode of understanding the complexity of the world (Valsiner & van der Veer, 2000). However, learners explicitly have to search for opportunities to exchange opinions and interpretations in order to make use of these options of e-learning. This implies that learners' perception of the necessity of social negotiation of meaning and knowledge is crucial. Thus, their epistemic beliefs are of utmost relevance.

Challenges for the implementation of e-learning: Epistemic beliefs and business organisation

Considering the pedagogic approaches of e-learning on the one hand and the results of the studies about e-learning in companies on the other hand, it can be argued that the current practices of using e-learning facilities clearly fail to exploit the potential of new media for learning and instruction. This can have reasons in the employees' learning approach and epistemic beliefs or in the business organisation of the enterprise.

Learning approach and epistemic beliefs

A challenge for educators is that the expenditure of coordination with e-learning is higher than with face-to-face learning (Tsai, 2004). Media didactics therefore argues to use simple, consistent, and intuitive user interfaces to meet a broad scope of individual demands.

It is also well-known that the individual virtual learner has to take much more responsibility for the coordination of e-learning processes than the learner in face-to-face courses. E-learners also have to express more self-motivation and self-discipline (Paechter, Schweizer, & Weidenmann, 2000). Döring (1997) therefore denied that internet-based learning environments in virtual courses are to be preferred from an instructional point of view. Beyond this argument, another problem which novices in virtual learning often face is the massive amount of information the internet offers.

The challenge for educators and companies is to encourage employees to develop an approach to e-learning which facilitates the widespread use of e-learning applications. Epistemic beliefs influence the perception of what constitutes knowledge challenges and learning. This is in particular crucial in a working environment, because modern companies permanently have to deal with substantial changes. Particularly in professional learning, epistemic beliefs thus influence the perception of purposes for e-learning. In addition, they influence how learning opportunities are perceived and how, consequently, learning strategies are selected and developed. Hence, epistemic beliefs determine the objects as well as the processes of e-learning. It was argued above that an elaborate epistemic belief system is supposed to support to make use of e-learning opportunities. In a study with university teachers, evidence was found that epistemic beliefs affected the usage of ICT for learning and instruction. The more university

teachers believed that knowledge is sure and clear, the more restricted their usage of ICT in teaching was (Harteis et al., 2006).

Organisational reasons

Literature on business education indicates two main organisational factors influencing employees' learning opportunities (Pittaway & Hannon, 2008):

- The size of an enterprise shapes explicit as well as implicit rules for business behaviour and can affect learning opportunities in a twofold direction. Small organisations on the one hand tend to have less bureaucratic regulations and provide, thus, more degrees of freedom for individual (learning) activities. On the other hand, cultural practices within small groups are highly sensitive to contributions from a particular individual. However, there seem to be differences across enterprises of varying sizes regarding the provision of learning opportunities.
- Modern concepts of business organisation include the employees' perspective, but they do so in terms of an unilateral connection: The connection is expressed as management's appeal to employees to behave as they are expected. Instead of considering employees' individual needs, functional aspects of management concepts prevail. Participation, employees' needs and trust serve their purpose by increasing effectivity of the production processes (Evans, Hodgkinson, Rainbird, & Unwin, 2006). However, even though modern approaches of business organisation claim to consider the needs of all employees in an enterprise, doubts remain if white collar employees and blue collar employees really experience similar support for learning (Evans & Rainbird, 2002). In terms of workplace learning, all hierarchies are suggested to experience similar learning affordances, but there is still a lack of empirical evidence concerning this issue.

Epistemic beliefs as individual learning approaches and business organisation of enterprises are crucial influential factors for a promising implementation of e-learning opportunities in enterprises. As both factors are challenging, a systematic examination of influences of epistemic beliefs and shapes of business organisation gains relevance.

A study was conducted that aimed to investigate the role of epistemic beliefs on the practices of e-learning of employees in German enterprises, both in industrial workplaces and in administration workplaces.

Research questions

The research questions resulting from the theoretical considerations above were:

- Do epistemic beliefs influence the amount and the quality of using e-learning devices in daily work-life? More precisely, how do epistemic beliefs affect the way of perceiving challenges and learning opportunities at workplaces?
- Do subjects from companies of varying sizes differ in their epistemic beliefs and their amount and quality of using e-learning opportunities?
- Do subjects who are in a leading position at their workplace and those without leading function differ in their epistemic beliefs and their amount and quality of e-learning?

Method

The Epistemic Belief Inventory (EBI) (Schraw, Bendixen, & Dunkle, 2002) was translated into German and applied in an online questionnaire. The EBI is based on Schommer's Epistemic Questionnaire (EQ) (Schommer, 1990), but it is less extensive. Additional to the EBI items the online questionnaire comprised questions on the amount of e-learning, on practices of negotiating meaning and on distributing knowledge (as indicators of the quality of e-learning). In detail, the questionnaire comprised the following scales:

- *Omniscient authorities* ($\alpha=.73$): 4 items indicating subjects' trust in authorities whose opinions are not to be challenged (e.g. "people shouldn't question authority").
- *Certain knowledge* ($\alpha=.82$): 5 items indicating subjects' trust in certainty of knowledge (e.g. "what is true today will be true tomorrow").

- *Quick learning* ($\alpha=.80$): 4 items indicating subjects' belief that learning has to occur quickly (e.g. "if you don't learn something quickly, you won't ever learn it").
- *Simple knowledge* ($\alpha=.64$): 5 items indicating subjects' belief that knowledge always can be illustrated in a simple shape (e.g. "too many theories can complicate things").
- *Innate ability* ($\alpha=.63$): 5 items indicating subjects' belief that knowledge is connected with innate capabilities (e.g. "people's intellectual potential is fixed at birth").
- *E-learning amount* ($\alpha=.99$): 2 items indicating the frequency of using e-learning devices ("learning with computer is daily routine" and "I often use my computer for learning purposes").
- *Negotiation of meaning* ($\alpha=.71$): 4 items indicating subjects' opinion that learning has to do with negotiating meanings and sense (e.g. "learning means that I have to discuss with other people about learning content").
- *Distribution of knowledge* ($\alpha=.83$): 3 items indicating subjects' experience that learning process comprise exchange and distribution of knowledge (e.g. "During learning processes I am often succeeding in offering solutions for other people").

The questionnaire was coded in a way that large scores indicate a high degree of the parameter. Thus, large scores indicate agreement e.g. on simplicity, certainty of knowledge – indicators for a less elaborated systems of epistemic beliefs.

After choosing the instrument and translating the items, an online version of the questionnaire was programmed on the basis of a Java application which stored all inputs directly into a database. Via newsletters, invitation letters distributed e.g. by regional chambers of commerce, and e-mail invitations a vast crowd of people were invited to participate in this study. As the distribution of invitations was partly organised via multipliers, it is not possible even to estimate a respondent rate. In total, 291 employees of different German companies participated voluntarily in the study and entered the online questionnaire. However, 35 persons dropped out during the procedure, so that $N=256$ subjects finally filled in the questionnaire correctly and completely.

A cluster centre analysis based on the EBI scales was conducted in order to possibly split the sample into groups of subjects with a more versus less elaborated system of epistemic beliefs. Then the influence of epistemic beliefs on e-learning activities was investigated through the analysis of correlation coefficients and mean comparisons.

Results

The first research question addressed interrelations between epistemic beliefs and the amount as well as the quality of e-learning. Table 1 shows the correlation coefficients concerning these interrelations. No considerable relation was found between epistemic beliefs and the amount of e-learning. However, there are small but significant correlations between beliefs on simple knowledge and negotiating meaning or distributing knowledge in e-learning processes and between the belief on certainty of knowledge and negotiation of meaning. Both, negotiation of meaning and distribution of knowledge were considered as indicators for a high quality of e-learning activities.

Table 1. Correlation coefficients between epistemic belief dimensions and e-learning

	E-learning amount	Negotiation of meaning	Distribution of knowledge
Omniscient authorities	-.04	-.05	.03
Certain knowledge	-.02	-.13*	-.08
Quick learning	-.00	.06	.05
Simple knowledge	.04	.17**	.14*
Innate ability	-.04	-.08	.06

Note: * $p<.05$, ** $p<.01$

Table 2. Results of cluster center analysis: Cluster centres (after 6 iterations)

	Less elaborate epistemic belief system	More elaborate epistemic belief system
Omniscient authorities	2.78	2.53
Certain knowledge	2.47	2.16
Quick learning	2.14	1.45
Simple knowledge	3.67	2.84
Innate ability	3.36	2.81

The cluster centre analysis helped to identify two sub-groups, of which group A ($n_A=141$) comprises the subjects with a less elaborate epistemic belief system, group B ($n_B=115$) the subjects with a more elaborate epistemic belief system. Table 2 comprises the cluster centres of the relevant variables.

After splitting the sample in these two groups, a *t*-test was calculated in order to investigate if both groups differ in the amount and quality of e-learning (table 3).

Table 3. Results of the t-test for independent samples (df=252)
Group differences regarding e-learning amount and quality of e-learning activities

	Group A		Group B		<i>T</i>	Significance
	Mean	SD	Mean	SD		
E-learning amount	3.85	1.03	3.70	1.32	1.06	<i>n.s.</i>
Negotiation of meaning	2.88	0.80	2.65	0.91	2.15	$p<.05$
Distribution of knowledge	3.94	0.75	3.71	0.85	2.26	$p<.05$

Note: SD = Standard deviation, *n.s.* = not significant

Both groups significantly differ in their experience that learning has to do with a negotiation of meaning and a distribution of knowledge, the subjects of group A (less elaborated epistemic belief system) rate these items higher than the subjects of group B (more elaborated epistemic belief system).

The second research question addressed differences between subjects from companies of different sizes. Table 4 shows the results of the analysis of variance.

Table 4. Analysis of variance, factor company size, df's=3,253
Group differences regarding e-learning amount and quality of e-learning activities

Company size	<i>N</i>	Mean	SD	<i>F</i>	Significance
E-learning amount	< 10	50	3.79	1.86	<i>n.s.</i>
	11-99	61	3.64		
	100-999	57	3.60		
	> 1,000	86	4.01		
	total	254	3.78		
Negotiation of meaning	< 10	50	2.86	1.20	<i>n.s.</i>
	11-99	61	2.64		
	100-999	57	2.70		
	> 1,000	86	2.88		
	Total	254	2.78		
Distribution of knowledge	< 10	50	3.70	3.24	$p<.05^1$
	11-99	61	3.65		
	100-999	57	4.04		
	> 1,000	86	3.92		
	total	254	3.84		

Note: SD=Standard deviation; *n.s.*=not significant. ¹Post-hoc test (Tukey-Kramer): 100-999 > 1-10, 11-99, 1,000 and more

The only significant differences found referred to the distribution of knowledge. The subjects from organisations of 100 up to 999 employees indicate to a higher extent than the other subgroups the opinion that learning processes comprise exchange and distribution of knowledge.

The third research question addressed differences between subjects who are in a leading function at their workplaces and subjects who are not. Table 5 shows the results of the *t*-test.

The only significant difference was found in negotiation of meaning. Subjects without a leading function at their workplaces indicate a higher agreement that learning activities comprise negotiation of meaning than subjects in leadership positions. The *t*-test for the EBI scales did not lead to significant results (all $ts<1$).

Table 5. Results of the t-test for independent samples (df=254)
Group differences rgd. e-learning amount and quality of e-learning activities

	Leadership		No leadership		<i>T</i>	Sign.
	Mean	SD	Mean	SD		
E-learning amount	3.59	1.28	3.88	1.10	1.85	<i>n.s.</i>
Negotiation of meaning	2.59	0.85	2.87	0.85	2.44	<i>p</i> =.05
Distribution of knowledge	3.75	0.83	3.88	0.78	1.26	<i>n.s.</i>

Note: SD = Standard deviation, *n.s.* = not significant

Discussion

A very clear result of this study is that epistemic beliefs do not influence the amount of work related e-learning. The correlations between the EBI scales and the amount of e-learning are close to zero. The same is to be observed when comparing the groups of more or less elaborated epistemic belief systems. This distinction can be interpreted as an attempt to create two groups whose members shape the biggest meaningful difference within the entire sample. Even under these conditions no relevant differences in the amount of e-learning were found. This unexpected result can be discussed under two perspectives: First, it is plausible to assume that the group of participants is biased regarding the use of computer devices in general. The study was conducted as an online study. Several target groups were addressed via newsletters, emails, and press notices, in order to invite a group of employees as large as possible and from different working sectors (e.g. industrial enterprises, service agencies, public administration, research). When the address of the URL of the online questionnaire was provided, the participants had to decide intentionally whether to become active and to participate in the study. Those without online access or bearing aversions against the use of computers probably did not participate. In that sense, the use of computers might be daily routine for all subjects; interest on the topic of e-learning might be overrepresented within the group of participants. Second, literature on epistemic beliefs discusses their influence on the usage of learning opportunities and their importance for people's way of making sense of learning environments (Tu, Shih, & Tsai, 2008). It can be challenged if the amount of e-learning depends on the way of making sense of a learning environment. It may rather depend on the access to technology and e-learning devices – as this is the first prerequisite for the initiation of e-learning activities. If the latter is true, it is plausible that no substantial correlation was found between the epistemic belief system and the amount of e-learning.

Positive but small correlations were found for the belief that knowledge is simple and the understanding that e-learning has to do with negotiation of meaning and distribution of knowledge. The data were coded in a way that large scores indicate a high degree of the parameter (e.g. large scores at certainty of knowledge indicate agreement on the belief that knowledge is certain). This result is coherent with the result of the *t*-test between the groups of more and less elaborated epistemic belief systems. The differences between both groups are significant concerning negotiation of meaning and distribution of knowledge. The group with a less elaborated epistemic belief system showed larger agreement concerning the connection of learning and negotiation of meaning respectively distribution of knowledge. Schommer (1998) found that the belief that knowledge is simple was positively correlated with superficial text processing. If this also applies for the negotiation of meaning and the distribution of knowledge, the quality of the communication processes may be insufficient and remain at the surface of the topics.

As the resulting correlation coefficients are quite small, expectations about the influence of epistemic beliefs on quantity and quality of e-learning might be disappointed. The fact that the instrument originally was developed for school and academic contexts may be responsible that it did not reflect detailed facets of workplaces in an appropriate way. However, even in school and academic contexts, the correlations found were quite small (Bendixen, Schraw, & Dunkle, 1998; Schommer, 1993).

To summarise the results for the first research question it can be stated that the epistemic belief system does not significantly relate to the amount of e-learning, but it is related with the quality of learning processes in a way that cooperative learning or problem solving remains only at the surface of the topics. This can be a problem for an ICT-based knowledge management within organisation which aims at the distribution of expertise, because for complex problem solving superficial communication processes may be insufficient.

The second research question addressed differences between subjects from organisations of varying sizes. For a discussion of the influence of epistemic beliefs on e-learning practices this question may be of little priority, but it is interesting that the organisation size does not make a difference for the amount of e-learning. Thus, the plausible assumption that bigger organisations offer a better infrastructure for e-learning can be rejected. The only aspect in which organisation size makes a significant difference concerns the distribution of knowledge. The subjects from bigger organisations with 100 employees or more to a higher extent indicate experiences of distribution of knowledge. This is plausible when work related e-learning processes primarily concern inner firm problems which usually must not be communicated outside a company. In big organisations more contact partners are available for distributing knowledge about inner firm problems. However, for effective problem solving it is important that the exchange and distribution of knowledge succeed in the creation of a common ground which allows to conduct deep problem analyses (Sessa & London, 2008). Grounding processes demand time and effort, and both conflict with less elaborated epistemic belief systems.

A further question addressed specific e-learning opportunities related to the type of function held within the workplace. Concerning the amount of e-learning or distribution of knowledge no differences were found, but significant differences were observed concerning the negotiation of meaning. The subjects without leading function reported more experience in negotiating meaning than those who have a leading function. On the basis of the data it is impossible to judge if this result reflects the fact that superiors are to be seen as authorities who do not have to negotiate meaning, particularly because both groups did not differ in the EBI scale belief on authority. However, the epistemic belief system reproduces general opinions and assumptions, whereas the questions on the quality of e-learning addressed inner firm practice which can follow different principles than the answer behaviour in responding to questions on general beliefs.

Conclusions

The findings of this study do not unambiguously confirm the theoretical assumptions about the influence of epistemic beliefs on employees' e-learning activities. On the one hand, the expected relation between epistemic beliefs and amount of e-learning could not be proofed, but plausible explanations were found. Thus, the findings should not be interpreted as a general rejection of this assumption. On the other hand, the findings concerning the quality of e-learning provide evidence that the consideration of epistemic belief systems is relevant for research on e-learning as well as for the implementation of e-learning in organisations.

Epistemic beliefs are important for research on e-learning, because the findings indicate that even if people report to conduct e-learning activities, the quality of their learning processes remains still unclear. The findings of this study indicate that subjects with a less elaborated epistemic belief system stronger agree on the idea that learning is connected with negotiation of meaning and with the distribution of knowledge than subjects who have a more elaborate epistemic belief system. Many studies on e-learning remain on a level of analysis which only covers the amount of e-learning, but do not consider the quality of learning activities. Critical analyses hint that employees do not benefit from e-learning devices in that way as intended. It would be interesting in how many cases failures of e-learning could be explained by the learners' epistemic belief systems, which do not support the full usage of the multidimensional didactical opportunities. The findings suggest the conclusion that research on e-learning under an educational perspective should consider the learners' subjective learning approach, because their epistemic beliefs influence the individual process of making sense of a learning setting. Recently work explains the importance of individual perspectives for an integration of working and learning processes (Billett, 2009).

The results of this study also provide information for improving practice. Enterprises and public administration invested in knowledge management systems and in e-learning devices in order to increase the exchange of expertise within their organisations. However, little is known about systematic evaluations of such efforts and their results. It was discussed above that negotiation of meaning and distribution of knowledge possibly remains on a superficial level if meeting a belief on simplicity of knowledge. That leads to the conclusion that the implementation of knowledge management and e-learning systems should be supported by efforts to establish a learning approach which breaks down ideas of simplicity, quickness and certainty of knowledge. This applies for employees with a leading function in the same extent as for those without. Superiors may be rather oriented towards beliefs on clearly structured knowledge as their lower agreement on negotiation of meaning indicates.

The study is limited by its realisation as an online study; the procedure supported an ICT biased selection of subjects. However, experienced computer users probably have a richer experience with e-learning devices. That also means that their learning attitudes result from a rich variety of practices and experiences which shape individual assumptions about the nature of knowledge construction. Thus, the findings seriously indicate the necessity to consider epistemic beliefs for interpreting and understanding work related e-learning practices.

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Diffusion of Web Supported Instruction in Higher Education – The Case of Tel-Aviv University

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ABSTRACT

This paper describes a study that focused on long-term web-supported learning diffusion among lecturers at Tel Aviv University (TAU), from an organizational point of view. The theoretical models we used to examine this process are Rogers' model for "Diffusion of Innovation" (1995) and Bass's "Diffusion Model" (1969). The study was conducted between the academic years 2000/01 and 2007/08. At that time TAU implemented a project aimed to integrate knowledge technologies in academic instruction. The main results show that the diffusion process among lecturers using web-based instruction was rapid and reached over 77% of the total lecturer population. However, differences in diffusion among lecturers were found in terms of academic units. The diffusion process found behaves similarly to Rogers' Diffusion of Innovation theory and Bass's diffusion model.

Keywords

Web supported learning, Higher education, Diffusion of innovation, Learning management system (LMS)

Introduction

The Internet has recently become a widely used means of instruction in academic institutions. Many educators implement ICT in their curriculum although both academic units and their lecturers differ in their levels of usage of web-supported teaching (Smith, Heindel, Torres-Ayala, 2008). This is reflected in a growing amount of academic websites and web-supported learning environments that offer a variety of instruction modes to augment traditional ones. Some believe that this change has virtually brought about a new learning culture. University leaders and administrators, too, are aware of the pedagogical and economical potential of advanced technologies and how they may help changing the structure of academic instruction. They believe that web-supported instruction should be included in a university's long-term strategy (Allen & Seaman, 2005, 2006; Allen, Seaman, & Garrett, 2007). Making online learning a central part of academic instruction requires organizational and pedagogical adjustments in the role of the lecturer, in subject matter, materials and presentation, and in instruction and learning processes (Bonk & Graham, 2006; Collis, 1999; Nachmias, Ram, & Mioduser, 2006; Wolcott & Betts, 1999). This, in turn, requires that the universities supply the environment and support necessary for online learning implementation and ensure long-term maintenance. However, because of the speed at which web-supported learning has become part of academic instruction there has been insufficient time for adequate preparation. This situation raises questions regarding both the nature and justification of the use of web-supported instruction, as well as the diffusion and adoption of technological innovation processes as a tool for instruction (Bates, 2000; Mason, 2000; Surry, 2000).

Studies addressing mainly micro-level questions regarding web-supported learning are available, but few macro-level studies exist, and even less are dedicated to the empirical examination of long-term diffusion of innovation in education, trying to identify factors affecting the process over time (AFT, 2001; Nachmias, 2002). Findings on the macro-level led to the development of theories and several models dealing with the diffusion of technological change in teaching in general and in higher education in particular. However, so far there has been no consensus regarding the best suitable model or approach for the recommended diffusion process.

This paper describes the results of a study that was conducted during eight academic years (2000/01–2007/08) and dealt with questions at the macro-level, focusing on long-term web-supported learning diffusion in higher education, from an organizational point of view. It does so by referring and comparing the findings to existing models describing adoption of technological innovation. The need to gain a better understanding of the process of diffusion of web-supported learning among lecturers in higher education as well as the causes that affect adoption rate, make this study essential for this field.

The objectives of the study were:

1. To characterize the diffusion process of web-supported academic instruction experienced by lecturers.
2. To forecast lecturers' potential use of web-supported learning.
3. To compare the web-supported academic instruction diffusion model generated by this study with theoretical models of diffusion of innovation.

To achieve these objectives, the following research questions were examined:

1. How does the diffusion process of web-supported instruction in higher education unfold over time?
2. Are there differences in the behavior of lecturers adopting web-supported learning in terms of their academic units? and
3. How does the diffusion process match existing diffusion models of technological innovation, referring to Rogers' (1995) and Bass's (1969) theoretical models?

Data were collected at Tel-Aviv University (TAU) that, in the year 2000, initiated a project aimed to integrate knowledge technologies in academic instruction. As part of the project, a web-supported tool (called *HighLearn*) was used enabling lecturers to construct web sites for their courses. This paper contributes mainly to the theoretical framework by adding knowledge and understanding concerning adoption and diffusion of web-supported academic instruction processes.

Review of the literature

Theories and models dealing with diffusion of innovation usually address questions relating to the success, rate and time of adoption of an innovative "idea" or "product". The current literature deals with such models and theories relating to organizations in general and those in education in particular. The seminal work of Everett Rogers (1995), led to the construction of various diffusion models, but these are not consistent and no unified theory has been generated. Each model focuses on a different aspect of the diffusion process or a different type of innovation or organization. Here, we survey the leading, general diffusion of innovation theories and models and then zoom in on education-related theories more specifically.

General diffusion of innovation theories

Everett Rogers is one of the most quoted theorists in the field of diffusion of innovation. His theory forms the basis for most subsequent work on the adoption and diffusion of innovation, including this study. In his book *Diffusion of Innovation*, Rogers (1995) defines innovation as an idea, object or practice that is perceived as new by the individual or organization. Various individuals may perceive the innovation differently and therefore decide to adopt the innovation at various points in the diffusion process. Thus, diffusion is defined as the process, over time, by which an innovation is conveyed through certain channels among the members of a social system. There are four main components in the diffusion of innovation process, according to Rogers' theory:

1. *Innovation* — an idea, practice, or object that is perceived as new by an individual or any other unit of adopters. There are five characteristics that determine the innovation's rate of adoption: (a) relative advantage, (b) compatibility, (c) complexity, (d) trialability, and (e) observability. Innovations that are perceived as having all these elements will be adopted more rapidly than other innovations.
2. *Communication channels* — the means by which messages get from one individual to another. Mass media channels are more effective in creating knowledge of innovations, whereas interpersonal channels are more effective in forming and changing attitudes toward a new idea, and thus in influencing the decision to adopt or reject it.
3. *Time* — the three time factors are: (a) innovation-decision process; (b) the time in which an innovation is adopted by an individual or group; (c) innovation's rate of adoption.
4. *Social system* — a set of interrelated groups of people that are engaged in joint problem solving to accomplish a common goal.

Rogers claims that the individual goes through five stages in the process of adopting innovation: Knowledge — learning about the existence and function of the innovation; Persuasion — becoming convinced of the value of the innovation; Decision — seeking for additional information and committing to the adoption of the innovation;

Implementation — using the innovation on a regular basis; Confirmation — the acceptance (or rejection) of the innovation by continued use based on the evidence of benefits or drawbacks.

The innovation process spread through society in a way that is reflected by an S-shaped curve, with early adopters selecting the technology first, followed by the majority, until a technology or innovation is considered common. Usually individuals will initially perceive innovations as uncertain and even risky. To reduce uncertainty, most people look for others like themselves who have already adopted the new idea and gained some experience. Rogers (in the latest, 2003 edition of his book "Diffusion of Innovation") argues that the Internet's powerful presence in our daily life speeds up diffusion processes.

Rogers (1995) also proposed a classification of potential adopters based on their receptivity: Innovators (2.5%) — are risk takers willing to take the initiative and time to try something new; Early Adopters (13.5%) — tend to be respected group leaders, the individuals essential to further adoption by whole group; Early Majority (34%) — the careful, safe, deliberate individuals unwilling to risk time or other resources; Late Majority (34%) — those suspicious of or resistant to change. The latter category includes those who are hard to move without significant influence, Laggards (16%) — who are consistent or even adamant in resisting change. Thus the spread of a new technology depends mainly on two types of adopters: the innovators and the imitators. Innovators are driven by their desire to try new technologies while imitators are primarily influenced by the behavior of their peers. The innovation and imitation factors determine *the speed* at which the technology is accepted into everyday use. Most of the studies that refer to Rogers' model (including education-related models) tend to focus on those categories of adopters that predict the speed of the diffusion process (Lin & Jeffres, 1998; Macchiussi & Trinidad, 2001; Surry, 1997). For example, Moore (1999) suggests that the first two categories (innovators and early adopters) form one unit that share features such as high interest in new technologies, new technological opportunities, etc. He claims that suitable strategies would have to aim at the early adoptive majority, as they form the hard core of the diffusion of innovation.

Other theories offer alternative definitions to Rogers' model for diffusion of innovation. One of these is suggested by Midgely and Dowling (1978) according to whom "innovation adoption" is the way that the individual is exposed to innovative ideas and makes her or his own, independent, decisions. Lin and Burt (1975) introduced the term *innovation's need*, defining it as the individual's need for updating himself or herself with new ideas and the willingness to take risks that will affect their decisions regarding the adopting of innovative technologies.

Bass (1969) is another famous theorist in the field of diffusion of innovation and his "Diffusion Model" is one of the most well-known models in the marketing field. It estimates how a new idea or new behavior spreads through the market over time. Bass analyzed the diffusion process through consumers' behavior, under the basic assumption that the probability of initial purchase is related linearly to the number of previous buyers. Buyers or adopters may be innovators or imitators. While the number of previous buyers does not influence innovators in the timing of their initial purchase, imitators are strongly affected by the number of adopters. Bass's model has been successfully used in various fields (industry, retail, agriculture, education, marketing, etc.) in order to forecast growth rate and usage of numerous new and innovative technologies (such as color TV, personal computers, Internet etc.) with an emphasis on predicting the ultimate level of penetration and the rate of potential adoption (Dodds, 1973; Lawton & Lawton, 1979; Mahajan, Muller, & Srivastave, 1989; Nevans, 1972; Tigert & Farivar 1981). This model implies exponential growth of initial purchases to a peak and then exponential decay. The shape of the diffusion curve is therefore a function of the rate at which awareness of the new product develops, as well as of the product's appeal. The model attempts to predict how many customers will eventually adopt the new product and when they will adopt. Bass's equation contains four main parameters: T = the number of consumers who have already adopted the innovation by time t ; N = the total number of consumers that will eventually adopt the innovation; p = the coefficient of innovation or the probability that an innovator will adopt the service at time period t and q = the coefficient of imitation or the probability that a non-innovator will adopt the service as a result of word-of-mouth-marketing and other socially, non-advertising based communications.. The rates of p and q will determine the shape of the diffusion curve. When these parameters are known we can forecast the potential innovation over time. If the curve is S-shaped it means that q is higher than p and the product is innovative (see Figure 1 and Figure 2). If the curve is J-shaped, then q is smaller than p and the product is less innovative and does not involve high risk (see Figure 3).

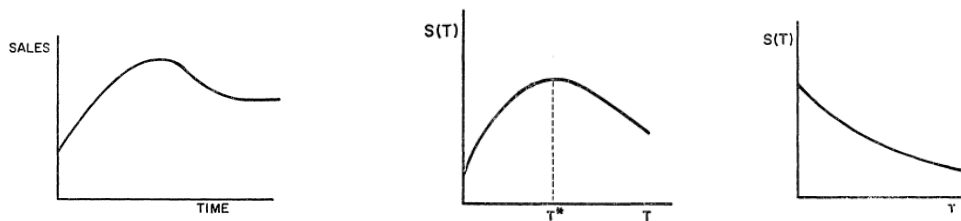


Figure 1: Growth of a new prod Figure 2: Growth rate ($q > p$) Figure 3: Growth rate ($q < p$)
 Note. These graphs were extracted from Bass (1969)

Instructional technology diffusion theories

In recent years, information and communication technologies have become an integral tool in education. As a result various models have been developed in order to deal with the process of diffusion of innovation among instructors. Most of these are based on the general theories for diffusion of innovation, as described above.

Surry (1997) deployed Rogers' theory in the education field, elaborating it to address organizational changes in the education system in general and in higher education in particular. In 2002, Surry developed a model for integrating instructional technologies into higher education. This model, called *RIPPLES*, consists of seven elements: Resources, Infrastructure, People, Policies, Learning, Evaluation and Support. Various studies strengthen the importance of these elements for successful adoption of web-supported learning (Derntl & Motschnig-Pitrik, 2005; Molenda & Sullivan, 2002; Ajjan & Hartshorne, 2008; Garrison & Kanuka 2004; Grant, 2004).

Harris (1994) used Rogers' model in order to understand what happens when we integrate technology into an organization and so as to teach teachers to use telecomputing tools. Based on her own experience with teachers, she suggests ten "tips" for teaching teachers that mainly relate to the necessary technological infrastructures as well as access availability. Her work emphasizes the need to provide local and longitudinal training accompanied by user-friendly guidance and instruction. She also advises to encourage and support those teachers who are most motivated to introduce the Internet (or technology tools) to others, this will allow the growth of use of grass-roots patterns.

Hall and Hord (1987) developed the Concerns Based Adoption Model (CBAM) that deals with changes in the education system as a result of the introduction of technologies in teaching curricula. The model focuses on the role of people within the organization in facilitating the innovation diffusion and includes three main elements: stages of concern; level of use and innovation configuration. There are, moreover, seven stages of concern, from awareness to refocusing, on which people within the organization can be situated.

Ely (1990) developed a strategy for implementing instructional technology innovation. He contends that implementation, the phase after adoption and before confirmation in Rogers' model, is a vital and essential part of the innovation process. Sometimes organizations tend to overlook this phase, but in order to succeed in the diffusion process you have to plan the implementation strategy. Several conditions must exist for planning an implementation strategy: skills and knowledge, availability of resources, availability of time, rewards and/or incentives, participation, commitment and leadership. Between and among these conditions interactive relations obtain, so each of them may affect the others.

Shea, Pickett, and SauLi (2005), used Rogers' theory in order to analyze the factors that prevent faculty from using technology in their class. They examined 913 lecturers in universities in the United States and found that factors such as level of interaction during the course, technical support, positive previous experience, university department and course content affect faculty's attitude to integrating technology tools in teaching.

Methodology

The study was conducted over eight years at Tel-Aviv University (TAU), the largest research-oriented university in Israel. Located in the center of the country it serves about 27,000 students annually. These students are enrolled in

about 6000 courses annually that are taught by about 2500 instructors in almost every academic discipline. The Virtual TAU (VT) project was based on an innovative idea developed by a small group of lecturers from the School of Education. The project aimed to initiate and catalyze a process in which more and more lecturers would use web tools to enrich learning processes and to make instruction more efficient and flexible. The lecturers design the course website according to their own approach using *Highlearn*, a Learning Management System (LMS). Similar to other LMS (e.g., Blackboard, MOODLE) *Highlearn* allows the easy creation of an information tree for the course content and didactic activities, and supplies both synchronous and asynchronous communication tools. In addition, it provides tools that assist the instructor in administrating the course (e.g., course scheduler, test builder, address book).

A key principle of the project is that instructors maintain full responsibility for the course website. It is their views of the objectives, syllabus, and instructional methods that lead the development and the implementation of the course. No pre-designed pedagogical solution is imposed. Most of the project activities are aimed at empowering the instructors, helping them in the realization of their pedagogical vision. In order to assist the instructor a central support center was established.

During the study, we counted, for each semester and for each year, the number of courses, faculty and students using VT. Data were collected by a data-mining tool (Power Data) supporting the VT online activity. The research population included all lecturers using VT at the university in nine academic units and two schools: Art, Social Sciences (including the School of Social Work), Management, Humanities, Engineering, Life Sciences, Exact Sciences, Law, Medicine, and the School of Education. The research method combined quantitative and qualitative approaches.

Results

This section presents the results of the VT diffusion process in TAU throughout the eight-year period, from the project's initialization. The results will be described with reference to the three research questions, i.e.:

1. How does the diffusion process of web-supported instruction in higher education expand over time?
2. Is there a difference in the behavior of lecturers adopting VT in terms of their academic units? and
1. 3. How does the diffusion process match existing diffusion models of technological innovation, referring to Rogers' (1995) and Bass (1969) theoretical models?

The results will focus on the diffusion process among lecturers and courses over time.

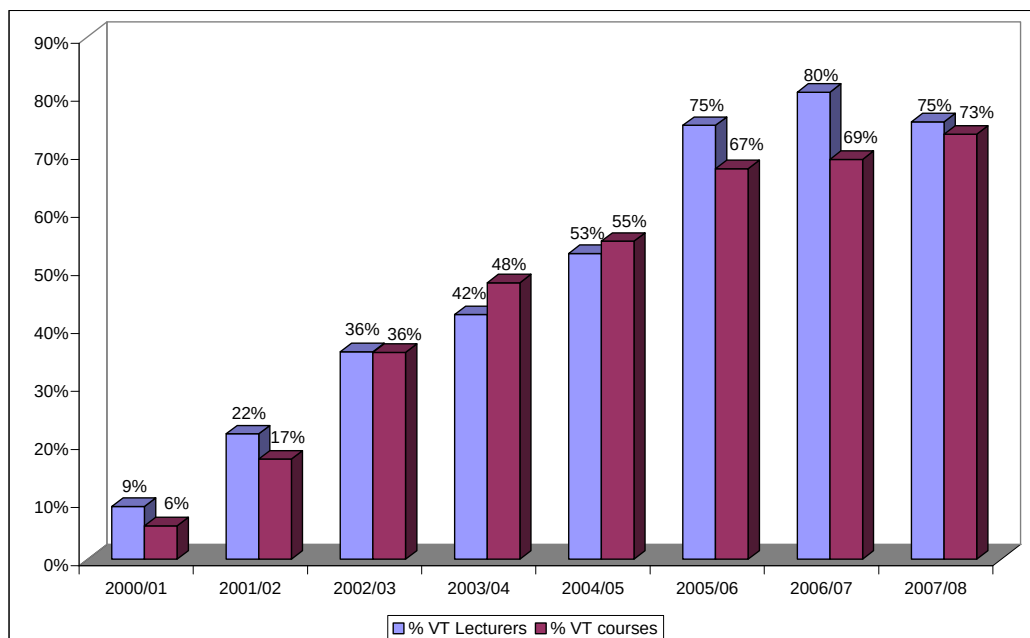


Figure 4: Percentage of Lecturers and Courses using VT over time

The diffusion process of web-supported instruction at TAU

VT diffusion among lecturers and academic courses

Data presented in Figure 4 describe the process of VT diffusion among lecturers and courses. The rate of diffusion of VT among lecturers was rapid and started from 227 lecturers in the first academic year to 2,012 lecturers in the eighth year. The percentage of lecturers who used VT relative to the total number of senior and junior teaching staff (2500 on average for this period) also increased from an initial 9% to 77% at the end of the eighth academic year.

Another way of assessing the diffusion process is to look at the number of academic courses into which lecturers integrated VT. Here we in fact analyze the diffusion process of academic courses that use VT. Figure 4 shows the results of this process over the eight years of the study. In the first year of the project the number of courses that used VT was 346, i.e., 6% of the total academic courses taught at that time. This number increased and reached 4,395 courses, or 73% of the total academic courses, by the end of the eighth academic year of the process, with each lecturer teaching an average of 1.8 courses integrating VT.

VT diffusion process among lecturers by academic unit

We examined the diffusion process among lecturers by academic unit during the first five years of the project. The faculty unit is a very important factor for understanding the diffusion process among lecturers. These academic units are organized as independent units and have considerable influence on lecturers' educational behaviors through for instance content and curricula, pedagogical methodologies, infrastructure technology and support and management decisions. The unit's influence becomes more important in adopting web supported learning that requires available technological support. Figure 5 describes the distribution of lecturers using VT as compared to the total lecturers at their unit, over time and among the various academic faculties. The results show significant differences in terms of academic unit concerning the lecturers' VT usage. In about half of the units, the percent of lecturers adopting VT exceeded 50% of the total lecturers in the unit. The rate was especially high at the School of Education, where the percentage of lecturers adopting VT was (83%, N=110), followed by the Faculty of Arts (80%, N=325) the Faculty of Engineering (69%, N=186) and the Faculty of Social Sciences (61%, N=315). On the other hand, low levels of adoption were found at the Faculty of Life Sciences (34%, N=156) and at Exact Sciences (13%, N=323). One of the reasons for these low results at the Exact and Life Sciences was that the lecturers in those units tend to use their own web-sites tools for instruction.

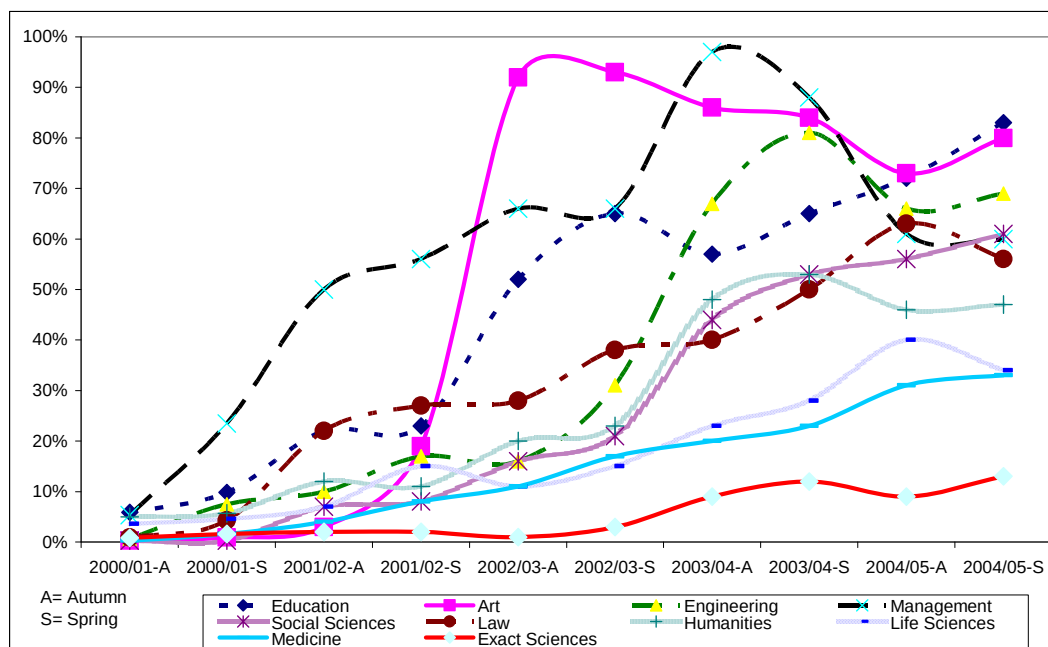


Figure 5: Percentage of lecturers using VT by academic units

The diffusion model of VT among lecturers at TAU according to Rogers' model

We analyzed Rogers' diffusion model at the university level as well as in each academic unit level in each semester of these five years.

VT diffusion model among lecturers at TAU

Figure 6 presents Rogers' diffusion curve compared with TAU lecturers adopting VT each semester. In this figure the diamonds represent the percentage of new lecturers adopting VT, while the curve represents Rogers' Diffusion of Innovation model. In addition, the broken lines represent Rogers' adopters' categories. We can see that the innovators started to use VT at the beginning of the process (2000/01-A). The early adopters group joined the process in the second year (2001/02-A), followed by the early majority and the late majority groups at the third and fourth years of the diffusion process. At the end of the fourth year and in the fifth year of the VT diffusion process we start to see a declining trend in the percent of lecturers who adopt VT, and this represents the so-called laggards. The most significant years for the VT diffusion process were between the third and the fourth years, when most of the potential adopters already joined VT. Results show that VT adoption among lecturers was a rapid process that behaved similar to Rogers' model for diffusion of innovation.

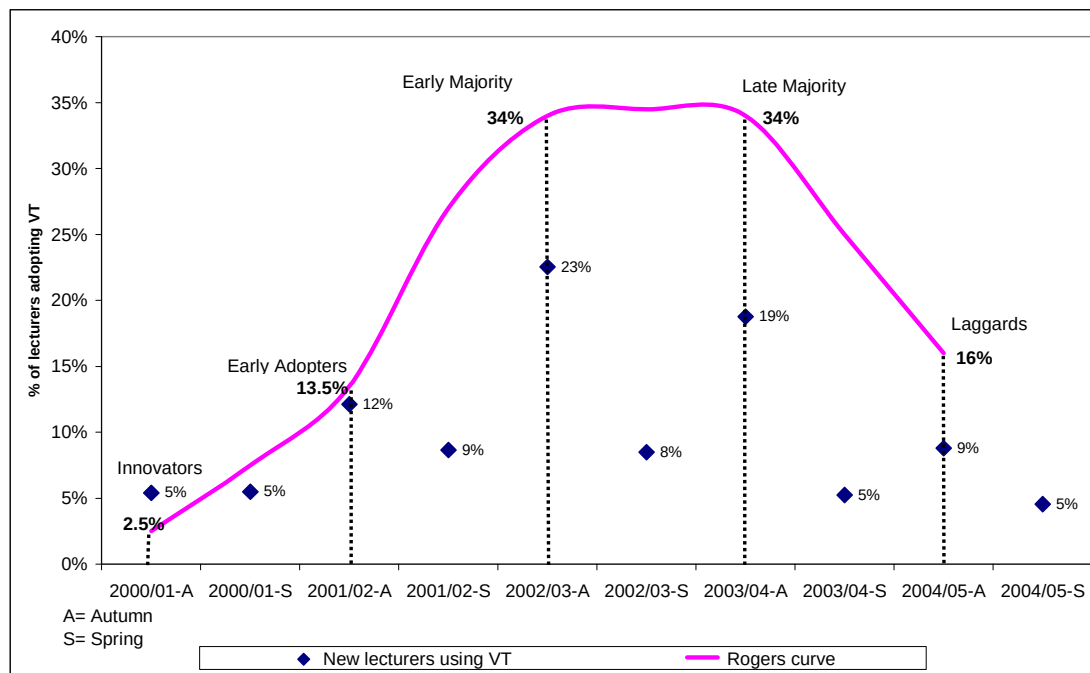


Figure 6: VT diffusion compared to Rogers' diffusion model

VT diffusion model among lecturers according to academic units

Rogers' diffusion model, when applied across the different academic units, shows important differences between them. For example, in the unit of Social Sciences, the diffusion process was very slow to begin with and only after the third year started to grow more rapidly, compared to the Management unit where the diffusion process was rapid from the beginning and declined after the third year. In some units no consistency in the diffusion process over time was found. In the Humanities, Art and Engineering units there was a negative trend in the fifth year, which indicates that the number of lecturers who were adopting VT was smaller than those who stopped using it. At the Management Faculty, for instance, most of the lecturers were classified as innovators. About 90% of them adopted VT in the first year of the project while in the fifth year we found a negative trend, suggesting that some of them were no longer using VT. A similar trend occurred at the Law Faculty, with a high rate of innovation adopters early on in the project, declining over time, but staying stable until the fifth year. In other units - such as Engineering (70%),

Humanities (68%), Exact Sciences (60%) and Social Sciences (57%) - we found that the late majority adopters were the hard core of the process. In these units we identified lecturers' need to first hear and be sure about VT usage benefits. We also found that the unit's policy toward VT adoption was very important and had a major affect on the lecturers' decision to adopt the tool.

VT diffusion model according to Bass's model

In order to predict the diffusion model of VT among lecturers we used the Bass Diffusion Model (1969). This model allows us to estimate the number of potential VT adopters in the university by providing a mathematical formula for predicting the rate of adoption.

Bass Diffusion Model of VT among lecturers at TAU

Figure 7 presents the results of Bass's diffusion model among lecturers using VT. The results show that $m=0.77$, $p=0.036$ and $q=0.524$. This means that the percentage of lecturers who use VT may reach up to 77%. It also shows that VT is perceived as an innovative product among TAU lecturers. Looking at values p and q we could say that the diffusion process developed slowly at the beginning and gained speed over time. These results show that the diffusion process was mainly influenced by the imitators group who were influenced by interpersonal communication channels (mostly peers and/or academic colleagues). The innovators, on the other hand, had much less influence on the VT diffusion process.

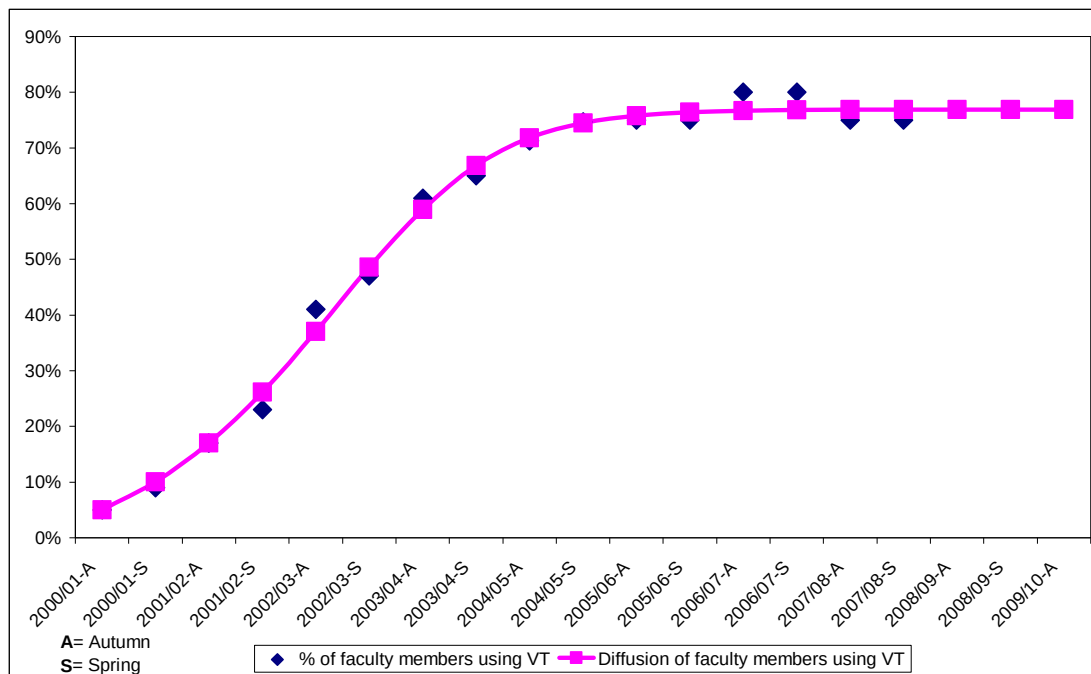


Figure 7: VT diffusion among lecturers according to Bass's model

Bass's diffusion model of VT among lecturers at academic units

Bass' diffusion model was examined separately for each unit. Table 1 presents the values of the three parameters that predict the diffusion model in each academic unit. From the resulting values we could observe the variance between the academic units. In general the unit (except Law) behaves according to an S-shaped curve with q being higher than p . The percentage range of potential adoptions of VT among lecturers is 35% to 84%, depending on the academic unit. These results are similar to those of the total lecturers at the university and support the idea that VT is perceived as an innovative product and that the process is mostly affected by imitators (those affected by

interpersonal communications). In some academic units such as Management, Law, Medicine and Education, we saw high values of p - even higher than in relevant Meta analysis studies (Lilien & Van den Bulte, 1999; Van den Bulte, 2002). This indicates innovators' significant influence on the diffusion process as well as its' speed. In other units such as Art, Engineering, Life Science, Humanities and Social Sciences the q value is high, pointing at high influence of the imitators.

Table1. Diffusion model's values for potential adoption of VT among lecturers

Academic Unit	p	q	m
Faculty of Art	-0.001	3.560	0.84
Faculty of Engineering	-0.004	1.593	0.71
Social Sciences	0.014	0.959	0.59
School of Education	0.062	0.451	0.79
Life Sciences	-0.134	1.391	0.35
Exact Sciences	0.002	0.259	1.16
Law Faculty	0.070	0.020	1.17
Management Faculty	0.260	0.413	0.74
Humanities	-0.161	1.681	0.48
Medicine Faculty	0.040	0.340	0.44
Total lecturers at TAU	0.036	0.520	0.77
Students	0.059	0.345	0.87
<i>Examples from Bass' Innovation models researches</i>			
Values of compared means	0.016	0.409	-
Values of compared means (Lilien & Van den Bulte, 1999)*	0.040	0.398	-
Cellular telephone diffusion period of 10 years (Van den Bulte, 2002)	0.008	0.427	0.45

*Meta analyses that compared values of diffusion of new technologies.

We also analyzed the Bass Diffusion Model of VT among students during this period. The results show that the percentage of students at the university who use VT reaches 87% ($m=0.87$, $p=0.059$ and $q=0.345$). This is a high rate of diffusion and it shows that VT is perceived as an innovative product by both lecturers and students; the latter actually reflect the lecturers' behavior.

Discussion and Conclusions

This paper is part of a broad-scope research study that deals with questions on the macro-level concerning the diffusion of web-supported learning in higher education and the factors that affect lecturers in adopting technological instructional tools.

The rate of adoption of VT for instructional purposes among lecturers was rapid. Our results strengthen those of previous studies that claim that the transformation process that integrates an innovative initiative through diffusion takes about five years (Collis & Moonen, 2001). Most lecturers joined the mainstream: the diffusion process started with 5% of the total lecturers using VT in their courses, rising to 77%, which indicates great success of the process in Tel Aviv University. It is important to mention that the total percentage of lecturers who are actually using ICT in academic instruction is even higher than reflected in this study, because there are lecturers (especially in the Exact Sciences) who use other technological tools than the ones offered by VT. Differences were found in the VT diffusion process among lecturers in different academic units. In about half of the units the percentage of lecturers who used VT was over 50% of the total lecturers in their unit. The highest percentage was found at the School of Education (83%), which was the initiator of the process, and the Faculty of Art (80%), which decided on a central policy to adopt VT. On the other hand, a very low percentage was found at the Exact Sciences faculty, whose staff uses their own websites as mentioned above. As of that we could claim that the academic unit' policy has a central affect on the speed and success of the diffusion process. It should be noted that during the research period various external factors (e.g. bandwidth, upgrade of the VT tool) may have affected the rate of adoption. These factors were not addresses in this study.

Another parameter examined relates to the diffusion of VT in academic courses. This diffusion process allows us to look at the change from traditional face-to-face learning toward web-supported learning or *blended learning*, as mentioned in Bonk and Graham (2006). The results indicate that the total percentage of academic courses that integrated VT reached 73% (of total academic courses) at the end of the eighth year of the diffusion process. These findings confirm the literature that argues that most current academic courses are enhanced by web-supported tools (Allen & Seaman, 2005, 2006; Allen, Seaman & Garrett, 2007; Shemla & Nachmias, 2007).

VT diffusion among lecturers at TAU matches Rogers' model for diffusion of innovation. However, it is important to mention that the diffusion of VT among the lecturers according to their academic units is not uniform and in some units it did not match Rogers' model. The findings show that by the start of the third year of diffusion a high rate of 50% among the potential adopters were using VT in their courses. These groups included the Innovators, Early Adopters and Early Majority. The results strengthen Moore's (1999) argument, that the first two groups of adopters have significant influence on the diffusion process curve. If those first two groups have significant mass they can easily influence the other potential adopters and speed up the diffusion of the innovation. This is unlike Rogers' diffusion model, that gives high importance to both groups of adopters, "early and late majority".

In order to predict the number of VT adopters at the university we used the Bass diffusion model. The findings show that VT diffusion behaves similar to the behavior of an innovative diffusion product. The rate of adoption among lecturers is predicted to reach 77% of the total lecturers and 87% of total students in the campus by 2009. The rate of potential adopters among lecturers varies from one academic unit to the other and ranges between 35% and 84%. It is, therefore, interesting to consider the different values of the models' parameters as explaining the rate and potential of VT adoption among lecturers. Thus, in some of the academic units such as Art, Engineering, Life Sciences, Humanities and Social Sciences the q value was high, which indicates that interpersonal communications channels were the major factor affecting the diffusion process. Lecturers from these units first needed to hear other opinions on using VT and to be convinced of its advantages. In other academic units such as Management, Law and the School of Education the value of p was higher, compared to other units at the university as well as other studies (Van den Bulte, 2002). In those units innovators were mostly affected by external sources. As a result we saw that type of academic unit has a major influence on the success of web-supported learning diffusion. Its influence concerns both the lecturers' initial decision to adopt the new technology tool for instruction and their further wish to continue the usage of web-supported instruction. Furthermore, existence of support policy at the academic unit, as well as campus wide support, is important for a successful diffusion of web-supported instruction among lecturers.

The diffusion of web-supported learning in conservative organizations like the university is rapid and intense. This allows us to examine the process until it reaches saturation level. The study shows that the process of diffusion of web-supported instruction into academic institutions matches Rogers' Diffusion of Innovation theory and Bass's diffusion model, which both characterize the introduction process of an innovative product. One may, hence, explain additional aspects of the process by means of these theories and forecast the potential usage of web-supported learning and its rate of diffusion in academic instruction in general.

In conclusion, the Internet revolution has become a reality. The information technologies, which in the recent decade started penetrating every field of our daily life, have entered education as well. Integrating instructional technology into higher education is no longer a nice extravagance but a "must have" for all universities. A rising demand from students for web-supported learning has led universities to recognize the need to implement technological tools into the teaching curricula. In this context it is important to clarify that the diffusion of web-supported academic instruction takes the shape of two parallel processes: The first focuses on having web-supported instruction interface and the second focuses on the depth of usage patterns within the web-supported interface (i.e., integrating web-supported learning materials and communication activities). As mentioned above, the diffusion process of web-supported learning is rapid and intense. The diffusion of usage patterns, by contrast, is in its initial stages (Soffer, 2006). We must not be misled by the success of web-supported learning diffusion, since the objective of significant improvement of teaching has yet to be achieved. To do so, deployment and long-term commitment is required by all the relevant partners: university leaders, managers and academic staff.

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Computer Games for the Math Achievement of Diverse Students

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ABSTRACT

Although computer games as a way to improve students' learning have received attention by many educational researchers, no consensus has been reached on the effects of computer games on student achievement. Moreover, there is lack of empirical research on differential effects of computer games on diverse learners. In response, this study empirically examined the effects of playing computer games on math achievement of 4th graders, with special focus on gender and language minority groups. The study used the 2005 National Assessment of Educational Progress (NAEP), a nationally representative database of the USA. The study performed regression analyses using more than 170,000 U.S. 4th-grade students by applying a proper weight and considering design effects to have high generalizability. The study specified three models for analyses: ELL Model, Gender Model, and Interaction Model. The results showed that English-speaking students who played computer math games in school every day displayed significantly lower math achievement than those who never played. Contrastingly, positive effects of daily computer use were noted among male students whose first language was other than English. Male language minority students who daily played computer games in math demonstrated higher math performance scores compared with their male English-speaking counterparts who never played.

Keywords

Computer games, math achievement, linguistic minority, gender difference, large-scale data

Introduction

As a way to improve student academic performance, educators have begun paying special attention to computer games (Gee, 2005; Oblinger, 2006). Reflecting the interests of the educators, studies have been conducted to explore the effects of computer games on student achievement. However, there has been no consensus on the effects of computer games: Some studies support computer games as educational resources to promote students' learning (Annetta, Mangrum, Holmes, Collazo, & Cheng, 2009; Vogel et al., 2006). Other studies have found no significant effects on the students' performance in school, especially in math achievement of elementary school students (Ke, 2008).

Researchers have also been interested in the differential effects of computer games between gender groups. While several studies have reported various gender differences in the preferences of computer games (Agosto, 2004; Kinzie & Joseph, 2008), a few studies have indicated no significant differential effect of computer games between genders and asserted generic benefits for both genders (Vogel et al., 2006). To date, the studies examining computer games and gender interaction are far from conclusive.

Moreover, there is a lack of empirical studies examining the differential effects of computer games on the academic performance of diverse learners. These learners included linguistic minority students who speak languages other than English. Recent trends in the K-12 population feature the increasing enrollment of linguistic minority students, whose population reached almost four million (NCES, 2004). These students have been a grievous concern for American educators because of their reported low performance.

In response, this study empirically examined the effects of math computer games on the math performance of 4th-graders with focused attention on differential effects for gender and linguistic groups. To achieve greater generalizability of the study findings, the study utilized a US nationally representative database—the 2005 National Assessment of Educational Progress (NAEP).

The following research questions guided the current study:

1. Are computer games in math classes associated with the 4th-grade students' math performance?
2. How does the relationship differ by linguistic group?
3. How does the association vary by gender?

4. Is there an interaction effect of computer games on linguistic and gender groups? In other words, how does the effect of computer games on linguistic groups vary by gender group?

Literature review

Academic performance and computer games

According to DeBell and Chapman (2004), of 58,273,000 students of nursery and K-12 school age in the USA, 56% of students played computer games. Along with the popularity among students, computer games have received a lot of attention from educators as a potential way to provide learners with effective and fun learning environments (Oblinger, 2006). Gee (2005) agreed that a game would turn out to be good for learning when the game is built to incorporate learning principles. Some researchers have also supported the potential of games for affective domains of learning and fostering a positive attitude towards learning (Ke, 2008; Ke & Grabowski, 2007; Vogel et al., 2006). For example, based on the study conducted on 1,274 1st- and 2nd-graders, Rosas et al. (2003) found a positive effect of educational games on the motivation of students.

Although there is overall support for the idea that games have a positive effect on affective aspects of learning, there have been mixed research results regarding the role of games in promoting cognitive gains and academic achievement. In the meta-analysis, Vogel et al. (2006) examined 32 empirical studies and concluded that the inclusion of games for students' learning resulted in significantly higher cognitive gains compared with traditional teaching methods without games. Similarly, Annetta, Mangrum, Holmes, Collazo, and Cheng (2009) tested the effects of educational computer games by incorporating them into a 5th-grade science class and found significantly positive results in the students' performance. Similar positive effects were observed in math performance by Ke and Grabowski (2007). They tested the effects of cooperative computer game-playing on the math achievement of 125 5th-graders compared with competitive game-playing and non-game-playing groups. The authors observed significantly higher improvement in math performance in both computer game-playing groups compared with the non-game-playing group.

However, other studies have not shown the same positive effects of games. By controlling for important contextual variables such as Socioeconomic status (SES), gender, and prior math achievement, Ke (2008) tested the effect of educational computer games compared with traditional paper-and-pencil drills. Ke did not find a significant effect of games on the math achievement of 487 5th-graders. In another study, Ke (2008) recruited 4th- and 5th-graders to play educational math computer games during the summer math camp and measured their math ability at the onset of the program. At the post-test, the author found no significant effect of computer games on math achievement.

As discussed above, despite increasing interest in computer games, there has been no consensus on their effects on academic achievement. To provide knowledge in this regard using a US nationwide database, the current study empirically examined the effect of educational computer games in school on the math achievement of 4th-graders.

Linguistic minority students, computers, and school performance

Recent statistics indicate that the number of linguistic minority students has increased rapidly, reaching almost four million in the US K-12 school system (NCES, 2004). In line with the dramatic growth in the number of those students, there has been a persistent effort by educators to close the performance gap. Liu, Anderson, and Thurlow (2000) studied Minnesota statewide assessment results and investigated the passing grade rate and average score of math achievement of 8th-graders for the period from 1996 to 1999. They reported the lower passing rate and average math score of linguistic minority students compared with their native English-speaking peers. Similarly, using the NAEP 2005, Perie, Grigg, and Dion (2005) found that 46% of 4th-grade linguistic minority students scored "Below Basic" in comparison with 18% of native English-speaking students.

As a potential way to improve the performance of linguistic minority students, some researchers have explored the use of computers (Ganesh & Middleton, 2006). These efforts are of critical importance for the increasing population of linguistic minority students. While there is a limited amount of research to empirically examine the effects of computer use to improve the math performance of linguistic minority students (Clarkson, 2008), a few studies have

reported that new features of computer promoted the participation of linguistic minority students in class activities by aiding their limited language ability (Gerbic, 2006). Out of new computer-related technologies, computer games have received a great deal of attention as a potential way to improve students' performance. However, there is a dearth of research to examine the differential effects of computer games on linguistic minority students.

Computer games and gender

Of various learner characteristics in relation to computer games, researchers have been interested in gender differences. In a review paper that studied previous research regarding computer games, Agosto (2004) found that both genders at the preschool age showed the same enthusiasm in computer games. However, the girls' excitement for the games starts decreasing as early as kindergarten age or as late as age 13. A study done by Young and Upitis (1999) showed the gender difference in the involvement with computer games. The authors conducted a study for 98 boys and girls aged 8 to 12 years, and their teachers encouraged the students to use computer games weekly. The authors discovered that boys played computer games more frequently and longer than girls, and discussed the games with other boys even during their free time to exchange the information and share the game strategies. Kinzie and Joseph (2008) conducted a survey on 44 students and presented a list of gender differences related to games among middle school aged students: More boys (more than 80%) played the computer game compared with girls (less than 30%); Students prefer games with characters of the same gender as theirs; girls prefer creative and explorative play, while boys prefer active and strategic play. In a similar vein, Hartmann and Klimmt (2006), based on two survey results—conducted respectively on 317 and 795 individuals of an average age of 21—found gender-specific preferences for game features. They showed that females enjoyed games featuring meaningful social interactions but were less attracted to competitive aspects of games compared with males.

Is there a gender difference in cognitive gain when students play games in school? Vogel et al. (2006), through the meta-analysis of various studies on gender, showed that there is no significant performance difference between the two genders and concluded that both genders benefited from games cognitively. Also, Annetta, Mangrum, Holmes, Collazo, and Cheng (2009) found no significant gender difference in science achievement in examining the effect of games on the science achievement of 5th-graders. On the same note, Ke and Grabowski (2007) tested the differential effect of games on the math achievement of 5th-graders of two genders. The study did not observe the main effect for gender or interaction effects between gender and computer games on the math achievement of 5th-graders. Papastergiou (2009) investigated the effects of computer games on science achievement of 88 high school students, finding no gender differences. Students who used computer games for their learning, regardless of gender, showed significantly better academic achievement, compared with students who did not use computer game.

Despite various gender differences in relation to games, the literature has shown no differential effects of games on the academic performance of students of either gender. Although the existing studies utilized statistically advanced designs such as a pre-test/post-test quasi-experimental design, there is a lack of studies using large-scale data to obtain high generalizability in the results. Therefore, the current study utilized a nationally representative US database to explore the differential effect of games on the two gender groups.

Methods

Data collection and procedure

The study used the NAEP 2005, a nationally representative US dataset, from the National Center for Education Statistics (NCES), a division of the US Department of Education. The NAEP gathers data every year on the US fourth-, eighth-, and twelfth-grade student achievement scores in various subjects such as reading, mathematics, writing, science, US history, and civics. The data collection method is a multi-stage probability sample design: in the first stage, units are the US counties (Primary Sample Units: PSU), the second-stage units are schools within the counties, and the last-stage units are students.

The NCES provided teachers with surveys to collect information on teacher instructional practices, educational context, and student behaviors. Although there are no available reported reliability and validity indices, the NCES made efforts to ensure the reliability and validity of measures. They had two or three experts construct the

questionnaires and scored the responses to ensure the reliability and validity of measures: at first an experienced rater scored the samples of responses; and when the first rating is finished, the second rater scored the responses. For several measures, even the third rater evaluated the responses.

The study used the 4th-grade math database of the NAEP 2005 for analyses. The study applied a weight and design effect adjustments to reach conclusions with high generalizability, which would represent the outcome of all US 4th-grade students. The student overall weight (ORIGWT) along with replicate weights (SRWT01-SRWT62) was used for the weight; Primary Sampling Unit (SCRPSU) and Stratum (REPGRP1) were applied for the design effect adjustment. The additional benefit of the application of the weight and design effect adjustment was the alleviation of the problems caused by oversampling of English Language Learners (ELL) and minority ethnic groups. The study used the Item Response Theory (IRT) scale scores to measure students' math achievement with five plausible values (MRPCM1-5).

The study attempted to control for the socioeconomic status (SES) of students, which is an important contextual variable for student academic performance. The study chose the variable of eligibility for the free school lunch program (Free_Lunch_Eligibility) as a proxy of SES because the 4th-grade math database of the NAEP 2005 does not contain the SES variable. Gender (Male=1; Female=2) and linguistic (Non-ELL=1; ELL=2) variables were also used for the study. These two variables were converted into two dummy variables: the dummy gender variable (Male=0; Female=1) and the dummy linguistic group variable (Non-ELL=0; ELL=1), respectively. The conversion into dummy variables enabled us to have a straightforward interpretation of the effect of computer game. In other words, the reference groups (Male and Non-ELL students, respectively) would be located on the intercept and, thus the effects on other groups would be interpreted as compared to the reference group. .

A computer game variable, the frequency of computer game use in math class, was the chief predictor variable which was teachers' response to the question, "How often do you have students play mathematics computer games?" The response was originally measured by a 4-point scale (1=Never or almost never; 2=Once or twice a month; 3=Once or twice a week; 4=Every day or almost every day). The study used three scales by combining "once or twice a month" and "once or twice a week" into "sometimes" and converted into two dummy variables: "Game_Sometimes" and "Game_Daily." Therefore, the reference group for these two variables was the student group that never played the math computer games.

The two computer game variables were also used by creating interaction variables with gender and linguistic group variables. The interaction variables with gender were named as "Gender*Game_Sometimes" and "Gender*Game_Daily," while the interaction variables with linguistic groups "ELL*Game_Sometimes" and "ELL*Game_Daily."

The study's analyses were done by splitting the total database into two gender groups to examine the differential effects of math computer games on two linguistic groups within each gender group.

Analysis

As a preliminary analysis, the study used graphical presentation to show the relation between computer game frequency and math achievement of both male and female students, respectively, among non-ELL and ELL students.

The study's main statistical analysis was multiple regression analysis using AM Statistical Software, which enabled the study to apply the weights and adjust design effects (Cohen, 2005). To explore the research questions of the study, three separate hierarchical regression analyses were conducted: ELL Model, Gender Model, and Interaction Model. The ELL model examined the differential effect on language minority student group as compared to that on the majority group. The gender model compared the effects of computer games for male and female students. Built on the two models, an interaction model analyzed the interaction effect of computer games. In other words, the interaction model explored the differential effects of computer games for linguistic groups contingent upon gender groups.

Results

Descriptive statistics, correlation, and graphical representation

Table 1 presents descriptive statistics and inter-correlations of all variables. The total weighted number of students used for the analyses was 3,732,411. And the total number of teachers who responded to the survey was 32,898.

Among all students, non-ELL students comprised 90.9% of the sample, while ELL students comprised 9.1%. The average math score was 237.871 on a 0-500 scale. The mean math score for males (mean: 239.110) was higher than that of females (mean: 236.598), and the mean math score of non-ELL students (mean: 239.927) was higher than that of ELL students (mean: 216.317).

Two dummy computer game variables also had significant relations with math scores, but in different ways. The students who played computer games sometimes showed high math scores ($r=0.031$, $p<.01$), but those who played computer games everyday tended to have low math scores ($r=-0.028$, $p<.01$).

The correlation results revealed that all variables had significant relationships with math scores. The variable of “Free_Lunch_Eligibility” showed a significant relationship with math scores ($r=0.404$, $p<.01$).

Table 1. Correlation and descriptive statistics

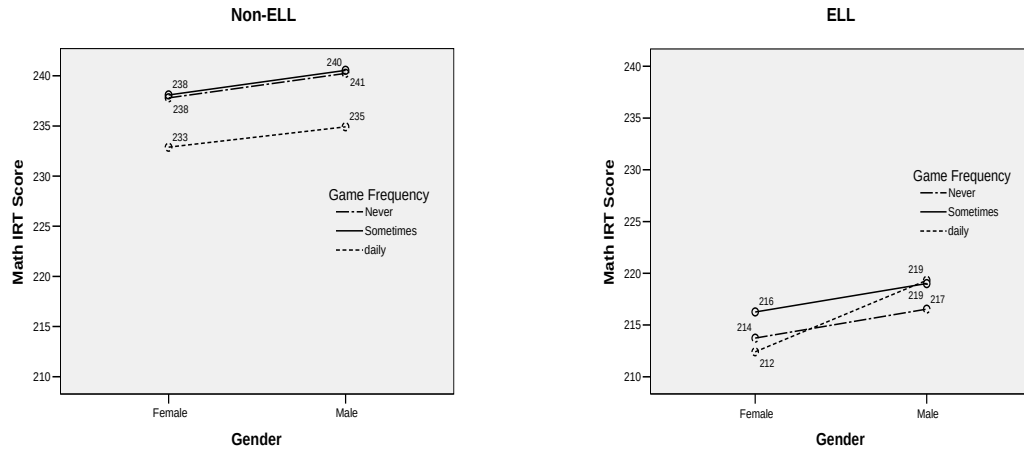
Variable	1.	2.	3.	4.	5.
1. Math IRT Score	—				
2. Free_Lunch_Eligibility	0.404**	—			
3. ELL	-0.243**	-0.247**	—		
4. Game_Sometimes	0.031**	0.035**	-0.037**	—	
5. Game_Daily	-0.028**	-0.026**	-0.018**	-0.270**	—
Mean	237.871	1.549	0.090	0.650	0.038
SD	28.410	0.498	0.287	0.477	0.190
Weighted N	3732411	3053698	3053698	3053698	3053698
	Percentage	Weighted Frequency		Math Mean	
Gender					
Male	51.0		1964708		239.110
Female	49.0		1888341		236.598
ELL					
Non-ELL	90.9		3482474		239.927
ELL	9.1		366130		216.317

Note: () indicate weighted cases

** indicate $p<0.01$; * indicate $p<0.05$

Figure 1 displays the association between computer game frequency and math achievement for non-ELL students. Overall, the effect of computer games was greater for males than for females, with a similar pattern for both genders. The pattern indicated that when students played math games sometimes, they displayed the highest math performance (mean for males=241; mean for females=238) among the three groups. The second performance group was the students who did not play math games at all (mean for males=240; mean for females=238), and the lowest performance group was the students who played math games everyday (mean for males=235; mean for females=233). The results highlight the finding indicating that daily math game for non-ELL students was negatively associated with math performance.

Figure 2 shows the relation between computer game frequency and math achievement for ELL students. The association patterns for ELL students were quite different from those for non-ELL students. The male ELL students demonstrated high math performance when they played math games sometimes (mean=219) or daily (mean=219), while male students displayed low performance (mean=217) when they never played math games. The female ELL students had the highest math performance when they played math games sometimes (mean=216), the second highest when they did not play (mean=214), and the lowest when they played every day (mean=212).



Figures 1-2. Mathematics Performance of Female and Male Students within Non-ELL and ELL groups

Regression Analyses

In this section, we presented three separate models as shown in Table 2. The 1st and 2nd models examined the differential effect of math games on the linguistic and the gender groups, respectively. The last model explored the differential effect for the linguistic groups embedded into male and female groups.

Table 2. Regression Results

Gender				
	Coefficient	(SE)		
Constant	204.471**	(0.586)		
Free_Lunch_Eligibility	21.994**	(0.310)		
Gender	-2.341**	(0.335)		
Game_Sometimes	0.802*	(0.384)		
Game_Daily	-2.795**	(1.014)		
Gender*Game_Sometimes	-0.199	(0.421)		
Gender*Game_Daily	1.530	(1.010)		
Total R ²	0.152**			
ELL				
	Coefficient	(SE)		
Constant	208.138**	(0.552)		
Free_Lunch_Eligibility	19.953**	(0.306)		
ELL	-15.635**	(0.758)		
Game_Sometimes	0.225	(0.309)		
Game_Daily	-3.086**	(0.881)		
ELL*Game_Sometimes	1.677	(0.941)		
ELL*Game_Daily	4.215	(2.328)		
Total R ²	0.170**			
Male			Female	
	Coefficient	(SE)	Coefficient	(SE)
Constant	208.626**	(0.641)	207.741**	(0.669)
Free_Lunch_Eligibility	20.377**	(0.356)	19.474**	(0.364)
ELL	-15.004**	(1.017)	-16.343**	(0.852)
Game_Sometimes	0.318	(0.387)	0.089	(0.369)
Game_Daily	-4.057**	(1.010)	-2.139*	(1.037)
ELL*Game_Sometimes	1.343	(1.221)	2.034	(1.148)
ELL*Game_Daily	7.360*	(3.633)	0.833	(2.780)
Total R ²	0.168**		0.173**	

** indicate $p < 0.01$; * indicate $p < 0.05$

Model 1: ELL model

ELL Model indicated a statistically significant effect, having approximately 17 % of the total variance explained by the model (total $R^2 = 0.170$, $p < .01$). Among non-ELL students, students who played games daily performed significantly lower in math than those who never played games ($b = -3.086$, $p < .01$). However, no significant effect was found for those who played games sometimes ($b = 0.225$, $p > .05$). For ELL students, any significant differential effects of math games were not noticed. However, when ELL students played math computer games daily, they tended to have higher math performance compared with the performance of non-ELL students who did not play games, although the effect was not significant due to the large error variance.

In terms of the background variables, Free_Lunch_Eligibility was a significant predictor of math achievement of 4th-graders ($b = 19.953$, $p < .01$). A significant math performance gap between ELL and non-ELL students was observed, with ELL students having significantly lower math scores than non-ELL students ($b = -15.635$, $p < .01$).

Model 2: Gender model

The model on the gender effect was also statistically significant, having $R^2 = 0.152$ ($p < .01$). A significant achievement difference among male students was noticed according to the frequency of playing math computer games. Compared with male students who never played games, students who played sometimes performed significantly better ($b = 0.802$, $p < .05$). On the other hand, when male students played math computer games daily, they performed significantly poorly compared with male students who never played ($b = -2.795$, $p < .01$). For female students, no significant interaction was found. Unlike male students, no significant performance difference was detected depending on females' frequency level of playing math computer games.

In the regards to the contextual variables, free lunch eligibility was a significant predictor of the math achievement of 4th-graders ($b = 21.994$, $p < .01$), indicating that the math achievement scores of students who were eligible for free lunch programs were significantly lower than those of non-eligible students. A difference in math achievement between male and female students was also detected. The math achievement scores of female 4th-graders was significantly lower than that of male 4th-graders by 2.341 points ($b = -2.341$, $p < .01$).

Model 3: Interaction model

The model for male students used separate data regarding male students and was found to be statistically significant (total $R^2 = 0.168$, $p < .01$). Among ELL male students, math achievement difference was also detected depending on the frequency of math computer games. Compared with Non-ELL students who never played math computer games at school, ELL male students who daily played math computer games achieved significantly higher math scores ($b = 7.360$, $p < .05$). ELL male students who played math games sometimes performed better than Non-ELL male students who never played math computer games, but the effect was not significant ($b = 1.343$, $p > .05$). Therefore, the frequent play of math computer games had a positive effect on the math performance of ELL male students.

Free_Lunch_Eligibility was a significant predictor of the math achievement of 4th-graders ($b = 20.377$, $p < .01$). A math performance difference between ELL and non-ELL students was also detected. Math achievement of ELL 4th-graders was significantly lower than non-ELL 4th-graders by 15.004 ($b = -15.004$, $p < .01$). A math performance difference among non-ELL male students was found depending on the frequency of playing math computer games. The math score of non-ELL students who daily played math computer games was significantly lower than that of non-ELL students who never played math computer games ($b = -4.057$, $p < .01$). However, the math achievement of non-ELL students who sometimes played math games was higher than that of non-ELL students who never played math computer games at school, but it was not significant ($b = 0.318$, $b > .05$).

Using a separate database comprised only of data regarding females, the regression analysis also yielded statistically significant results (total $R^2 = 0.173$, $p < .01$). Just like male non-ELL students, when female non-ELL students played computer games daily, they tended to have significantly lower math scores compared with those students who never played math computer games ($b = -2.139$, $p < .05$). However, its effect was weaker compared to the effect for males ($b =$

4.057, $p < .01$). In the 3rd step, neither of the two interaction terms was significant ($b = 2.034$, $p > .05$; $b = 0.833$, $p > .05$, respectively).

As observed in the male model, both Free_Lunch_Eligibility and ELL were significant predictors of math achievement scores of female 4th-grade students ($b = 19.474$, $p < .01$; $b = -16.343$, $p < .01$, respectively). The female model also indicated a math performance gap between female ELL and non-ELL students, making the gap slightly greater than that in the male model (female: $b = -16.343$; male: $b = -15.004$). The similar effect of math computer games was found for female non-ELL students. There was no significant performance difference between students who played sometimes and who did not play.

Discussion

One of our study's objectives was to examine the differential effects of computer games on the math performance of students from the linguistic and gender groups. In the first model, the study performed an analysis to examine the differential effect of computer games for students of two linguistic groups. Among native English-speaking students, the male students who played math computer games daily performed significantly worse than the students who never played. However, the study did not observe a negative effect for ELL students who played math computer games every day.

In the second model, the study found a gender-based differential effect of computer games on math achievement: the computer game was significantly associated with males' math achievement, but not with females' achievement. This result does not match the findings of previous studies that did not find a differential effect and reported the generic benefits of computer games for both genders (Annetta et al., 2009; Ke & Grabowski, 2007; Papastergiou, 2009; Vogel et al., 2006). In that sense, the current study brings up a new result that would be a new addition to the knowledge base of research regarding the effects of computer games on students' cognitive development and academic success in school. As Oblinger (2006) mentioned, games could help students to engage with math content by making class enjoyable; according to the results of the current study, it was especially true for male students who played math games sometimes.

The current results on the effects of computer games varied by frequency of play also highlight the importance of the proper amount of time for game play in class. When male students played math games too frequently—namely everyday—they showed low math performance. In contrast, when male students played computer games sometimes in math class (from once a month to twice a week), they demonstrated higher performance than male students who did not play computer games at all. According to Annetta et al. (2009), 5th-grade boys in the USA, on average, spent 2.1 hours a day playing video games. Considering the large amount of time that boys spend on computer games, the study results regarding frequency of computer game play would provide a guideline for teachers and parents. Moreover, the results would provide educators with a basis to guide students to play games even for education appropriately. At the same time, the study recommends a future study to explore the optimal frequency of playing computer games for educational purposes.

The study further analyzed the differential effect on two linguistic groups by dividing them into two gender groups. A significant effect was detected for male students. While English-speaking male students showed low math achievement scores with daily math games, ELL male students demonstrated high performance with daily math games in class. It was interpreted that daily games for English-speaking male students can be a distracting factor for their school engagement, but daily games for ELL male students can be an educational stimulator. This result was also consistent with a previous researcher's assertion that features of computer games helped ELL students to associate with other students and overcome their limited English ability (Gerbic, 2006). This significant effect, which was not found without the consideration of two learner characteristics, has some implication for future study. The study suggests that various learner characteristics should be considered when attempting to explore the effects of computer games. This suggestion comprises the case for implementing games in class. For example, teachers should be able to implement various methods and different ways of presenting those methods considering the interaction effects of computer games on students with various characteristics.

Overall, the study confirmed the differential effects of math computer games on the academic achievement of diverse students from different linguistic and gender groups. However, caution is necessary in making direct causal

inferences, as this study was based on the survey questionnaire rather than a controlled experimental study. In addition, as the current study used the variables of computer games from the secondary database, the study cannot identify the details of what design features of computer games were utilized and how learning was promoted. Therefore, the current study suggests future studies to explore how specific features of computer games promote academic performance of diverse learners with an experimental design, especially for male ELL students who demonstrated high performance in math classes with daily math computer games.

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Using SOLO to Evaluate an Educational Virtual Environment in a Technology Education Setting

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ABSTRACT

The present research investigates the contribution of an interactive educational virtual environment on milk pasteurization to the learning outcomes of 40 students in a technical secondary school using SOLO taxonomy. After the interaction with the virtual environment the majority of the students moved to higher hierarchical levels of understanding on the structure and operation of the pasteurization apparatus, the different paths and temperatures of fresh and pasteurized milk, hot and cold water, and the way heat is exchanged. The functional nature knowledge the students constructed, led them to develop physical nature knowledge, knowledge of the relationship between physical and functional nature, and finally process knowledge. The design of the three dimensional virtual environment, its content and the meaningful learning tasks are important for technology knowledge.

Keywords

Virtual reality, Educational virtual environments, Technology education, SOLO taxonomy

Introduction

Technology education constitutes a separate educational sector of the educational system. Generally, by the term Technology Education (TE) we refer to that particular part of the curriculum that is related to the support offered to students in becoming technologically capable, to the identification of the human needs for which technological solutions are required, to the design and manufacture of suitable products, to the evaluation of product quality and potential social and environmental repercussions (De Vries, 1997, 2005; De Vries & Tamir, 1997). Today TE is undergoing an important transformation. The increasing complexity of society has resulted in a shift of interest from the acquisition of manual skills towards the development of mental skills. The curricula of technological studies in developed countries are changing direction and from providing specific knowledge and practicing skills, emphasis is given to the procedures of problem solving, decision making on technological matters and knowledge of the productive processes (DFE, 1993; ITEA, 2000). Technology educators have to bring together scientific, technological and social knowledge (De Vries, 1997).

Information and Communication Technologies (ICT) are considered to be the most powerful tool for the support of the learning process. ICT with their flexibility, adaptability, their capability of being applied at the work place, their good cost-performance ratio, are being used widely in TE as learning tools. From the various technological approaches of ICT, Virtual Reality (VR) is considered to be the most powerful learning tool, because of its unique characteristics that can be summarized as follows (Mikropoulos & Bellou, 2006):

- creation of three dimensional (3D) spatial representations, namely virtual environments
- multisensory channels for user interaction
- immersion of the user in the virtual environments (VEs)
- intuitive interaction through natural manipulations in real time.

The present work proposes the design, development and evaluation of an Educational Virtual Environment (EVE) in TE for the support of the understanding of the milk production processes as a case study, in a technical school of secondary education. The aim of this study is to investigate the contribution of the proposed EVE to the development of the four different types of technological conceptual knowledge, namely knowledge of the physical nature; knowledge of the functional nature; knowledge of the relationship between the physical and the functional nature, and the process knowledge (De Vries, 2005). For the evaluation of knowledge construction after the EVE-supported intervention, the Structure of the Observed Learning Outcomes (SOLO) taxonomy is used (Biggs & Collis, 1982).

Literature Review

Over the last years a number of VR applications have appeared aimed at the support of the educational process in the field of Technology Education. TE includes a vast number of fields of application such as industry, manufacturing, energy, and transportation; therefore the virtual environments concern a wide variety of applications.

Weyrich & Drewes (1999) have developed a desktop VR system for training in the planning and manufacture of model products, without presenting any empirical data. Parkinson & Hudson (2002) report on the training of 14-16 year old students in the manufacture of automobiles using a desktop system, and found some improvement in the generic process of engineering design. Yap et al. (2003) propose an immersive system for training in the development of industrial products. Their results show a reduction in the design time and the design of more precise products. Hashemipour et al. (2009) present a virtual computer integrated manufacturing laboratory for various engineering disciplines. They report on positive students' attitudes and learning outcomes in undergraduate courses. These four applications aim at training in productive processes. The users manufacture virtual products, interact with the virtual environment, compare and improve the products. From the four applications only one is aimed at secondary education and reports some general positive outcomes (Parkinson & Hudson, 2002).

Another direction on using VR in TE is quality control and ergonomics. Crumpton & Harden (1997) report an improvement in labour behaviour in the handling of materials and placement of employees using a desktop VR system. Chung et al. (1999) report on a more rapid implementation of inspecting the thickness of industrial parts with college students in an augmented reality environment. Vora et al. (2002) have found more precise and easier tracking of imperfections compared to multimedia application by training students with an immersive system.

Some articles report on the training of technicians using machine operation simulations in desktop systems. Song (1996) have found improvement in the quality and speed of performing welding activities, while McLachlan and Papaioannou (1999) report a decrease in the training time compared to the traditional methods in robotic welding. Lapointe and Robert (2000) note a greater harvest of timber, lower cost of repair and maintenance of machines in handling forestry machines in wood harvesting. Lin et al. (2002) report less time and errors on an automatic virtual lathe. Finally, Huang and Gau (2003) report on time reduction in handling a self-propelled lifting crane, but state difficulties with the technicians' perception of the 3D environment.

Concerning assembly tasks, understanding of industrial activities and management of productive processes, four desktop applications and one immersive have been found. Bullinger et al. (2000) propose an immersive system for training in assembling and disassembling objects in planning operations, without giving any empirical data. Wittenberg (1995) reports on the reduction in training cost and the improvement in quality of work, Bell & Fogler (1995) on better comprehension of abstract technical concepts in chemical engineering, while Mills & de Araujo (1999) give positive results for the traditional teaching method in the management of nursing units. The three above studies were conducted with employees, out of the educational system. Finally, Fernandes et al. (2003) propose a virtual factory that allows users to navigate and interact with machines and equipment, but they do not present any empirical data.

There are also some desktop VR systems that simulate safety issues in working environments. Squelch (2000) and Filigenzi et al. (2000) simulate mines; Zayas (2001) proposes safety training at a chemical laboratory, Dobson et al. (2001) at a railway station and a nuclear plant. Duffy et al. (2003) present a virtual environment for risk reduction without any empirical data. However, none of the above five studies are in an educational context and they remain at the description of the virtual environments. Only Squelch and Dobson et al. comment on the contribution of the realism of their virtual environments.

Three desktop systems are proposed for the training of civil engineers in structural analysis (Chou et al., 1997), of students in construction technology (Li & Love, 1998) and in CAD and design (Ou et al., 2002). The positive results reported mainly concern attitudes and skills.

Concerning maintenance and repair of industrial equipment there are two desktop systems without empirical data (Kashiwa et al., 1995; Oliveira et al., 2000) and a virtual environment reporting the reduction of the cost of training (Li et al., 2003). Another virtual learning framework for troubleshooting of automotive chassis has been reported by Liang (2009), together with positive learning outcomes coming out from university students.

From the literature above we observe that 17 out of 29 applications do not report on any training results, but simply make proposals for the educational or training process or even the VEs. In the majority of applications where results are presented, they have not been concluded from systematic evaluation but are based on opinions and statements of usually a small sample. In only a few of them a systematic evaluation has been presented (Chung et al., 2002). In most of the applications, the opinions of experts are reported, as well as the demonstration of VEs and general estimations concerning possible benefits that could be gained by the application. Usually they focus on the design and development of original applications rather than on their assessment by the users. Shewchuk et al. (2002) report that from all the applications they studied, in only 10% of them were systematic empirical studies carried out. Moreover, in those applications that were followed by a statistical analysis of the findings, most of them can be characterised by their many deficiencies such as the small number of the sample, the inhomogeneity of the subjects based on age and the industrial experience. Also minimal are the cases in which the sample consists of students in an educational context.

The above problems lead to a decreased reliability in reference to the results and the conclusions of research (Crumpton & Harden, 1997; Mills & de Araujo, 1999; Antonietti et al., 2001). A basic characteristic of the empirical studies is the emphasis given to the processes of training and acquisition of technical skills. The important element of construction of knowledge in reference to concepts, physical magnitudes and phenomena that are involved in the simulated activities are not studied in depth. The ongoing evolution of technology in all fields requires the comprehension of the relevant physical phenomena, before the training in matters of handling and control. It seems that the researchers using ICT and especially VR to support TE do not exploit all the categories of technological knowledge that is structural and functional rules, technical know-how, socio-technical understanding and technological laws (De Vries, 2003). They probably remain with the ‘concepts of technology’ leaving the ‘concepts in technology’ meaning the theoretical concepts that are used in technological activity out of their research interests (De Vries & Tamir, 1997).

Experiments

The subject under study

Based on the bibliographic review, research was conducted at technical educational institutions and industries aimed at choosing the most suitable topic for the development of an EVE in order to use it as a teaching tool in the educational process. The prerequisites for the choice of topic under study were:

- ascertained needs of education and training
- processes difficult or impossible to be presented and taught by other means
- suitable sample regarding the number, educational level and working experience.

Based on the above criteria, the dairy school of Ioannina, Greece was chosen because on one hand its laboratory contains a complete milk production line and on the other hand the students’ profile fits mostly to future technicians, since after their graduation they are employed on the production line.

Initially, a pilot study was conducted as a pre-test to establish the level of students’ understanding before the intervention with the EVE. The sample of this pilot study consisted of 48 students in their 2nd year at the dairy school (25 boys and 13 girls) aged 17 – 22 as well as the six teachers of the school, five agronomists and one mechanical engineer. The research was conducted at the school. In order to determine the specific topic of the EVE, the study aimed at the investigation of students’ ideas in the process of milk production, the determination of the topics in which the students have misconceptions, and the detection of those particular procedures difficult to be taught by traditional means. For the collection of data for the sample of students a closed type questionnaire was chosen, while for the sample of teachers the method of semi-structured interview was used. Table 1 shows the correct answers of the students, concerning terms, definitions and processes in the milk production line.

The findings show that most of the students showed great misunderstanding in questions that referred to integrated processes of the milk production line such as the preparation of the fresh milk, pasteurization and butter production. The students placed the processes in the wrong order or added others irrelevant to the production line. On the contrary, questions that were related to definitions or certain tasks in a more general production process, gave positive results.

Table 1. Students' correct answers (N = 48)

	Question	Frequency	Percentage (%)
1	Matching terms (homogenization, cream separation, pasteurization) with definitions	42	88
2	Putting procedures in milk production line in order	10	21
3	Definition of homogenization	44	92
4	Definition of pasteurization	46	96
5	Physical processes inside the pasteurization apparatus	11	23
6	Process of cream separation	43	90
7	Feta cheese production	42	88
8	Other cheese production	40	83
9	Butter production	25	52

Regarding the teachers' interviews, all the teachers reported that students show great success in definitions and visible productive processes such as making feta cheese. All the teachers also agreed that pasteurization is the process where students have misunderstandings. They also reported that this is a chronic problem, not only presented in this particular sample. The teachers reported that although, apart from their theoretical teaching they made use of other means, still the students faced difficulties in topics that involve knowledge of the functional nature, knowledge of the relationship between physical and functional nature, as well as process knowledge (De Vries, 2005). Pasteurization, that is the application of heat to destroy pathogens in foods, is a process where the theoretical (physical phenomena) and technical (inability to disassemble the system) difficulties cause misunderstandings in the educational process. It seems that although the students possess knowledge of the 'concepts of technology', they need to acquire knowledge on the 'concepts in technology'.

In conclusion, the students' and teachers' findings showed that the biggest problem is located in the process of pasteurization with difficulties in:

- comprehending the construction, the operation and the inner structure of the pasteurization apparatus
- comprehending the physical phenomena that occur during the process inside the pasteurization apparatus (exchange and regaining of heat)
- the knowledge of the correct flow of the different fluids (hot and cold water, hot and cold milk) and the role they play in the related process
- controlling and confronting incorrect procedures during pasteurization.

The above difficulties that students faced, mainly concern the functional nature knowledge, knowledge of the relationship between physical and functional nature, as well as process knowledge. The process of pasteurization is a characteristic example of a topic where the use of VR seems to show its potential. It is a case where information is hidden, there is no possibility of interacting with the process and it cannot be experienced or be conceived by human senses (Sanchez et al., 2000). Thus, pasteurization was chosen as the specific topic of the case study for the investigation of the VR-supported intervention in TE.

As has been shown by the pilot study, the students have the functional nature knowledge as descriptive knowledge. The research axis of the VR-supported intervention is the investigation of its contribution mainly to the three other types of technology knowledge i.e. is the physical nature knowledge, the knowledge of the relationship between physical and functional nature, and the process knowledge.

Specifically, the intervention investigates if students:

- acquire functional nature knowledge by learning that milk passes through the pasteurization apparatus in order pathogens to be destroyed
- acquire physical nature knowledge by learning that metal plates contribute to heat exchange
- construct the knowledge of the relationship between physical and functional nature by learning that the metal plates inside the pasteurization apparatus contribute to heat exchange between fresh, pasteurized milk and water
- construct process knowledge by learning that pasteurization is the process of destroying pathogens in foods using the application of heat by passing milk through the pasteurization apparatus that contains metal plates for heat exchange between fresh, pasteurized milk and water.

The Educational Virtual Environment

The entire milk production line is simulated and emphasis is given to pasteurization. Particular attention is given to the users' interaction with the virtual objects through free navigation, and the possibility of changing specific variables of the simulated operations. Objects are not designed symbolically but realistically and in correspondence to the real ones. Finally, attention is paid to the attributes of the EVE so as to correspond to the characteristics, the needs of the students and the pedagogical principles of TE.

For the development of the EVE the Superscape VRT software was used. The basic characteristics of the EVE are the 3D representations of the production line equipment at the dairy factory, free and guided navigation and interaction. Specifically:

- The tanks of fresh and pasteurized milk, the cream separator, the constant-level supply tank, the pasteurization apparatus, its inner parts (plates and their cross sections, the hot, cold water pipes and fresh, pasteurized milk pipes and the holding tube of milk) are designed
- The surfaces of the virtual objects are colored so as to be photorealistic. Especially for the pipes and the flow of the fluids, different colors play an important role, as each one symbolizes a different fluid
- Proper textures are used in order to enhance the true likeness of the objects especially in the cases of the pasteurization apparatus and the plates
- An operational and control panel is designed by which the functions of the equipment are controlled. It is placed at the side of the EVE in order to avoid any interference with the students' navigation
- Physical properties are given to the virtual objects such as transparency to the pipes and velocity to the fluids
- The flow of the pasteurized and fresh milk, cold and hot water, the inner part of the pasteurization apparatus, display of temperatures at the appropriate time, case of faulty pasteurization are properly programmed.

The EVE is divided into three levels of operation. The first one includes building the pasteurization apparatus, the second one the various paths of the fluids and the third one the exchange and the regaining of the heat between the fluids as well as the case of faulty pasteurization. The users had the ability to activate any level, according to the operation they wished to study. Figure 1 shows the open pasteurization apparatus and its inner parts (plates and their cross sections, the hot and cold water pipes, fresh and pasteurized milk pipes and the holding tube of milk). Each level of operation begins with a guided navigation, while the choice of free navigation is also activated for free moving and observing of the operations from the users' viewpoints. Before all these actions take place, the user navigates freely in the EVE in order to be familiar with it and to be able to identify the equipment.

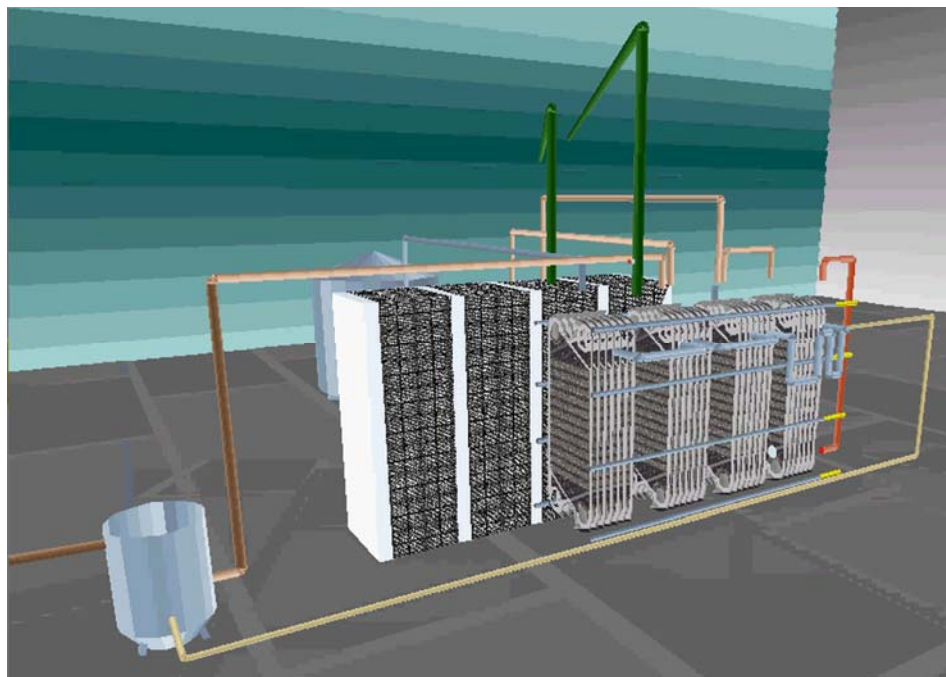


Figure 1. The open pasteurization apparatus and its inner parts

Sample and procedure

The sample consisted of 40 students (others than those of the pilot study) of the dairy school of Ioannina, ages 18 – 22. The students, following their curriculum, attended the lecture given by the traditional method. Just after the lecture, the students were given printed questionnaires with 16 questions related to the taught topic. After that, the students interacted with the EVE. The procedure took place in the computer lab of the school. At the beginning the researcher explained the use of the software and he allowed each student to navigate for a few minutes and become familiar with the EVE. Afterwards there was individualised intervention. After the interaction the students answered the same as before questionnaire. The 16 questions included memorization, comprehension, knowledge construction, analysis and design skills. For the purposes of the present study the findings from five questions are qualitatively analyzed -those that are closely related to knowledge of the physical nature, knowledge of the functional nature, knowledge of the relationship between physical and functional nature, and process knowledge.

After searching relevant references on the suitable tools for qualitative analysis, the SOLO taxonomy was chosen. “In the SOLO taxonomy, the growth of competence is characterized as a shift from accruing the elements of a task in a quantitative fashion, to a qualitative restructuring of the elements and, at the highest level of competence, their subsequent reformulation and generalization” (Biggs, 1996). SOLO provides a systematic way of describing how a learner’s performance grows in complexity when mastering many academic tasks. The taxonomy has been widely applied to research for the estimation of knowledge presenting different hierarchy levels expressing the development of knowledge construction. Students’ understanding is classified in the following five hierarchical levels:

1. Prestructural. The student avoids or repeats the question, makes an irrelevant association.
2. Unistructural. The student selects one relevant datum and closes on that.
3. Multistructural. The student selects two or more relevant data, uses them inconsistently and reaches an alternative conclusion.
4. Relational. The student uses most or all relevant data, integrates it with a relating concept and reaches the right conclusion.
5. Extended abstract. The student uses abstract principles that show the specific example is just one of many possible results.

SOLO is effective in TE since through its hierarchical levels, the transition from functional and physical nature knowledge to the knowledge of the relationship between them and the process knowledge can be evaluated.

Results and Discussion

Concerning the subjects’ prior computer use experience, all of them (N = 40) had more than one year experience in general purpose software applications. The most common use for 28 students was game playing.

The EVE

During their interaction with the EVE, the students were asked to identify six apparatuses that are involved in the production process of pasteurization. From a total of 280 answers, 261 (93%) were positive. Concerning the realism of the virtual objects, the answers were positive. There were 176 answers reporting that the objects resemble the real objects a lot, 46 that they resemble them a little and only eight that there is no resemblance. Most of the students also noted that it was easy to identify the apparatuses not only because of their realistic representations, but also because of their particular place and role in the production line that was simulated. This shows that the students acquired physical nature knowledge during their interaction with the EVE, since they realized that “artifact A has physical property p” (De Vries, 2005). Regarding the ease of navigation in the EVE, 27 students found it very convenient, 11 showed a little difficulty and only two reported great difficulty. The different colors of the pipes which matched the different fluids provided assistance to 37 students, while they confused only three of them.

There was a typical question referring to the sense of the user’s presence inside the EVE (Slater, 1999): ‘during your navigation in the virtual environment did you feel like you were inside the factory or did you think that pictures of the factory passed in front of you?’ Thirty students felt that they were inside the virtual factory while only 10 sensed it as images on the computer screen.

The above results show that the students evaluated the characteristics of the EVE positively and indicate that the EVE contributed to the knowledge of the physical nature. The careful design of the virtual environment is essential to enhance the possibilities of success when it comes to the cognitive area. Our findings enhance those of Yap et al. (2003) reporting that 3D models and simulations can capture dynamic mental visions and concepts of products: ‘they not only provide full form geometric representations of objects but also illustrate procedural knowledge (i.e. object functions)’.

SOLO analysis

The prestructural, unistructural, multistructural, and relational hierarchical levels have emerged from the SOLO analysis of the five questions. The last extended abstract level has appeared neither before, nor after the students’ interaction with the EVE. We follow De Vries’ approach to technological knowledge that is students ‘must learn to make judgements about effectiveness ... that makes it distinct from scientific knowledge’ (2005). So, for technology education we believe that there is no need for the students to use abstract principles that show that the specific example is just one of many possible results.

The five questions are summarized as follows:

Q1: Describe the inner part of the pasteurization apparatus and draw a sketch of it (both physical and process nature knowledge).

Q2: Explain the role of the holding tube pipe (both physical and functional nature knowledge).

Q3: Explain the operation of the constant-level supply tank (knowledge of the relationship between physical and functional nature).

Q4: Explain the way the recuperation of heat is accomplished (knowledge of the relationship between physical and functional nature).

Q5: Explain the way the pasteurization apparatus’ plates operate (process knowledge).

Figures 2 and 3 show the SOLO levels before and after students’ interaction with the EVE for questions Q1 and Q2 that represent physical nature knowledge.

Concerning Q1, the majority of the students are classified at the first two levels before their interaction with the EVE, while a shift towards multistructural and relational levels is observed after the EVE, leaving only one student at the prestructural level. This great shift indicates the contribution of VR to topics where it is impossible for students to have experiences in the real world. This is enhanced by the correct descriptions concerning the way the plates operate, the explanation regarding the part of the apparatus where the pasteurization process integrates, as well as the part where the milk is finally cooled.



Figure 2. SOLO levels for Q1

The pasteurization apparatus consists of four parts, each one consisting of a series of parallel plates helping the heat exchange in milk. Fresh milk flows through the plates gradually increasing its temperature, with the final part of the pasteurization to be held in the fourth plate. The pasteurized milk is finally cooled in the first plate. The heating process is done by the hot water flowing through the three plates, while the cooling process is done by the cold water in the final stage of the process. After the interaction with the virtual apparatus, 29 students described correctly the paths of cold and hot water inside the plates. The results for the paths of the milk were also improved, with 19 correct descriptions for the fresh milk and 21 for the pasteurized. Although the correct answers for the milk after the EVE are at a satisfactory level, they are considerably less than those for the water circulation. It seems that the role of the water inside the apparatus is clearer to the students than that of the pasteurization process itself. The satisfactory descriptions of the fluids' paths can be associated with the high score for the correct answers concerning the structure of the apparatus. It seems that although the students have understood its structure, they cannot discriminate the exact role of its parts in relation to the four fluids. Apart from the students' descriptions this is also indicated by their sketches that show a polyline representing the fluid pipes before the EVE. After the interaction with the EVE, the sketches represent the four metal plates and the pipes with accuracy.

The same shift towards higher SOLO levels is observed in the role of the holding tube (figure 3), which is located after the fourth plate, controls milk's temperature and certifies the pasteurization. Here most of the students moved to the unistructural and multistructural levels, while five of them returned from multistructural to the unistructural level. It seems that the specific physical nature knowledge requires three different factors, time, temperature and pasteurization where the students have misconceptions that a visual representation cannot overcome.

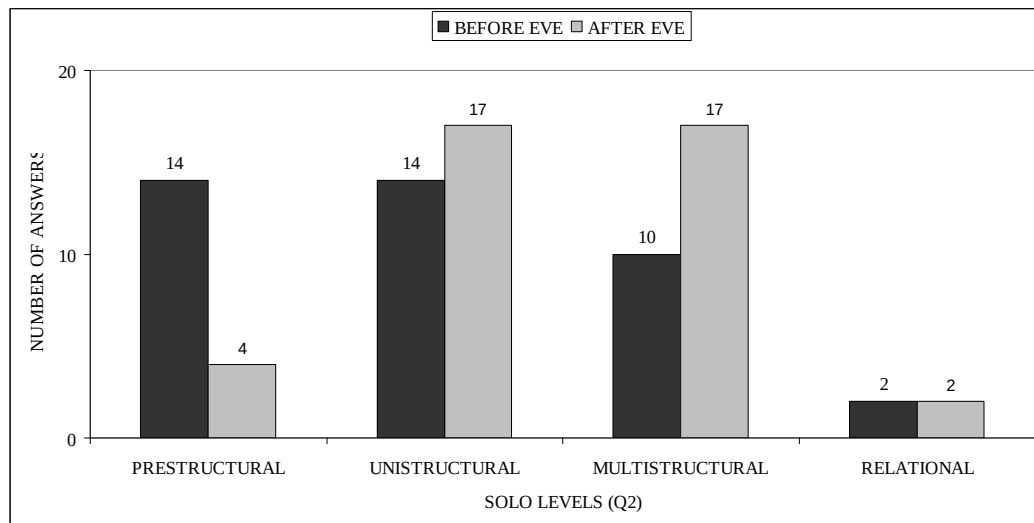


Figure 3. SOLO levels for Q2

Two students' comments follow.

S1, before EVE: "Because the milk is too much, it cannot remain inside the plates; thus, it remains in the holding tube".

The student invents an explanation based on the etymology of the term. The answer is classified at the first, prestructural SOLO level.

S1, after EVE: "Milk stays in the holding tube for 15sec in order for the pasteurization process to be accomplished".

The same student S1 refers to the role of the holding tube and the staying time, but not to the temperature. The answer is classified at the multistructural level, showing a two – level shift.

S2, before EVE: "Milk stays for 15sec".

The student has a descriptive and inert knowledge concerning one of the factors for the role of the holding tube. The answer is at the unistructural level.

S2, after EVE: "Milk stays in the holding tube for 15sec at the correct temperature in order for the pasteurization process to be integrated".

S2 uses and relates all the appropriate factors. The answer is shifted from unistructural to the relational level.

Figure 4 shows the SOLO levels for Q3 concerning the operation of the constant-level supply tank. This is placed before the pasteurization apparatus and ensures the steady flow of the fresh milk. In case of wrong pasteurization, milk returns to the tank and the process starts again. This is considered to be knowledge of the relationship between physical and functional nature. Six students from the prestructural are shifted to higher levels. One of them is classified at the unistructural, while five at the multistructural level after their interaction with the EVE.



Figure 4. SOLO levels for Q3

Two students' comments follow.

S3, before EVE: "Milk flows from the tank to the pasteurization apparatus".

The student generally refers the place of the tank, but ignores its purpose. The answer is at the unistructural level.

S3, after EVE: "The tank ensures the steady flow of the fresh milk; milk returns to the tank in case of incorrect pasteurization".

S3 knows the operation of the tank, but ignores its location. The answer is shifted to the multistructural level.

S5, before EVE: "The tank is located before the pasteurization apparatus and pumps milk to it".

The student uses only one datum and his answer is at the prestructural level.

S5, after EVE: "The constant-level supply tank ensures the steady flow of the fresh milk; milk returns to the tank in case of incorrect pasteurization".

S5 knows the operation of the tank, but ignores its location. The answer is shifted to the multistructural level.

Figure 5 shows the SOLO levels for Q4 concerning the way the recuperation of heat is accomplished. It is observed that 21 students moved from the first, prestructural to multistructural and relational SOLO levels, showing an understanding of the relationship between physical and functional nature. It is noteworthy that the relational level is occupied by 14 students after their interaction with the EVE, in contrast to only two answers before the interaction.

Some examples of students' comments follow.

S1, before EVE: "Milk passes through the recuperation part. At the same time hot water passes too, and heat exchange is accomplished".

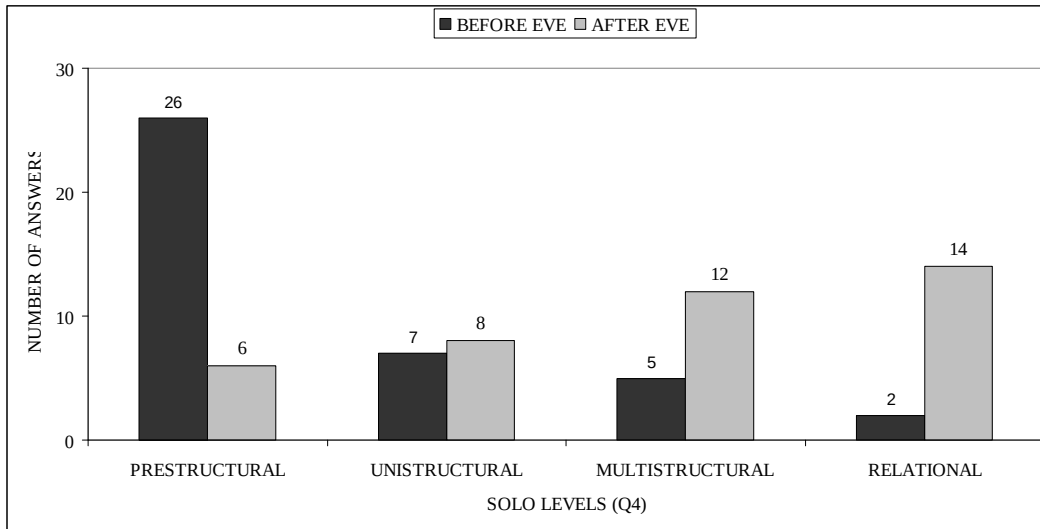


Figure 5. SOLO levels for Q4

The student uses only one datum, that of the milk, but confuses heat recuperation with heat exchange. The answer is at the unistructural level.

S2 and S3, before EVE: No answer.

No answer is at the prestructural level.

S1, S2 and S3, after EVE: “Fresh milk switches with pasteurized milk inside the metal plates and heat recuperation is done”.

The three students spot the place where the phenomenon is done and understand the process. Their answers are shifted from unistructural and prestructural to relational level. Question 4 belongs to a high level of technology knowledge that involves a physical phenomenon and a resulting process. The findings show the contribution of the EVE in cases where students have neither previous experience of the system and the process, nor mental models about the phenomenon.

Figure 6 shows the SOLO levels for Q5 concerning the integrated operation of the pasteurization apparatus that is classified as process knowledge. After the interaction with the EVE, students’ answers move mainly from prestructural to multistructural and relational levels, indicating together with Q1 a better understanding.

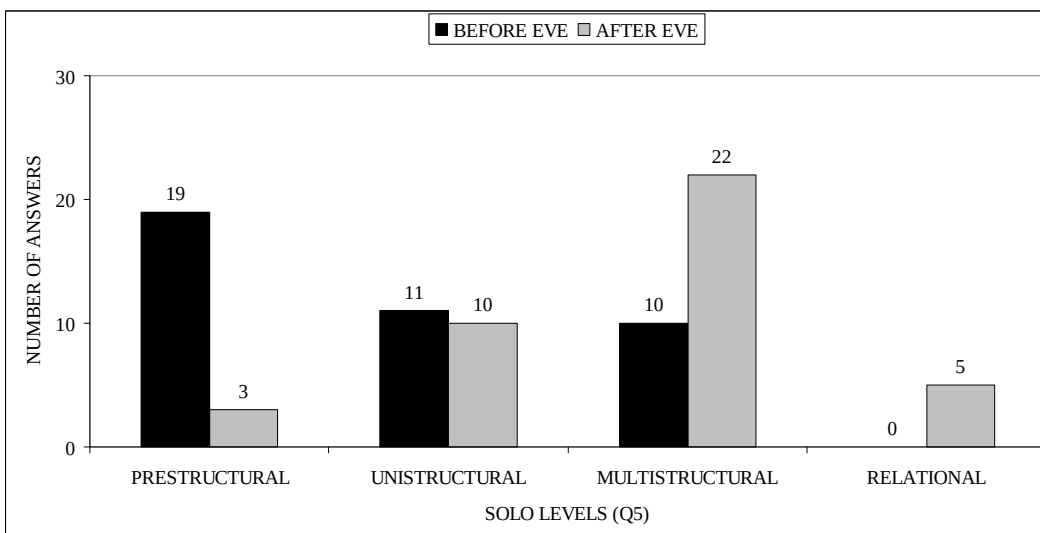


Figure 6. SOLO levels for Q5

Two students' comments follow.

S1, before EVE: "The first plate pasteurizes milk to 75°C, the second heats it to 40°C, the third up to 60°C, and the fourth cools milk at 5°C".

The student confuses plates with the apparatus parts. The same student did not manage to sketch the apparatus. Moreover, he does not know the heating and cooling processes. The answer is at the unistructural level.

S1, after EVE: "The plates are parallel to each other. Cold and hot water, fresh and pasteurized milk pass through them and the processes are integrated".

The student differentiates plates from parts, understands the construction and the operation of the system. His answer shifts to the relational level.

S5, before EVE: "Hot water or water vapour, hot or cold milk is in the heat inverter. Using the ice tank and water, hot milk is cooled".

The answer is general and unclear. The student uses irrelevant data. The answer is at the unistructural level.

S5, after EVE: Same as S1.

The answer shifts from the second to the fourth relational SOLO level.

In order to have a total picture of the students' SOLO levels, we have calculated the average level for each student taking into account the findings of the four above questions (Figure 7).

The students' average hierarchical levels accumulate at the first two levels before their interaction with the EVE. Thirty three students are at the prestructural and unistructural levels, indicating that either they do not understand the questions or their answers are unclear based only on one datum. After the interaction with the EVE there is a shift towards the higher levels with 26 students concentrated at the multistructural level. This shows that the students are able to select more than one relevant data, use them and reach a correct or satisfactory conclusion. The only one classification at the relational level in the total picture comes from the averaging. As one can see from the hierarchical levels for each one of the questions, there are many students classified at this fourth level.



Figure 7. Average SOLO levels

Conclusions

The present study investigated the contribution of an EVE in TE and especially in milk production. The aim was to investigate the contribution of the proposed EVE to the types of technology knowledge that is the functional nature knowledge, the physical nature knowledge, the knowledge of the relationship between physical and functional

nature, and the process knowledge. These types of knowledge are detected by analysing 40 students' answers using the SOLO taxonomy that classifies students' understanding at five hierarchical levels.

The results of the students' interaction with the EVE showed a shift from lower to higher SOLO levels, indicating an improvement in students' understanding concerning certain parts of the pasteurization process. Students could conceive unseen processes of production, comprehend complex operations and compose technically acceptable opinions. The qualitative analysis shows in greater detail the changes in technological knowledge after the interaction with the EVE. Specifically the students:

- constructed knowledge and decreased their ambiguities and misconceptions
- were able to compose in a more efficient way concepts and productive procedures
- compared the different parts of equipment with the activities with which they are connected
- developed skills of a superior level essential for the performance of complex tasks
- understood at a satisfactory level the inner part of the pasteurization apparatus and comprehended the processes which they are related to.

Our findings show a greater benefit for students classified at the prestructural and unistructural knowledge level, since the number of questions left undone or totally wrong answers were decreased dramatically. The results of the present study are in accordance with Yap's et al. conclusions stating that spatial, aesthetic, ergonomic, and functional knowledge in 3D visual representations is better communicated by visually observing objects, forms, and processes in motion (2003). Furthermore, our results extend Yap's conclusions, since the interactivity and the sense of presence in our EVE contribute to physical nature knowledge, the knowledge of the relationship between physical and functional nature, and the process knowledge, bringing positive learning outcomes not only to technology knowledge, but also to scientific concepts. It seems that the context and the content of the EVE along with specific learning tasks is an important factor affecting task performance and knowledge construction.

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Perceptions of the Computer-Assisted Writing Program among EFL College Learners

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ABSTRACT

This study aimed to investigate the perceptions of a computer-assisted writing program among EFL learners in a college composition class. A mixed method research design was employed combining both qualitative and quantitative techniques. Forty-five junior students in a Taiwanese college writing class were introduced to the computer-assisted writing program *MyAccess*. After using the program in class, students completed a survey questionnaire and nine students were selected for follow-up interviews based on their writing proficiency. Survey results showed that the majority of students held favorable attitudes towards using *MyAccess* as a writing tool, but were less positive concerning its use as an essay grading tool. Evidence obtained from a multiple choice question in the survey showed that a majority of the students benefited by using the computer-mediated feedback to revise their essays. Moreover, interview data revealed that the computer-mediated feedback had a positive effect on writing skill development, particularly in suggesting changes for form rather than for content. Finally, eight of the nine interview participants suggested that *MyAccess* could be utilized in future writing classes. Further discussions of the benefits of adopting computer-assisted writing software such as increased learner motivation and learner autonomy also indicate that this kind of software can be a useful support tool in the EFL classroom.

Keywords

Computer-assisted writing instruction, computer-mediated feedback, learner motivation, learner autonomy, EFL

Introduction

The rapid development of computer technology together with the use of computers by linguists and literary researchers, and the increasing importance of computer-assisted language learning (CALL), computer-mediated communication (CMC), and computer-assisted language instruction (CALI) has greatly influenced both writing instruction and writing research in recent years.

Since the 1980s, CALL software applications have tended to shift the locus of control from the computer to the learner. Later generations of CALL viewed the computer as *a tool* controlled by the learner rather than *an expert* controlled environment for the learner (Kern & Warschauer, 2000).

Some studies have suggested that the use of writing software applications in students' texts may be positively correlated with the text quality or L2 proficiency (Ferris, 1994; Grant & Ginther, 2000; Jarvis, Grant, Bikowskia, & Ferris, 2003). On the other hand, other studies have shown negative effects for novice writers (Brock, 1990a, 1990b; Pennington & Brock, 1990). Pennington and Brock (1990) noticed that when ESL students used a text analyzer alone without teacher feedback, the results were that writers tended to accept the analyzer's suggestions, even when those alternatives were inappropriate. Studies conducted by Brock (1990a, 1990b) suggested that L2 writing errors are more idiosyncratic and harder to classify than L1 errors.

Automated essay scoring software was originally designed to reduce teacher work load in grading large numbers of student essays. Two of the most popular computer-based writing tools in Taiwan are *Criterion* by Educational Testing Service and *MyAccess* by Vantage Learning. By means of these tools, learners can choose from a range of essay topics to practice multiple drafts and receive immediate feedback in the form of both holistic scores and diagnostic comments on grammar, theme, usage, organization, and content development. Elliot and Mikulas (2004) concluded that over 85% of learners rated their satisfaction with the automated feedback on their essays as both helpful and accurate after using *MyAccess*. On the contrary, the study conducted by Herrington (2001), revealed that the scoring engine of *MyAccess* could be circumvented by writers because it assessed scores based on essay length.

Previous studies conducted in Taiwan have discussed the effectiveness of *MyAccess* in the writing classroom (Chen & Cheng, 2006; Yang, 2004). Chen and Cheng (2006) reported the students' dissatisfaction with the computerized feedback. An important reason was that it failed to offer specific feedback concerning the essay content. However,

the results of the study by Yang (2004) showed students' positive attitudes toward the automated essay grader tool, in terms of the rapid speed of feedback.

In addition, several researchers have emphasized the use of computer programs to enhance learner autonomy in second language learning, particularly in the field of ESL/EFL writing (Milton, 1997; Williams, 2005). According to Williams (2005), if the use of the computer software is carefully modeled, it can offer students both assistance and autonomy in the writing process. Furthermore, Milton (1997) suggested the use of computer programs to serve the aim of the autonomous development of writing skills, particularly for EFL writers.

Above all, because of the many pitfalls in the use of writing software with L2 or EFL students, writing teachers need to be aware of the possible benefits and drawbacks for their learners. Therefore, the present study focuses on obtaining a deeper understanding of the effectiveness of a specific computer-assisted writing program, *MyAccess*, from the learners' perceptions in an EFL context.

A brief overview of the writing software, *MyAccess*, used in this study

MyAccess was offered to 45 junior students divided into two classes in their third-year EFL composition course in the Department of Applied Foreign Languages at a technological university in Taiwan in the spring semester of the 2007 academic year. After watching demonstrations of two computer-based writing tools, *Criterion* and *MyAccess*, the instructor decided to adopt *MyAccess* to supplement classroom instruction due to the department with insufficient funding to carry out both computer-based writing programs simultaneously. In fact, this was the first time computer-based writing software had been applied to any English composition class in the department.

An automated essay grader

MyAccess, developed by Vantage Learning, is one of the most popular computer-assisted writing programs in Taiwan. It was used both as an essay grader and as a writing tool in this writing course. As an automated essay evaluation tool, students can choose from a defined number of practice essay topics, then write their multiple drafts, and receive immediate feedback in the form of both holistic scores and diagnostic comments on grammar (in the Language Use section), theme (in the Focus section), usage (in the Mechanics & Convention section), organization, and content & development. The electronic grader in this writing program was trained to check for lexical complexity, syntactic variety, topic content, and grammatical errors based on "known score" essays marked by human graders.

A writing tool offering diagnostic feedback

With regard to *MyAccess* as a writing tool, two other important functions were adopted in the writing course offered to these students: 1) My Editor, and 2) My Tutor. My Editor is a proofreading system, providing spelling correction and analyzing text to detect and correct errors in grammar. Moreover, it also offers an explanation of any problems that arise and offers suggestions about how mistakes might be corrected. My Tutor offers prescriptive feedback throughout the writing process on the following five domains: 1) Focus, 2) Content, 3) Organization, 4) Language Use, and 5) Mechanics & Convention.

Research questions

This study examined qualitative and quantitative aspects of using the computer-assisted writing program, *MyAccess*, in an EFL composition class from the learners' perceptions. The following three research questions were specifically addressed in this study:

1. What are the learners' attitudes toward the use of *MyAccess* in the EFL writing class?
2. In the computer-mediated setting, what are the effects of using computer-mediated feedback for the revision of learners' essays and for learner writing skill development?
3. What are the learners' perceptions of using *MyAccess* in the future?

Method

Participants

The participants in this study comprised forty-five junior students in the Applied Foreign Languages Department of a vocational and technological university in Taiwan who were volunteered to fill out a questionnaire. The questionnaire was given to these juniors divided into two classes on May 31, and June 4, 2007 at the end of the spring semester. All of these Mandarin-speaking students were enrolled in the required course, Intermediate English Writing, for the spring semester, 2007. Although they had already taken a basic writing course in their second academic year, their writing skills were quite elementary. Among the forty-five students who participated in the study, eighty-nine percent were female and eleven percent were male. Nine percent of the students were between 18 and 20 years old, eighty-nine percent were between 21 and 25 years old, and two percent were between 26 and 30 years old.

Follow-up interviews were conducted with nine students. The students were selected by the teacher on the basis of their English writing proficiency: 3 from the top 33%, 3 from the middle 33%, and 3 from the bottom 34%. Informed consent forms were signed by the participants before they were interviewed by the researcher. To maintain the anonymity of the participants in the interviews, each student was assigned a number from 1 to 9.

Student Participant Background

Table 1 provides an overview of student participation in English writing activities outside of school, which was considered to be very relevant to this study. As Table 1 illustrates, 47% of the students who filled out the questionnaire answered 'yes' to Question 18: "Do you ever use English to write outside of your school activities?" From the responses to Question 19, "For what purpose(s) do you write in English outside of classroom work?" we find that 16% of students wrote English letters, 23% wrote English compositions, 18% wrote English songs, 18% exchanged emails with e-pals, 22% kept English diaries and 3% wrote drafts of English speeches.

Table 1: Extracurricular English Writing Activity for the Student Sample (N=45)

Description		Frequency	Valid Percent
18. English writing outside of school	Yes	21	47
	No	24	53
19. Kinds of English writing:	English letters	10	16
	English compositions	15	23
	English songs	11	18
	English diaries	14	22
	Exchanging emails with e-pals	11	18
	Chatting with friends through MSN		
	Writing a draft of an English speech	2	3
20. Using computers outside of school	Yes	45	100
	No	0	0
21. Purpose for using computers:	Writing English assignments	38	33
	Chatting with friends in English over the Internet	17	15
	Obtaining information from English Internet sites	42	36
	Exchanging emails with e-pals	8	7
	Practicing English writing through e-mail	10	9
22. Preferred feedback	Computer feedback from MyAccess	4	9
	Teacher's written feedback	41	91
23. Helpful in improving English writing	Computer feedback from MyAccess	6	13
	Teacher's written feedback	39	87

As shown in Table 1, all of the students used computers outside of school. We find that 33% of the students did so in order to write English assignments, 15% to chat with their friends in English over the Internet, 9% to practice English writing through e-mail, 36% to obtain information from English Internet sites, and 7% to exchange emails with e-pals. Furthermore, it was found that 91% of the students preferred their teacher's written feedback, and only 9% preferred the computer feedback from *MyAccess*. As to Question 23, "Which feedback do you think is more helpful in improving your English writing?" we can see that 87% chose their teacher's written feedback, and 13% the computer feedback from *MyAccess*.

Data collection and analysis

The data used in this study came from survey questionnaires completed by forty-five junior students, and semi-structured follow-up interviews with nine student participants.

Survey Questionnaire

The questionnaire consisted of two sections containing twenty-three questions in total. The survey was carried out anonymously to reduce the potential for uncomfortable feelings among the participants. Section I contained nine items that were designed around a five-point Likert-type scale to identify the participants' perceptions of the activity, writing essays with *MyAccess*, during their English composition classes. After collection, data was coded in an SPSS for WINDOWS datasheet for the purpose of analysis. It also included one multiple choice question, number 10, designed to elicit the students' responses to the computer feedback, and one open-ended question, number 11, designed to elicit any students' feelings about the activity, which may not have been captured by the Likert-type questionnaire items.

Section II contained twelve questions designed to elicit background information from the participants, such as gender, age, their major in senior high school, English writing activities outside of school, computer use in practicing English writing activities, and responses to writing feedback.

Interview

The follow-up interviews with the nine selected student participants took place individually in the university on June 13 and 14, 2007 at the end of the spring semester.

The semi-structured interview style was conversational, involving open-ended questions that would encourage the participant to embellish and expand on the ideas proposed. The researcher used a portable cassette tape recorder during the interview, and the recordings also gave the researcher a chance to perform "member checking" (Creswell, 1994; Lincoln & Guba, 1985; Maxwell, 2005; Merriam, 1988, 1998), whereby, after each interview, the participant was given a transcript of the interview through e-mail. This sharing technique ensured that any material that made the interviewee uncomfortable was excluded from the study and that the participant's perspective was precisely presented. In addition to the first interview with the participant, second, or third follow-up interviews were conducted with the participant through e-mail or by telephone. These follow-up interviews were designed to elicit further details suggested by the earlier interview, in order to best serve the purposes of the study, and suggest potential themes in the process of data analysis. The analysis of data followed the general recommendations of Marshall and Rossman (2006) for in-depth interviewing, and of Strauss and Corbin (1998) for grounded theory. Strauss and Corbin (1990) assert that "analysis in grounded theory is composed of three major types of coding, (a) open coding; (b) axial coding; and (c) selective coding. At the conclusion of the study, the interview data from all of the participants were compared and categories were established. Themes were broken down into these categories, as reflected by the interview data, for the purpose of report-writing.

Results

Research question 1: What are the learners' attitudes toward the use of *MyAccess* in the EFL writing class?

From the questionnaire results, the student participants' attitudes toward writing essays with *MyAccess* during the writing classes were analyzed in terms of the mean scores of their answers on a 5-point Likert-type scale (5 for strongly agree, 4 for agree, 3 for not sure, 2 for disagree, and 1 for strongly disagree). Mean and standard deviations of students' responses are listed in Tables 2 and 3. The results are reported in Figures 1 and 2 as well as Tables 2 and 3.

Learners' attitudes toward using *MyAccess* as an essay grader

Items 1 to 6 relate to the use of *MyAccess* as an essay grader (see Table 2). The results of the data analysis showed that the mean scores were all above 3.0, but below 3.50 for all six items.

Table 2: Distribution of mean scores of learners' attitudes toward the use of MyAccess as an essay grader (n=45)

Item Description	Mean	S.D.	Rank
1. I feel satisfied with the automated grading system of <i>MyAccess</i> .	3.22	.93	6
2. I feel satisfied with the computer feedback to the organization of paragraphs offered by the automated grading system.	3.07	.92	9
3. I feel satisfied with the computer feedback to the content of my essay offered by the automated grading system.	3.13	.94	7
4. I feel satisfied with the computer feedback to English vocabulary offered by the automated grading system (Conventions).	3.09	.98	8
5. I feel satisfied with the computer feedback to English grammar offered by the automated grading system (Language).	3.24	1.03	5
6. I feel satisfied with the computer feedback to the theme of my essay offered by the automated grading system (Focus).	3.40	.89	4

As shown in Table 2, the mean score of item 1, "I feel satisfied with the automated grading system of *MyAccess*" was 3.22 and the mean scores of the other items related to the use of *MyAccess* as an essay grader were all above 3.0, but below 3.50. This suggests that the majority of the learners seemed to have less positive attitudes toward the use of *MyAccess* as an essay grader.

Questions 1 to 6 in Figure 1 also indicate the degree of students' agreement about the use of *MyAccess* as an essay grader. Indeed, the results of Q1 show that only 46.6% of learners felt satisfied with the automated grading system of *MyAccess*; 28.9% of them were dissatisfied with it and 24.4% of respondents said they were not sure. Particularly, below 40% of respondents agreed with the following three items (Q2, 3, and 4) relating to the use of *MyAccess* as an essay grader. Thus, the majority of the learners were dissatisfied with *MyAccess* as an essay grader.

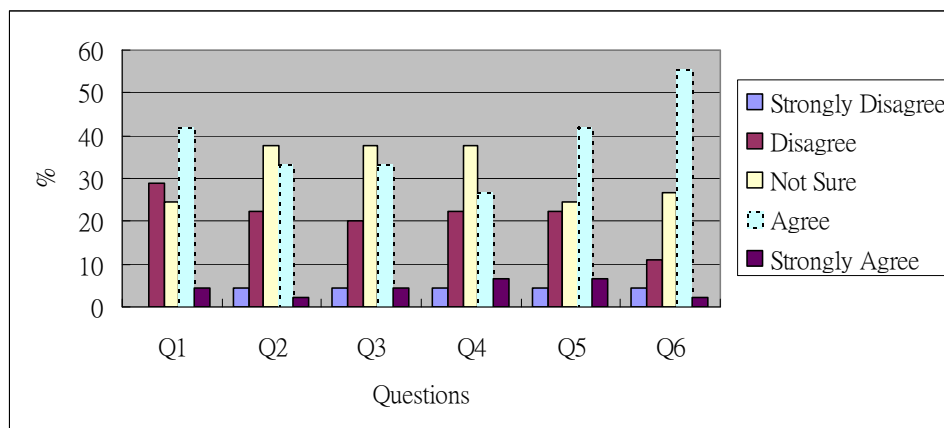


Figure 1: Learners' Attitudes toward Using MyAccess as an Essay Grader

Learners' responses to the use of MyAccess as a writing tool

The results of the data analysis revealed that the mean scores were between 3.0 and 4.0 for the other three items. Items 7 to 9 relate to the learners' perceptions of using *MyAccess*, particularly as a writing tool.

As Table 3 illustrates, the top two items with which the students agreed were (1) "I will correct my grammar and revise my essays after using My Editor of *MyAccess*." (M=3.89), and (2) "I will read the computer feedback and revise my essays after using My Tutor of *MyAccess*." (M=3.73). This suggests that the learners' responses to the use of *MyAccess* as a writing tool were positive since My Editor and My Tutor were the two important writing tools the learners used to revise their essays.

Table 3: Distribution of mean scores of learners' responses to the use of *MyAccess* as a writing tool (n=45)

Item Description	Mean	S.D.	Rank
7. I will read the computer feedback and revise my essays after using My Tutor of My Access.	3.73	1.03	2
8. I will correct my grammar and revise my essays after using My Editor of My Access.	3.89	.86	1
9. Writing essays with My Access helps me to improve my English writing.	3.47	1.01	3

In addition, the results presented in Figure 2 showed that about 85% of the learners agreed that they would correct their grammar and revise their essays after using My Editor (item 8), and only 6.6% of them disagreed. Nearly 74% agreed that they would read the computer feedback and revise their essays after using My Tutor (item 7), while 11.1% said they disagreed.

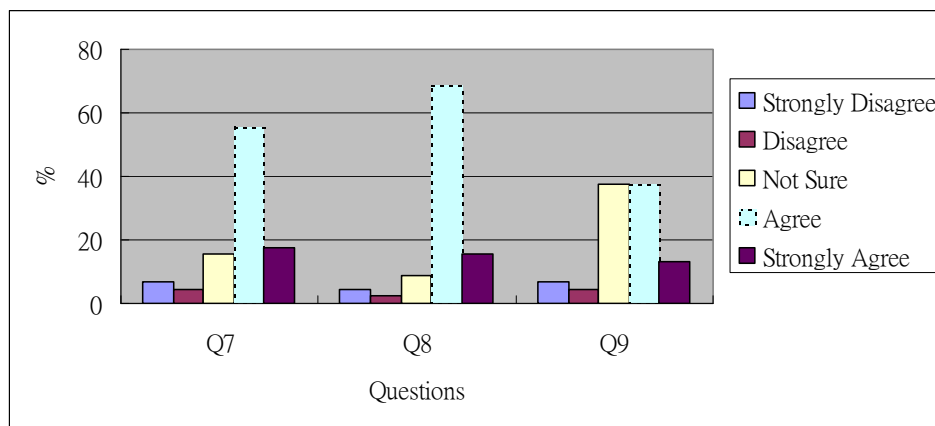


Figure 2: Learners' Responses to the Use of MyAccess as a Writing Tool

In general, the top two of the nine items with which the students agreed were (1) "I will correct my grammar and revise my essays after using My Editor of *MyAccess*" (M=3.89), and (2) "I will read the computer feedback and revise my essays after using My Tutor of *MyAccess*" (M=3.73). This suggests that the learners' responses to the use of *MyAccess* as a writing tool were positive. Obviously, the EFL learners favored the writing tool function over the grading function offered by *MyAccess*.

Research question 2: In the computer-mediated setting, what are the effects of using computer-mediated feedback for the revision of learners' essays and for learner writing skill development?

The majority of students replied that they would revise their essays according to the computer feedback. Evidence for this can be found in their answers to multiple choice question 10: "When you read the computer feedback on your essays, what was your response?" (see Figure 3).

As seen in Figure 3, of the forty-five students who answered this question, 40% said that they would revise their essays according to the feedback; 56% indicated that they would follow some parts of the feedback when revising; 2% specified that they would discuss with their classmates first and then revise according to the feedback; and only 1

student (2%) said he or she would ignore the comments. The effects of using computer-mediated feedback for the revision of learners' essays were clear. The findings suggest that the majority of the learners would revise their essays following the computer feedback since only 2% of them would ignore the feedback.

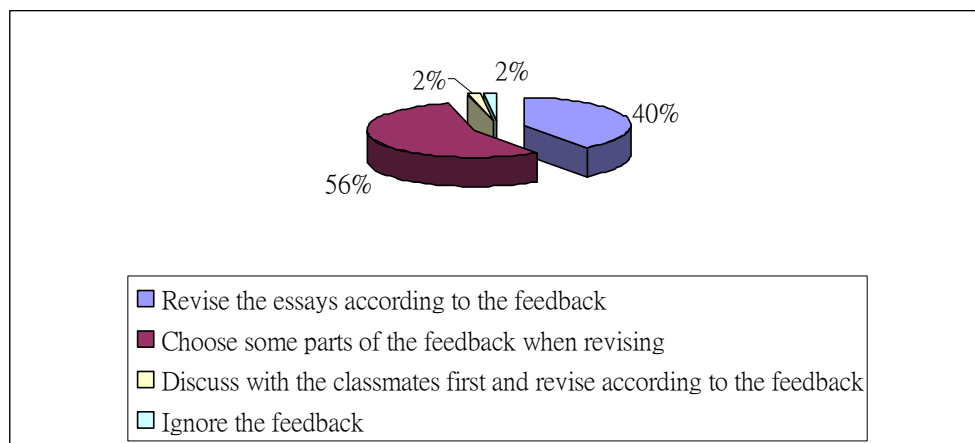


Figure 3: Q10: Response to the Computer Feedback on the Essays

According to the results of the interview data, the nine selected student participants found using computer-mediated feedback helpful for writing skill development. Three students described the prompt feedback of the automated grading system as helpful while four students preferred the My Editor function for improving their vocabulary, punctuation, spelling, word usage, and sentences. Two of them reported the My Tutor function useful for correcting their grammar. In other words, the majority of the learners indicated that the computer-mediated feedback had a positive effect on their writing skill development, particularly in the changes for form.

To improve the surface-level changes of their essays

- Interviewer: Which function of *MyAccess* do you feel satisfied with and think really helps you to improve your English writing: 1) automated grading system 2) My tutor 3) My Editor?
- Student 1: My Tutor. It offers me some suggestions, like word usage.
- Student 7: My Tutor. It offers some suggestions, like punctuation or vocabulary.
- Student 8: My Tutor. It helps me to write sentences.
- Student 9: My Tutor. It helps me with spelling.

To improve their English grammar

- Interviewer: Which function of *MyAccess* do you feel satisfied with and think really helps you to improve your English writing: 1) automated grading system 2) My tutor 3) My Editor?
- Student 4: My Editor. It offers some suggestions in grammar.
- Student 5: My Editor. It can improve my writing. It helps me to correct my grammar.

In sum, the results confirm that most of the participants experienced some benefit from the computer-mediated feedback in revising their essays and the computer-mediated feedback also had a positive effect on learner writing skill development, particularly in the changes for form rather than for content.

Research question 3: What are the learners' perceptions of using *MyAccess* in the future?

Learners' reactions to the suggestion of using *MyAccess* in the future emerged from the interview data. The major theme was: suggestion for future use. That is, eight of the nine learners suggested that *MyAccess* be utilized in the writing classes in the future.

Suggestion for future use: Eight of the nine student participants suggested using *MyAccess* in composition classes in the future. Specifically, four of them (students 3, 5, 6, and 7) mentioned that *MyAccess* offered the opportunity for them to practice English writing; three of them indicated it would reduce the teacher's load and help to give comments or correct students' drafts; one of them (student 2) felt it was a kind of good software. Only one of them, student 8, did not suggest using *MyAccess* in the future. Here are some excerpts from the interviews:

To practice English writing

- Interviewer: Do you suggest using *MyAccess* in composition classes in the future? Why or Why not?
- Student 3: Yes, it has its advantage for students to practice English writing, although it can't replace the teacher's role.
- Student 5: Yes. I think it will offer some help for us to practice English writing.
- Student 6: Yes. It increases the opportunities to practice English writing. The three functions have different roles to help us.
- Student 7: Yes. It offers the opportunities for students to practice English writing in class and after class.

To reduce the teacher's load and to help give comments or correct students' drafts

- Interviewer: Do you suggest using *MyAccess* in composition classes in the future? Why or Why not?
- Student 1: Yes. It will reduce the teacher's load and help to correct students' drafts.
- Student 4: Yes. It helps the teacher to correct students' drafts.
- Student 9: Yes. It replaces the teacher to give comments.

To be a kind of good software

- Interviewer: Do you suggest using *MyAccess* in composition classes in the future? Why or Why not?
- Student 2: Yes. Although it is not like the teacher who gives the perfect comments, it is a kind of good software

In conclusion, the learners' suggestions of using *MyAccess* in the future were obvious.

Discussion and Suggestions

From the results of the survey questionnaire, the learners' attitudes toward writing essays with the computer-assisted writing program, *MyAccess*, have been investigated. The results revealed the learners' favorable attitudes toward the use of *MyAccess* as a writing tool, but less positive attitudes toward its use as an essay grader.

A number of studies have discussed the positive as well as negative effects of students' attitudes toward CALL software in the ESL/EFL computer-aided writing instruction. A study conducted by Braine (2001) in Hong Kong indicated that EFL writers' drafts in traditional classes improved more than those in the classes using LAN software programs. However, the current study found that the majority of the learners had favorable attitudes toward the use of the computer-assisted writing program, *MyAccess*, as a writing tool. Also, the results of the multiple choice question showed the learners' gave positive responses to the computer-mediated feedback for the revision of their essays when using *MyAccess*. In addition, the findings obtained from the interviews indicated that the computer-mediated feedback had a positive effect on the learner writing skill development, particularly in the changes for form rather than for content; it verified the previous findings that less-skilled writers tend to focus predominantly on low-level, convention- and rule-governed changes to their texts and tend to focus more on word level revisions rather than revisions of larger chunks of text as suggested by Fitzgerald (1987). Moreover, eight of the nine selected learners suggested the use of the computer-assisted writing tool, *MyAccess*, in the writing classes in the future. Therefore, the adoption of computer-assisted writing instruction is worth taking into consideration in the EFL composition classroom.

On the contrary, the results of the survey questionnaire revealed that the majority of the learners held less positive attitudes toward the use of the computer-assisted writing program as an essay grader. Moreover, the findings from the open-ended question 11 found that half of the forty-four students who responded did not like the program since they felt the automated grading system was not fair. They also thought the computer software was unable to replace the teacher's role. In other words, they were not so satisfied with the automated grading system. Likewise, the learners' background information showed that the majority (91%) of them preferred their teacher's written feedback to the computer feedback of *MyAcces*; additionally, the majority (87%) of them felt that their teacher's written feedback was more helpful than the computer feedback in improving their English writing. In fact, Richmond (1999) clearly explained that "all forms of integrated CALL, despite their considerable advantages, suffer from one significant shortcoming: the difficulty of providing linguistic guidance and correction for the learners using them" (p. 309).

However, the learners' motivation for language learning is an affective factor, as Pennington (1999) mentioned that "intrinsic motivation drives performance far more reliably than extrinsic rewards or sanctions, and this basic fact about motivation applies to writing just as much as it does to other areas of performance. Most importantly, the self-motivated writer keeps pushing back the goal-posts for achievement" (p. 281). Similarly, Olsen (1980) conducted a survey on the use of CAI in departments of foreign languages across the United States, and the results showed that some of the support for the use of CAI was based on the perceived effect of the use of CAI on students' motivation and attitudes. Nevertheless, a study carried out in China by Huang (2005), indicated that "Chinese students' apparent passivity in the classroom is more likely to be a consequence of students' lack of proficiency, confidence and motivation" (p. 610). Therefore, it is important to motivate students to become aware of the value of independent learning outside the classroom as the study conducted with tertiary students in Hong Kong suggested that only the most motivated learners are attracted by the independent learning program (Lee, 1998).

As discussed above, it is suggested that fostering learner motivation to develop learner autonomy in the CALL environment be critical in an EFL context. As Tschichold (1999) emphasized, there is a need to increase users' autonomy when using CALL software, and grammar checkers, and she further suggested that students could become less dependent on the machine and on its often imperfect performance if they were given more autonomy and responsibility for their own text. Furthermore, Milton (1997) suggested the use of computer technologies to serve the aims of the autonomous development of writing skills, particularly for EFL writers. He explained the concept of autonomy that computers need to become learners' tools rather than expert tutors, and that new technologies are very promising for allowing CALL to develop in a more autonomous direction.

Limitations and Recommendation for Future Research

Since the results of the study demonstrated mixed effects, several limitations have to be noted here. First, the subjects of this study were 45 EFL students enrolled in an EFL writing class at a technological university in Taiwan. Thus, the findings are limited to subjects with a profile similar to those participating in this project, and the finding of this study cannot generalize to students of other levels. Future research in this area might attempt to include a larger population or compare their previous academic backgrounds, for example: English majors vs. non-English majors, and high-achiever vs. low-achiever student writers. Moreover, to better understand the effect of using CALL on EFL writing performance, future research studies may focus on examining the differences between an experimental group (computer-assisted writing group) and a control group (traditional classroom group), or on comparing the effects of using different computer-assisted writing programs in case of sufficient allocations for the department.

Conclusion

The study reported here was carried out as a small exploratory scale. While the results of the study shed light on some aspects relevant to the use of the computer-assisted writing program, *MyAccess*, in an authentic environment, the most important findings were that the majority of the learners preferred the use of *MyAccess* as a writing tool; moreover, eight of the nine selected student participants also recommended the use of *MyAccess* in the writing class in the future. Additionally, most of them benefited from the computer-mediated feedback in their writing skill development, particularly in the changes for form rather than for content. The results of this study are similar to those of New (1999). When implementing the computer-aided writing software, *Systeme-D*, into a foreign language

writing class, she suggested that surface-level changes far outnumbered the changes to content. Because there were a number of weaknesses and limitations in the current study, such as the adequacy of the scoring engine, we probably need to examine different learning and teaching contexts if we have sufficient allocations for computer software programs in the department. In addition, as previous studies claimed that all computer-based writing programs cannot be used as a replacement of a teacher (Warschauer & Ware, 2006), the results of this study revealed some learners' similar ideas. However, instead of comparing the differences between an experimental group (computer assisted writing group) and a control group (traditional classroom group), it hopes to enhance language teachers' awareness of how such a computer-assisted writing tool, MyAccess, can be used more effectively in the writing classroom to benefit EFL student writers as well as the writing instructor in this exploratory study. Therefore, in the teaching process of EFL writing, it is essential that EFL writing instructors encourage student writers to make the most of diverse resources, such as computer-based writing programs in order to become autonomous learners.

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From MMORPG to a Classroom Multiplayer Presential Role Playing Game

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ABSTRACT

The popularity of massively multiplayer online role-playing games (MMORPGs) has grown enormously, with communities of players reaching into the millions. Their fantasy narratives present multiple challenges created by the virtual environment and/or other players. The games' potential for education stems from the fact that players are immersed in a virtual world where they have the opportunity to manipulate and explore, thus motivating the construction of knowledge. The interaction and collaboration between participants allows students to exchange information, test their understanding and reflect on what they have learned. Given the promising results of using MMORPG technologies for educational purposes, this paper translates the multiplayer role playing game (MRPG) aspect, the essential concept behind MMORPGs, into the classroom context. We present the abstraction behind a *Classroom Multiplayer Presential Role Playing Game* (CMPRPG) and the development of a CMPRPG for teaching ecology. The game has a quest structure in which each result highlights a key teaching objective. It is implemented at a high level, with interaction between reusable game elements defined using triggers. It is observed that the implemented CMPRPG has appropriate usability levels, benefits the learning and application of the concepts of ecology and, in the interactive dimensions, it encourages participation and collaborative narrative structures among participants.

Keywords

Learning, classroom, multiplayer game, MMOG, virtual worlds

Introduction

The convergence of high-speed Internet connections, increasingly sophisticated graphics cards and powerful microprocessors has driven the appearance of many video game titles that are now omnipresent in our culture, particularly among children and adolescents (Delwiche, 2006; Rhyne, 2002]. This phenomenon has led to much research and debate over the educational potential of these games (Mitchell & Savill-Smith, 2004). Some studies have concluded that video games develop skills such as high-level thinking, reaction times, visual attention and literacy (Delwiche, 2006) while others have unearthed evidence that long exposure to video games can diminish brain activity, create emotional and behavioral problems (Mori, 2002) and even increase aggressivity and violent conduct (Anderson & Bushman, 2001). Researchers have also raised gender concerns in that females have been found to display less positive attitudes towards technology use (Young, 2001) whereas males devote much more time to video games (Bryce & Rutter, 2003; Griffiths & Hunt, 1995). Even so, a significant inflow of women to the video game market has been detected (ESA, 2009; Yee, 2001). This entire debate will no doubt grow in the future with the ongoing expansion in the number of video game players.

As research proceeds on their educational possibilities, video games continue to incorporate the latest technological innovations in the push to further their development and capture ever more enthusiasts. Perhaps the best example at present is the highly popular World Of Warcraft (Cohen, 2008), that belongs to the genre known as massively multiplayer online role playing games, or MMORPGs (Bessière, Seay & Kiesler, 2007). MORPGs are characterized by: their fantasy environment that favors immersion and flow (Csikszentmihaly, 1990), the interactivity with the virtual world and peers through the virtual world, having a history and a structured script in challenges and missions that develop critical thought, teamwork, and problem-solving strategies (Dickey, 2007), as well as the generation of new situations produced by the interaction of players (Steinkuehler & Duncan, 2008).

This type of game is dependent on two main technical considerations, Internet connection speed and computer graphics and processing capacity. These factors are essential to the development of high-quality detailed virtual environments that large numbers of players can connect to and thereby interact with other players and the virtual environment through fictional characters they invent for themselves in a fantasy narrative filled with challenges created by the environment and other players. These virtual environments share a number of characteristics with

interactive learning environments (3-D technologies), whose emergence has been propelled by the integration of this type of technology with educational materials and an epistemological shift towards the ideas of constructivism.

It is these common characteristics that underlie the extensive analyses by many researchers into the educational potential of MMORPGs. The theoretical assumption behind interactive learning environments is that students construct understandings through interaction with information, tools and objects in the environment as well as collaboration with other students (Dickey, 2007). To motivate this construction in interactive environments, they must be able to manipulate and explore (CTGV, 1990; Jonassen & Rohrer-Murphy, 1999). MMORPGs are built as 3-D spatial representations that allow players to move and interact in simulations of fantasy or realistic environments.

Conversation, discussion and collaboration are also important in learning environments for their contribution to negotiation, socialization and learning (Lave & Wenger, 1991), allowing students to exchange information, test their understandings and reflect upon what they have learned (Duffy & Cunningham, 1996; Jonassen & Rohrer-Murphy, 1999). Most MMORPGs are social environments where players communicate, collaborate, plan, design strategies and socialize with other players. Finally, learning environments must have the ability to pose interactive challenges that require players to synthesize, analyze and evaluate information and apply critical thinking to formulate strategies and solve problems. MMORPGs provide many opportunities for such challenges through the narratives created in this type of game (Dickey, 2007).

The objective of this paper is to present an adapted MMORPG to the classroom needs, denominated “Classroom Multiplayer Presential Role Playing Game” (CMPRPG), and an experience to teach ecology with CMPRPG. The following work introduces the fundamentals CMPRPG concepts; we then presents a CMPRPG to teach ecology within the framework of Chile’s 6th grade school curriculum and describe its technical implementation. Afterwards, we present the exploratory study results carried out with students. Finally, we discuss these results and submit our conclusions.

CMPRPG: MMORPG for the classroom

Given the promising results of using MMORPG technologies for educational purposes, this work translates the multiplayer role playing game (MRPG) aspect, the essential concept of MMORPGs, into the classroom context. Since the number of students in this context is not massive and play takes place within a single room rather than on the Internet, we have changed the terms “massively” and “online” to “classroom” and “Presential” respectively, thus giving us the new designation “Classroom Multiplayer Presential Role Playing Game” (CMPRPG). This game type involves all of the students in a class playing at the same time in a virtual world projected onto the walls of the room in which each student interacts through an individual input device (e.g., mouse).

MMORPGs use virtual worlds to create immersive interactive environments where players participate simultaneously to achieve personal and group objectives, which are fundamental aspects of motivation according to Yee (2006). The essential contribution of MMORPGs to interactive learning environments is thus their support of intrinsic motivation. Game developers have succeeded in motivating players to extreme levels, even to the point of addiction. This issue has also been widely studied, and the main factors found to lie behind this phenomenon are a player’s character in the narrative and the quest model (Dickey, 2007).

Research into the importance of players’ characters in the intrinsic motivation of a game (Stone, 1995; Turkle, 1995; Curtis, 1997; Reid, 1994; Jakobsson, 2002; Jakobsson and Taylor, 2003) demonstrates that players invest much time in differentiating their characters by gaining experience points that allow them to add and modify character attributes. Due to the time limitations inherent in a classroom context, our CMPRPG model excludes the ability to save a particular instance of a game and continue it later with the same characters, unlike MMORPGs in which a virtual world continues indefinitely. The differences between the characters available in CMPRPGs are directly related to the roles players can choose.

According to Luff (2000), successful role identification helps the student escape the confines of contemporary norms and beliefs. The players are forced to change perspective and see the world differently. Bell (2001) notes that the ability of role-playing techniques to affect attitudes and behavior has been fully demonstrated. As with many

MMORPGs, roles in CMPRPGs are chosen at the start of a game and develop automatically in accordance with the behavior of the players during the virtual world activity so that the incentive to differentiate their characters as they wish is maintained, at least temporarily.

The nucleus of an MMORPG design is the narrative, the game's background story. It is made up of a series of mini-narratives known as quests. Generally, people have difficulty understanding and remembering information received out of context or a long time before they can use it (Barsalou, 1999; Brown, Collins & Duguid, 1989; Glenberg & Robertson, 1999). Quests provide information to players moving through a world as and when they need it, supplying indications on its meaning and how it applies to that world (Gee, 2003; Delwiche, 2006).

A quest allows players to interact with the system by interacting with the narrative, presenting them with characters, missions, information related to the missions, etc. This interaction has three principal objectives. The first is to expose the players to various resources (information, tools, objects), particularly those that are key to advancing in the game. The second is to provide the experience needed to further the development of their characters, expressed in terms of a score that determines the level and attributes the character may choose at a given moment in the game. Finally, the third objective is to stimulate collaboration and strategy development by generating new quests that require multiple players to complete (Dickey, 2007).

The multiplayer aspect of MMORPGs makes individual players part of a community, and through their participation in it they understand the world and themselves from that community's perspective (Delwiche, 2006; Gee, 2003). In CMPRPGs the community is created through students' classroom interaction, thus facilitating group work, discussion, collaboration, etc. This social interaction allows ideas to be exchanged for the construction of knowledge, a fundamental factor in educational development (Cole & Stanton, 2003). When individuals work together on a given problem they communicate and mobilize knowledge, energy and motivation (Zurita & Nussbaum, 2004). However, the mere fact people are working in the same environment will not guarantee such collaboration (Nussbaum et al, 2009); to ensure it is achieved, CMPRPGs must enable interactivity and include the necessary tools to foment group work and discussion through a game's narratives.

As for virtual environments, they immerse players in the game through a narrative defined within a certain context. Studies have demonstrated that immersion in a digital environment can support education in at least three ways: by allowing players to observe phenomena from different perspectives, by placing them in locations and contexts where the phenomena are occurring, and by facilitating transfer, defined as the application of knowledge learned in one situation to another situation (Dede, 2009). In CMPRPGs the use of 3-D technologies and cameras to define which virtual world zones are displayed at a given moment allows phenomena to be shown from different perspectives as needed to aid in their understanding. Also, the narrative and the environment situate the players in the place and context where phenomena occur, providing them with the information and tools that will have to be used there. The concepts to be delivered are thus communicated at the appropriate time and place so that players can use the information and knowledge acquired in a simulation that closely resembles the real world, thus shortening transfer distances.

A CMPRPG for teaching ecology

Objectives

In this section we introduce a CMPRPG for use in teaching ecology. The teaching objectives of the game are the ones laid down by the Chilean Ministry of Education for the 6th Grade course in Nature Study and Comprehension (Mineduc, 2004), and are shown in Table 1. These objectives can be divided into two categories: 1) transversal objectives, which refer to the general training of students in moral and social conduct; and 2) vertical objectives, which involve the acquisition of skills in specific areas of knowledge and personal development and are defined for specific courses and curriculum levels. The table also indicates the associated teaching activities, that is, the educational activities that facilitate the analysis and comprehension of a given knowledge or skill to be taught. Finally, the table includes the expected learning, i.e., the knowledge and/or skills that students should attain by the end of the educational or classroom experience (Mineduc, 2002).

Table 1: Teaching objectives

Transversal teaching objectives	Vertical teaching objectives	Teaching activities	Expected learning
To promote collaboration, responsibility and personal autonomy. To use knowledge and be able to select relevant information. To promote initiative and teamwork	To describe and comprehend the processes of flow and exchange of material and energy between living beings in a hypothetical ecosystem.	Notions of dynamic ecosystem equilibria are applied to given situations: prey and predator. Notions of rupture of the ecosystem equilibria by natural factors are applied to given situations.	Ability to recognize the material and energy flows that occur in food chains and webs.

Quests

The ecology game includes a number of different quests following the CMPRPG model, each one designed to emphasize a key teaching objective. They are arranged linearly so that the end of one marks the beginning of the next. This order is determined by the curriculum structure set by the Ministry of Education and ensures that the course concepts are delivered incrementally.

Three of the game's quests are aimed at achieving specific vertical objectives (Table 2). In the first Quest, a new foreign species joins the ecosystem. This new predator starts feeding on the predators that were previously at the top of the food chain transforming the ecosystem. The players must protect the ecosystem by scaring away the new species; to do this they must approach the new predator species in groups of not less than three players so as to lead it away from the playing zone.

In the second Quest, a strange parasite starts to affect all the animals and it turns into an epidemic. The players have to contain this epidemic. To do this, two roles are defined in the game, the hunter who paralyzes the infected animal, and the Shaman who later cures it.

In the third Quest, there is an explosive reproduction of the herbivorous population becoming a risk to plant life. In the virtual setting, the plant ecosystem is comprised of three areas, and its existence is at risk from this increase in herbivorous predators. The players must work together to prevent these herbivores from destroying the ecosystem by killing off plants in each one of these three zones. The players must plant more plants, kill the herbivores when they become too numerous and ensure that there are always carnivorous predators in each zone.

Table 2: Game activities and related teaching objectives

Description of activity	Specific vertical objectives	Expected player behavior
Quest 1: A foreign species is introduced into the ecosystem breaking the ecological equilibrium.	1.1. To characterize the food chain of the carnivorous predator.	Observe that tigers feed on bears.
	1.2. To recognize human involvement in achieving ecological equilibrium of the secondary consumer.	Control and eradicate the tigers before they eliminate the other species.
Quest 2: An epidemic spreads among the animal population.	2.1. To recognize the action of the parasite.	Observe that the animals are being weakened by a virus.
	2.2. To recognize human involvement in the control of pathogenic parasites.	Control and eradicate propagation of the virus by curing or destroying infected animals.
Quest 3: Deer reproduction rises to plague proportions.	3.1. To characterize the food chain of the herbivorous predators.	Observe that herbivores feed on plants.
	3.2. To recognize human involvement in achieving ecological equilibrium of the primary consumer.	Encourage hunting of deer to control their population.

Chile's 6th grade primary school curriculum states that, in addition to achieving vertical objectives, the teaching activities need to be aimed at transversal objectives (Mineduc, 2002). In the Ethical Formation field, the collaborative work in the three Quests enables players to exercise increasing degrees of freedom and personal autonomy. In the Personal Growth and Empowerment area, collaborative work enables the participants to distinguish and choose relevant information to the task as a group, as well as exercising the ability to express and communicate opinions in order to reach an agreement. In the area of Person and Environment encourages the protection of the natural setting as a human development context through the development of personal initiatives and team work.

The optimum interdependency of actions between peers that ensure meeting activities objectives and the the game's aim: i.e., to recover or preserve the ecosystem's equilibrium, is shown in Table 3.

Table 3: Activity-collaborative strategies relationship

Activity Description	Collaborative Strategies (Optimum Interdependence)
Quest 1	The sum of players' actions in groups of three in the three virtual zones defined in the game, help frighten off or eradicate the predator to protect the ecosystem. This implies awareness of the problem, of one's own role and willingness to add actions between peers that help achieve the goal.
Quest 2	Only a set of actions in groups of two players – first the Hunter immobilizes the sick animals and then the Shaman performs the cure – enables epidemic expansion control. This implies awareness of one's own role, use of information that will allow the ranking of actions, and willingness to dialogue that will enable recognizing the pertinent actions in each case.
Quest 3	Player organization and their distribution over the three different spaces of the virtual environment ensure the efficient care of the entire ecosystem. This implies understanding of the problem, personal autonomy and responsibility in upholding the group agreement that ensures the goal is achieved.

Implementation of the CMPRPG

Technical considerations

The activities were developed using the 3D NeoAxis engine, modified in order to be used with the Multipoint SDK (which uses a more recent version of .NET).

The ecology game is processed on one PC with a single graphics output device and multiple input devices to allow interaction between the student players. This was achieved using Microsoft Multipoint SDK, which supports processing independently the information captured by the input devices (Pawar, Pal & Toyama, 2006). Thus, each player can have his or her own pointer controlled by a mouse in order to interact with the system. In the implementation we used regular mice, because Bluetooth and wireless mice experienced technical difficulties: using more than four wireless devices caused interference and poor device performance. Bluetooth devices, in turn, have a restriction in terms of the number of devices per antennae (they support up to seven devices), which, together with the impossibility of using in Windows multiple drivers for different antennae, becomes an insoluble problem.

Among the benefits of this single-computer design are its low cost and portability compared to a setup using separate machines for each player, which would require multiple computers in a dedicated room.

The game can support a maximum of ten players. This is due mainly to the space restrictions within the virtual world given that the players' characters must be displayed on the same output device, thus limiting visible space.

Game elements

The players are assigned to one of two roles, hunter or shaman. Each of them has a particular ability and needs the other to perform properly. Both roles have four attributes in common: life points (the amount of harm players

experience before dying), energy points (for exercising special abilities), speed of movement, and attack (harm inflicted on animals when attacked). Hunters are more adept at hunting and thus have more highly developed attack, life point and speed attributes than the shamans. The latter, although weaker than hunters, have the ability to cure other characters (hunters or shamans), and in doing so consume their own energy points. The two groups are interdependent because they require each other to carry out complex tasks. The players must constantly feed on animals and plants or die of starvation. The animals are either herbivores or carnivores, the former eating plants and inoffensive to players and the latter eating other animals and aggressive toward any character that approaches. The animals also reproduce periodically. A description of each game element is given in Table 4.

Table 4: Elements of the Ecology Game

Type of element	Description	Specific element
Map	Contains the complete set of elements that define the activity.	
Characters	Represent the players in the virtual world. They have four attributes: life points, energy points, speed of movement, and attack.	Hunters: most highly developed attributes are speed of movement, life points and attack. Shamans: are able to cure their allies in exchange for energy.
Animals	The principal source of food for the characters. They must also eat periodically or they will die. They can reproduce.	Herbivores: Deer. They feed on plants and are inoffensive. Carnivores: Tigers and bears. They feed on other animals and are aggressive toward characters.
Plants	Static objects that reproduce periodically. They are consumed by herbivores and by shamans to regain energy.	
Decorative objects	Purely aesthetic. They provide a realistic setting for the game.	These objects include trees, rocks, smoke, etc.
Zones	Define three-dimensional spaces in which the game's actions take place.	Sphere, cube
Items	Objects that can be collected or used by the players.	Food

Figure 1 shows the different described elements for the Ecology activity in a snapshot of the overhead projected image in front of which the students interact face-to-face..



Figure 1: Snapshot of the implemented CMPRPG

Elements of interaction

Interaction between the various game elements occurs by means of triggers, a model used in commercial games such as WarCraft III. Triggers consist of events, conditions and actions, and function according to the following logic: if an event occurs and certain conditions are satisfied, a given action is taken (El-Nasr & Smith, 2006). A trigger is thus initiated by an event, which may be any of a variety of situations that arise during an activity ranging from a user input to changes in an element state such as the death of an animal, a player or some other game unit.

An array of different actions may be exerted on game elements as a result of the occurrence of an event together with the satisfaction of the associated conditions, including interface functions (*e.g.*, the display of a message) and actions to control game units and characters. For example, in the second quest the players must frighten off the tigers who invade the ecosystem, but they will flee only if they are pursued by at least three players. In this case, the event is the entry of players within the zone of a tiger, the condition is that the players number more than two and the action is that the tiger retreats to the point furthest from the players within a radius defined by the game editor.

The main advantage of programming with triggers is that they can be used to define the interactions between game elements in a high-level language. A further advantage is that the specific rules of an activity are defined as elements and are therefore reusable for creating other games. In Figure 2, we exemplify the interaction between one participant and the elements of the game, performing the action of attacking a group of animals. This snapshot is contained in Figure 1.



Figure 2: Player attacking a deer

Exploratory study

Objectives and methodology

An exploratory study was carried out with three objectives: a) To measure the learning on the defined ecological objectives, b) To determine the type of communicative interaction that is attained among students, and c) Perform a usability study.

The study involved 10 students from the 7th grade, in regular Primary school, ages ranging from 12 to 14, in a mid-level socioeconomic school of Santiago de Chile. Children from 7th grade Primary School were chosen because; a) they are already aware of the ecological equilibrium and food chain concepts as these are included in their study plan from the previous year, and b) the designed Quests are applicative; namely, knowledge of the balance concept and the food chain is a pre-requisite – although not necessarily the understanding of such-.

Procedure

1. Two days prior to the session using the CMPRPG model, the command of prior knowledge on the ecological equilibrium of all players was evaluated, using the NEE (Notions on Ecological Equilibrium) test, which was built

for the vertical objectives of the presented CMRPG . The test that was reviewed by three primary school teachers, experts in this subsector of the school curriculum.

2. On the day the CMRPG model was applied the following series of actions was performed:

- An interactive tutorial of the CMRPG was developed, to delimitate a) the games structure and objectives, b) the meaning of the elements on the screen, and c) the use of the mouse so that each player can interact with his/her peers through their avatars.
- Following the tutorial, the game activities were initiated. At the end of the 3rd activity, the researcher team gathered general impressions on the game from the students.

3. Three days after the CMRPG session, the group was evaluated using the NEE test.

The usability conditions of the CMRPG were recorded on a Usability Observation Scale (Table 6) by two bystanders. Additionally, the session was filmed using two fixed cameras for subsequent analysis of communicative interaction (Table 7).

Exploratory Study Results

Notions on Ecological Equilibrium Test Results (NEE)

Taking into account that the activity permits working with 10 students simultaneously, this number of participants were used in the pre-test session and in the CMRPG activity. However, only 8 students were able to take part in the post-test evaluation – 5 females and 3 males – the remaining two members being sick. Consequently, the comparative analysis of the results of the NEE pre and post test was performed on 8 valid cases. Table 5 shows the Mean and the standard Deviation in the 8 cases used in the study.

Table 5: Descriptive statistics results of post-test in the Notions on Ecological Equilibrium (NEE) Test

Test NEE	Mean	N	Standard Deviation
Pre-test	7,4	8	1,3
Post test	7,9	8	0,8

It may be observed that in the post-test, students increased their score in the NEE test. Compared to the pre-test, the scores obtained by the 8 cases rose 7%, this being a non significant difference of $p=0.227$) reaching a medium effect size of ($d_{Cohen}=0.50$). Likewise, analyzed independently, both females and males increased their scores in the post-test, where a slightly higher increase was observed among the males (14% in males and 3% in females).

Usability Results

The usability of the CMRPG was assessed through observation scales adapted to each of the teaching activities raised in the Quests. The designed items evaluated three aspects of usability:

1. *Identification of map elements*; refers to items that assess to what degree the students were able to recognize the dynamic, contextual and informative elements regarding their participation in the map.
2. *Activity Understanding*; refers to the items that assess to what degree the students were able to play the game according to screen instructions and use the action possibilities of the character chosen to address the Quests.
3. *Activity participation among players* refers to items that measure the existence or not of collaboration with others through the game character and its respective emotional expression.

The usability of the Tutorial was only evaluated for Aspects 1 and 2. Aspect 3 - *Activity Participation among players*, was not considered because it is an activity that is guided by the system so that students learn to operate the game. The various items of Aspects 1 and 2 were coded according to the following scale: 0 = Not achieved; 1 = Achieved with help; and, 2 = Achieved alone. The items regarding Aspect 3 were coded according to the following categories: 0 = Does it; and, 1 = Does not do it.

The behavior of each game player was observed and classified through the items of each of the three indicated dimensions. Subsequently, the scores obtained by the group in each item and then in each dimension were tallied. For purposes of analysis, these were converted to percentages, where the 0 tendency means no usability and the 100 tendency indicates full or adequate usability. Table 6 presents a summary of the usability achievement percentages by the group of players in each activity presented.

Table 6: Quest Usability achievement percentage in each usability dimension evaluated

Usability aspects	Achievement % Tutorial	Achievement % Quest 1	Achievement % Quest 2	Achievement % Quest 3
Identification of map elements.	87,5	91,1	100	100
Activity Understanding	83,8	80	72,5	40
Activity Participation among players	Not applied	65,7	60	45

Table 6 shows that the Tutorial offers adequate initial information to students for the identification of the map elements and for activity understanding. Over the course of the session, the usability measures in the three dimensions reflect variations associated to what is called for in each Quest's.

As the game progresses the identification of map elements improves, but not so the understanding nor the participation among players. This affects the success achieved in each Quest. Quest 1 was played three times; however in the three opportunities the students did not reach the objective of maintaining ecological equilibrium. Quest 2 was played twice; the first time they failed, but the ecological equilibrium objective was achieved on the second run. Quest 3 was played only once and the students did not reach their objective of maintaining the ecological equilibrium of the virtual ecosystem. The usability level of the 1st dimension, *Identification of map elements*, reached 100%, and the remaining 2nd and 3rd dimensions tended to drop. This occurred because, as map element identification improved the students became more independent in terms of screen information on how to address the Quests, and their interaction in class did not transfer to their character's activities on the screen. The 3rd dimension, *Activity participation among players*, was particularly impacted by the absence of coordinated actions between the players. On the other hand, in all activities the players clearly evidenced satisfaction and positive emotion about their involvement in the game.

Interactivity Results

The Quests set had an approximate duration of 35 minutes. Quest 1 took approximately 20 minutes, Quest 2 took 10 minutes and Quest 3 lasted for 5 minutes. The ten participants interacted amongst themselves as well as with the map elements shaping different communicative interchanges.

Table 7: Communicative type interchanges

Definition of Interchange Types
Incomplete Interchanges: Interventions (statements, affirmations, actions) that are independent of the activity or hegemonic narrative between speakers in the classroom, and does not constitute a dialogue with any specific speaker or with the group.
Interchange of Information: interventions and actions aimed at solving absences of functional information for individual actions. This involves at least two different interlocutors in the dialogue. In the CMPRPG activity, the other spokesperson can be a specific player, the group or the activity map.
Negotiation: Interventions where speakers state two or more excluding action strategies that seek to converge into new strategies.
Leadership: Intervention by one of the players who organizes the action of one or more players.
Coordination: two or more players narrate in order to share interdependent actions on screen with an aim to achieving an objective.

From a pragmatic and interactive perspective, the interchanges consist of interventions from different speakers in a dialogue. There are different types of interchange or dialogue units according to the objective. Not all interventions constitute dialogues; although they might have a communicational intentionality; in which case they are defined as *Incomplete interchanges*. The collaborative work is a blend of interchange structures where the speakers build actions of interdependence through their interventions (Atencio, 2004; Iverson & Duveen, 2005). In this case, the collaborative work is a blend of interchange structures such as: Negotiation, Leadership and Coordination. Table 7 defines the types of interchange that are analyzed in this activity.

In turn, different variants and categories for achieving the objective can be internally identified in these types of interchange. Although a majority of student interventions became dialogs related to the proposed activities, as in the case of *Information exchanges*, the latter did not achieve the same success level in order to become collaborative dialogues. Table 8 shows the categories *Interchange of Information, Negotiation, Leadership and Coordination*. It can be seen that of the 46% of interventions linked to collaborative dialogues, only 22% were successful – the *leadership and coordination* categories-. Likewise, it can be seen that the males, compared to the females, had more Incomplete Interchanges and Leadership; and the females stand out in *Interchange of Information and Coordination*.

Table 8: Frequency of interventions corresponding to student interchange types and categories

Types of interchange	Categories	Percentage of Interventions	% Male	% Female
<i>Incomplete Interchanges</i>	Statements and actions that are not linked to the activity, nor are directed to any speaker or group.	6%	10%	3%
<i>Interchange of Information</i>	Question/answer narratives regarding information on game usage between two specific interlocutors.	33%	31%	36%
	Question/answer narratives regarding information by one speaker to the whole group.	9%	10%	8%
	Player interaction with screen instructions.	6%	3%	8%
<i>Negotiation</i>	There are differing opinions among the players on how to address the activity and no agreement is evidenced.	4%	4%	4%
	There are differing opinions among the players on how to address the activity and agreement on a new strategy is evidenced.	0%	0%	0%
<i>Leadership</i>	One player indicates tasks and/or roles to others but there is no evidence that peers have followed these directives.	6%	8%	3%
	One player indicates tasks and/or roles to others and it is evident that peers have followed these directives.	13%	15%	10%
<i>Coordination</i>	One player states his/her intention of sharing actions with another player in order to reach a goal, but they do not define the complementary nature of their actions.	15%	10%	20%
	One player states his/her intention of sharing actions with another player in order to reach a goal and they define the complementary nature of their actions.	9%	10%	7%
	TOTAL	100%	100%	100%

Discussion

The use of the CMPPRG model integrated, in a structured and entertaining manner, a set of activities aimed at achieving transversal and vertical teaching objectives of the school curriculum. The exploratory study demonstrates that the proposed activities motivate the participation of the students and promotes team work. The game enabled

visualization of the food chain and the ecological equilibrium concepts. Even more complex is the understanding of the consequences of human actions, the handling of which the virtual world enables through different scenarios. For example, in Quest 3, the student eliminated all the bears from the virtual ecosystem and that triggered an excessive increase in deer. When the student was asked the consequence of his/her actions, the student said that there would be an increase in deer and this would provoke a decrease in plants, and, in addition that the air would get worse; this latter element was not even considered in the game.

The analysis of the usability results suggests the need to calibrate the growing complexity of the Quests. Simplifying the relation between concepts, in our case the ecological chain, can benefit coordinated participation in the game.

The ethnographic observation of the session and the analysis of the interchange structure demonstrate that there are qualitative differences in the participation. The male players demonstrated greater leadership and emotional expression during the game as compared to the women. The female participation was more oriented towards obtaining information, interaction with the events on the map – interchanges of information-, and actions oriented to coordinating actions.

The participants failed in achieving their goal in two of the three Quests. The collaborative interdependence indicated in Table 3 for Quests 1 and 3 did not occur. Both Quest 1 and 2 have two common elements for achieving the objective: a) that the participants organize in groups of at least three players, independent of their characters' attributes and b) agree with the other participants to delimit an action zone. In Quest 2, the basic element of collaboration is the organization of players in partners with different roles. It is up to future work to explore whether collaborative relationships requiring the coordination of fewer participants (whose roles are defined by the attributes of their characters) would increase the possibility of success in this activity. The difficulty for students to successfully address all the Quests does not lie in the understanding of the task but rather in the coordination of actions. The students understand that, for example, it is better to spread out in zones to protect the ecosystem, but they have trouble putting this into practice. In a future work, a way to solve these problems should be researched, developing effective mechanisms of communication and reflection.

In on-line games, the players have two ways of communicating: text and voice. Text messages are generated only between two people or among a sub-group of players. This helps in guiding the communication more effectively which is not possible in a CMPPRG model. Verbal communication in the classroom was, at times, chaotic. This was because the students are not used to being responsible for organizing their communication given that this is usually done by the teacher. This was demonstrated negatively in the last activity where the relevant information could not always be communicated effectively, which led to its failure. A future study should research if the systematic and periodic use of the CMPPRG model develops this personal-presence communicative skill.

At the end of each Quest a reflective activity was carried out. The objective of this reflection was oriented towards showing and ensuring that the teaching concepts were assimilated by the students. During this reflexive activity, the students became so wrapped up in the screen elements that these paradoxically became a distracter of the actual reflexive activity. A future study should analyze how to use virtual world elements together with the reflexive work performed by the teacher.

Additionally, time in the classroom is limited, as opposed to on-line games where the players have more time at their disposal. This implies that although it is expected that the collaborative activities should emerge naturally – as in on-line games – the time constraints in the classroom need guided reflection to ensure and step up the achievement of transversal and vertical objectives. The leadership actions observed in students dissolved in a communicative context that was at times chaotic. A mediation action is needed to strengthen the collaborative strategies that emerge from the group. With regard to the above, an opportunity emerges for the teacher to participate actively as a reflexive mediator of the teaching processes.

The use of computerized supports increases the learning time needed, this being due, on the one hand, to the time required to understand and dominate the virtual world, and on the other because as the students are participative actors of their own learning they require more time for their interactions. In our first experience, this required a minimum time of 60 minutes. It is recommended therefore that CMPPRG models be used to work academic contents that have greater time assigned in the curriculum. Thus, fuller advantage could be taken from the collaborative dimension promoted by the use of a CMPPRG model.

The results of the exploratory study must be understood considering two methodological limitations. One of them is the absence of a Control Group; although we found that learning increases after the test, we ignore whether such improvement would also have been achieved with the same exposure time but using traditional teaching methods. The second limitation has to do with the different devices used by each participant; these were devices wired to the central computer that restricted student mobility and thus their collaborative possibilities. Future studies should consider analyzing learning compared to a control group and using wireless devices, so as to allow greater participant mobility.

Conclusions

In this article we introduced a new tool denoted CMPPRG that is derived from the concept of a MMORPG and can be used in the classroom to achieve immersion in an educational activity and collaboration between students via a MRPG with curriculum content. We found that the structure of a quest facilitates the development of a series of curriculum objectives through a ludic language and concluded that, for future CMPPRG designs, it is recommended that: a) the conceptual relationships to be worked out be made operational through a process of increasing complexity; b) the students be offered more time for practicing and commanding their characters' attributes in the virtual world; and, c) the teachers' role in the deliberation of the learning content applied to the game be defined.

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Development and Evaluation of a City-Wide Wireless Weather Sensor Network

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ABSTRACT

This project analyzed the effectiveness of a city-wide wireless weather sensor network, the Taipei Weather Science Learning Network (TWIN), in facilitating elementary and junior high students' study of weather science. The network, composed of sixty school-based weather sensor nodes and a centralized weather data archive server, provides students with current weather data at specific locations in the city. In 2006-2008, annual weather science tournaments were held to encourage students to use this resource, and up to now 171 registered teams, including 447 grade 4-9 students and 220 teachers, have participated in competitions. This study of the tournament data makes clear the over-all efficacy and usability of the network. An analysis of the students' weather science ability demonstrated that they could perform well in the questioning phase, the planning phase and the analyzing phase but not as well in the interpreting phase of their specific weather-science inquiries.

Keywords

Wireless weather sensor network, Weather science learning, Taipei weather science learning network

Introduction

Generally, scientific inquiry means the process by which scientists study, analyze and try to explain natural phenomena. In order to develop student inquiry competences, teachers need to provide opportunities for them to experience how scientists actually do science. Scientific inquiry competences include observation, questioning, generating hypotheses, conducting experiments or investigations, analyzing and explaining data, proposing answers and so on (AAAS, 1993; NRC, 1996; NRC, 2000; White & Fredriksen, 1998; Sandoval, 2001). The meaning of scientific inquiry changes with time. In the 1960s, inquiry referred to scientific learning through laboratory work and as a reasoning process for seeking answers to questions. In 1995, the National Science Council's National Science Education Standards focused on inquiry. According to these Standards, inquiry can have two meanings: "First, it refers to the abilities students should develop to be able to design and conduct a scientific investigation and to the understandings they should gain about the nature of scientific inquiry. Second, it refers to the teaching and learning strategies that enable scientific concepts to be mastered through investigations (CSMEE & NRC, 2000, p. XV)."

Instead of memorizing factual knowledge, repeating answers, and listening to lectures, higher-order thinking skills such as inquiring, exploring, proposing questions and independent problem solving are important for students who must face a world filled with new challenges. Science learning is essentially a question-driven, open-ended process, and students must have some personal experience with scientific inquiry to understand the fundamental aspects of science (Linn, Songer & Eylon, 1996). Science learning activities help students develop cognitive abilities (e.g., critical thinking and reasoning) as well as scientific knowledge (Linn, 2003). Many studies have proposed learning models to explain the student inquiry process and to provide a basis for curriculum design and professional development of teachers in order to facilitate science learning. Krajcik *et al.* (1998) proposed an investigation web to facilitate student inquiry and problem solving. White (1993) used an inquiry cycle to interpret the process of students' scientific inquiry. This technology helps students to collect and analyze data, and share their ideas with others. In some cases, technology can be used as a tool for knowledge construction and critical thinking (White, 1993; Jonassen, Peck & Wilson, 1999). Information and communications technology, then, can be used not only to store and manipulate huge amounts of information but also to encourage students' interaction with information in a variety of formats, help them perform complex computations, support their communication and respond rapidly to individual users (Blumenfeld *et al.*, 1991).

Mobile and wireless technology can provide substantial support in science learning. One of the novel mobile and wireless technologies is the wireless sensor network technology, which can be applied by embedding sensors in the

everyday living environment and connecting these sensors to a network. A wireless sensor network consists of spatially distributed autonomous devices that use sensors to cooperatively monitor physical or environmental conditions (Akyildiz, Su, Sankarasubramaniam & Cayirci, 2002). In the present study, a city-wide wireless weather sensor network, the Taipei Weather Science Network (TWIN) which physically covers the whole of Taipei City, was built to automatically log the day-to-day weather conditions in Taipei City (Chang, Wang & Lin, 2009). Sixty schools have been involved in TWIN. As a novel learning platform, TWIN is an open Taipei City weather data archive providing students with a data-rich environment to explore, investigate and study. Hence it can facilitate weather science learning by making readily available real-time, past or historical weather data in any part of the city.

City-Wide Wireless Weather Sensor Network

The geography of Taipei City consists of a basin surrounded by mountains and several rivers. The highest mountain in the city is 1,120 meters. The unique geography of Taipei City makes for an extraordinary climate. In order to collect the Taipei City weather conditions and then applied them to students' weather science learning, a city-wide wireless weather sensor network, TWIN, was established. TWIN provides a distributed wireless weather sensor network throughout Taipei and promotes weather science learning activities for students. The TWIN project was initiated in December, 2003. The Taipei City government first set up thirty wireless weather sensor nodes in thirty schools, and then added thirty more nodes in other schools in May, 2004. Taipei City is divided into twelve districts, each of which has a unique geographical landscape. Therefore, the locations of the weather sensor nodes in the sixty schools were carefully selected. The deployment rule was that each district should be allocated at least three wireless weather sensor nodes. Some special geographical locations, such as mountain areas or river regions, were allocated more nodes in order to gather more detailed weather data. The sixty weather sensor nodes were connected by a centralized archive server. The weather data from the area around the weather sensor node were collected every five minutes and wirelessly transferred to the TWIN server. Figure 1 shows the distributed architecture of TWIN.

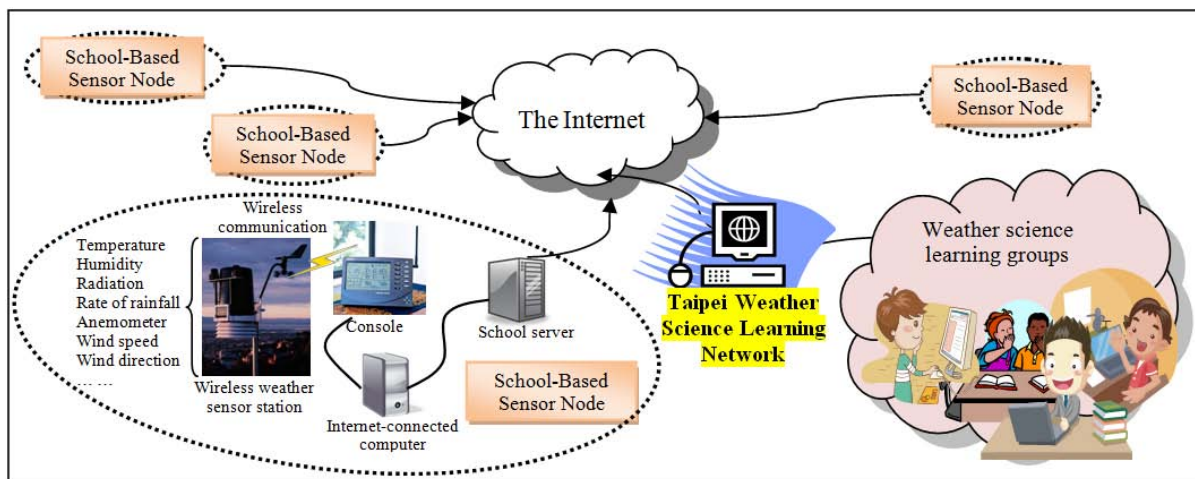


Figure 1. Taipei weather science learning network architecture

The TWIN website is open to the public (Figure 2); users who are interested in using the data for Taipei City weather science learning can freely access the database. The website provides not only the current weather status at a particular weather sensor node, but also the past data for all nodes and for elapsed-time periods of five minutes, an hour, a week, or a month. Additionally, desired weather data can be downloaded in Excel file format for further processing.

School-based weather sensor node

TWIN comprises sixty school-based weather sensor nodes distributed throughout Taipei City. A school-based weather sensor node includes a wireless weather sensor station, a data receiving console connected to an Internet-connected computer, and a school server. The weather data in the school server is obtained from the weather sensor

station installed on the campus. The weather sensor station used on TWIN is a commercial component named Vantage Pro. The device can detect temperature, humidity, barometric pressure, UV radiation, rainfall rate, wind direction, wind speed and other data. The weather sensor devices are solar powered, and each is equipped with an accumulator and a wireless module that enables the station to work twenty-four hours a day, seven days a week, independently. The weather data measured by the sensor station is transmitted automatically and wirelessly to the console to generate such data as dew point, wind chill temperature, temperature-humidity-wind (THW) index, and heat index. The weather school server displays the current weather status in both numerical and graphical type. As Figure 3 shows, this data provides essential weather data such as highest and lowest temperature of the day, month, and year as well as a 24-hour temperature change curve, etc. By studying the data, the students will become more aware of their living environment.

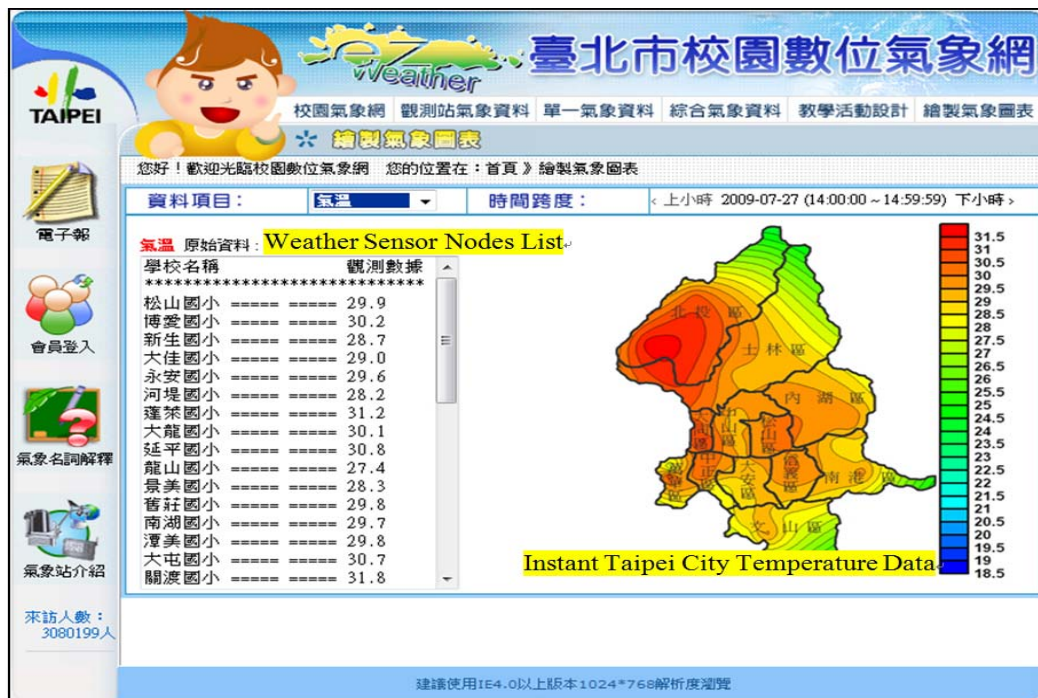


Figure 2. Instant weather data on TWIN

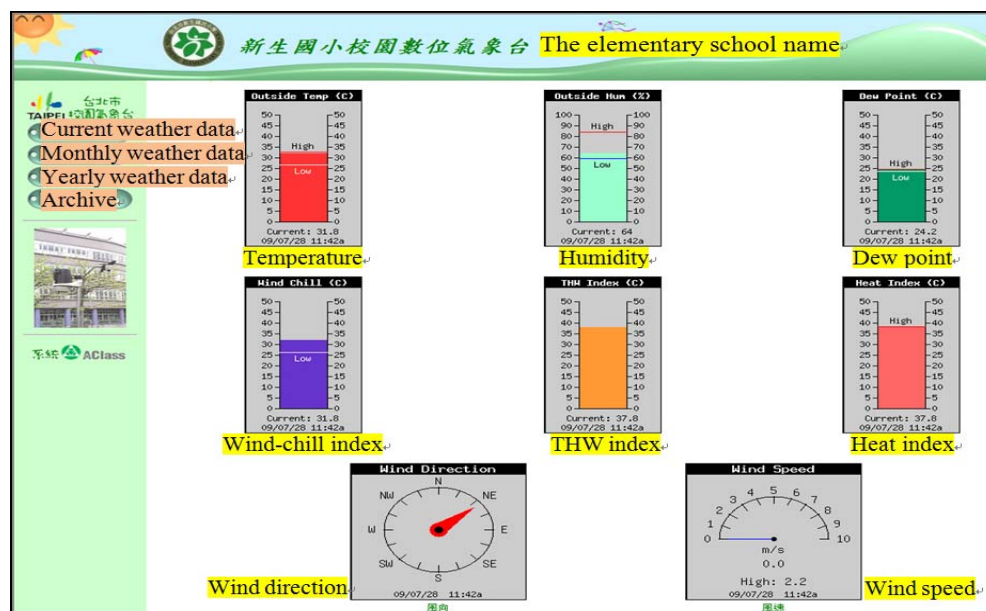


Figure 3. Xin Sheng elementary school-based weather sensor node

These school-based weather sensor nodes are connected by the TWIN server, and all of Taipei City's weather data will be automatically transferred from all the school-based nodes to the TWIN server, or retrieved by the TWIN server if it did not receive the uploaded data. The bidirectional data transmission mechanism ensures that current weather data is securely saved on the TWIN server.

The benefits of practicing weather science learning on a city-wide wireless sensor network

As an ad hoc wireless network, TWIN makes Taipei students' study of their own weather more convenient and more effective. The advantages of using TWIN in the learning of weather science are the following:

- Students are provided with actual and real-time data: The TWIN provides actual and real-time weather data for Taipei City where the students live. These data are logged and analyzed automatically. The students who participated in the task-oriented TWIN project spent less time in collecting raw data but more time in analyzing and applying data.
- Students practice weather science learning in a geographically unrestricted exploratory environment: TWIN detects the current weather status at various points around the city and provides this data to the public. The students can access and explore this data easily through the Internet.
- This activity is student-oriented: TWIN is a data-rich weather platform. The role of the TWIN teacher is that of a consultant rather than an instructor. The students acquire the weather science knowledge by themselves. They must decide which topic or problem to explore and then develop strategies for studying the topic or solving the problem they have proposed.
- A digital archive is created: The TWIN is an automatic operating system. Since 2004, this system has collected and archived Taipei City weather data which is available to all teachers and students.

Four-Phase Weather Science Learning Activity Design

TWIN provides a large Taipei City weather database and a platform for students to explore. However, providing an exploratory environment is only the first step. To provide a complete weather science learning activity for students, a four-phase learning activity was designed. The students who are interested in the TWIN weather science learning program are asked to form a team and explore and analyze the data collaboratively.

Questioning phase

A questioning phase preceded the weather science activity so teachers and students could first select the weather science problem they wanted to inquire. In this stage, the students were asked to participate in surveys and make certain assumptions. The goal of this phase was to encourage students to identify a problem that they were interested in solving. Initially, the students knew very little about TWIN and the problem they wanted to investigate. To help them determine their own problem they discussed their own experiences of Taipei weather. Four anchored topics were provided to trigger the student discussions:

The four anchored topics were the following:

Anchored topic 1: Choose a physical area in Taipei City and study its humidity.

Anchored topic 2: Choose two different topographies in Taipei City and study the humidity data.

Anchored topic 3: Study the hottest or coldest area in Taipei City.

Anchored topic 4: Study the area of Taipei City that has the highest rainfall.

Others: Select your own topic if you are not interested in any of the above topics.

These four anchored topics were then used to help students clarify their ideas and the weather science learning problems that were most interesting to them. The team members were encouraged to engage in reading, discussion and brainstorming at this stage. Worksheet I in Table 1 was used to guide students in formulating a weather science problem. Each team was requested to complete it in one week.

Planning phase

After selecting its own weather science problem in the first stage, each team was asked to generate a plan for solving their problem in the second stage. Team members were encouraged to have group discussions of the problem and to make initial assumptions. They were asked to do preliminary research using the TWIN database to help generate their hypothesis. This stage required students to decide the data items, the quantity of data, and the types of statistical graphs needed for solving their problem. Each team then divided the problem solving tasks into subtasks and dispatched them to each member. Worksheet II listed in Table 1 was used to guide the students in designing a scientific investigation, answering a question or testing a hypothesis. Each team was asked to complete the task within one week.

Analyzing phase

In this phase, the students kept their assumptions and hypotheses in mind and set out to find their answers. They were required to find evidence from the TWIN data to support their hypotheses. The students thus needed to explore the data retrieved from TWIN and filter out only the data directly relevant to their inquiry problem. After the first and second phases, the students began to have a clearer idea about how to use TWIN and the question they were interested in answering. Following these two phases, the third phase encouraged the students to find data, evidence, and statistical results from TWIN to support the assumptions and hypotheses they had proposed in the second phase. The students were required to work in teams to analyze the TWIN data and to use tools such as Excel to calculate the weather data and create graphics to display this data. Worksheet III listed in Table 1 was used to guide students in collecting, organizing, and displaying the data they used to support their analysis. All teams were required to complete and upload their completed worksheets within one week. Of course, the students were allowed to refer back to the previous phase if they found some cues that did not support their assumptions or hypotheses.

Interpreting phase

In the final phase, the students had completed their weather science inquiry process and were asked to verify their results. They had to demonstrate their findings in terms of concrete values, graphs, and tables. Some tasks, such as data analysis, group discussion, and writing reports, were performed during this phase. Each team attempted to reconcile its findings with its original hypothesis and then draw some conclusions and engage in discussions at this stage. Worksheet IV listed in Table 1 was used to guide the students in summarizing and analyzing data, interpreting results, and selecting reasonable and accurate interpretations and implications. The students were required to complete worksheet IV in one week.

Table 1. Four-phase inquiry worksheets

Worksheet I: Questioning phase Finding inquiry topic. Related questions following the topic. The final inquiry problem. Why was this problem selected as the inquiry problem? Possible solutions to the problem. Difficulties encountered in this phase.	Worksheet II: Planning phase Revise the previous worksheet if needed, and list the reasons. List the data items to be collected and explain the relationships between and among the data and the proposed items. Give the elapsed time for the most recently logged data and reasons for logging it. List the data sources. How can these data sources be used? Difficulties encountered in this phase.
Worksheet III: Analyzing phase Revise the previous worksheet if needed, and list the reasons. During the inquiry process, how much data was logged in terms of total quantity. Convert the logged data to graphics. List the patterns described by the logged data. Difficulties encountered in this phase.	Worksheet IV: Interpreting phase Revise the previous worksheet if needed, and list the reasons. According to the data and graphics provided, can the questions be answered? According to the data, graphics, and proposed questions, what evidence is available? Do the findings support the assumptions listed in the worksheet I? Why? Do these findings support the questions listed in worksheet I? Why? Difficulties encountered in this phase.

Four-phase weather science learning worksheets

As mentioned above, the four-phase worksheets shown in Table 1 were designed to facilitate student weather science learning activities. These worksheets were presented in question-and-answer format. The questions were intended to trigger interaction among team members and to provide a guideline for accomplishing their inquiry tasks. The worksheets were given once weekly. Before starting each worksheet, the teams were requested to upload the completed previous worksheet.

Practice and results

The TWIN platform was established in 2004 as an open platform for the public. In 2006, after the establishment of the infrastructure, a series of annual weather science learning tournaments was held, organized by Taipei City volunteer elementary school teachers. The students registered for the tournaments through the TWIN voluntarily, and completed the four worksheets using outside-class time. Each team was composed of three to five students, and each was assigned one or two teachers as coaches. A coach could consult with more than one team. Each tournament was a five-week event. Following the four-phase weather science learning worksheets mentioned in Table 1, the team members were asked to complete the worksheets for each inquiry phase once a week. Oral presentations were given in the last week. After completing the last worksheet, all worksheets were reviewed by ten elementary and junior high school science teachers, who selected thirty to forty teams to attend a workshop. All the selected teams' worksheets were then reviewed by three experts: one computer science professor, one natural science education professor, and one weather scientist. Each selected team had to prepare a PowerPoint file based on their findings for the workshop. Each group was asked to deliver presentations and answer three to five questions proposed by the experts. So far, 171 teams including 447 grade 4-9 students and 220 coaches have participated in these events. The number of teams in 2006, 2007 and 2008 were twenty-six, fifty-four, and ninety-one. In 2006, 30 coaches and 67 students participated in the tournament; in 2007, 71 coaches and 144 students participated; in 2008, the number of coaches and students soared to 119 and 236, respectively. While the number of participants increased dramatically each year, some teams failed during the tournaments. In 2006, three teams quit the tournament during a 5-week period; in 2007, fourteen teams quit and in 2008, twenty-one teams quit. See Table 2 for a summary.

Table 2. Basic data for the 2006-2008 weather science IBL tournament series

	2006	2007	2008
Registered Teams (coaches, students)	26 (30, 67)	54 (71, 144)	91(119, 236)
Valid Teams (WSN, non-WSN)	23(15,8)	40(25,15)	70(35,35)
Invalid Teams (WSN, non-WSN)	3(1,2)	14(7,7)	21(10,11)

WSN: their school has a weather sensor node

Usability study of the TWIN platform

The infrastructure of the TWIN is huge, and covers the sixty schools in Taipei City. One question was therefore whether the TWIN could be used by the students even if their school did not have a weather sensor node. For the purposes of statistical study, the registered teams were catalogued as WSN (having a weather sensor node) and non-WSN. In 2006, twenty-six teams (including valid teams and invalid teams) registered to participate in the tournament. Among them, sixteen were WSN and ten were non-WSN. Of the fifty-four teams that attended the event in 2007, thirty-two were WSN and twenty-two were non-WSN. In 2008, the number of registered teams soared to ninety-one. Among them, forty-five were WSN and forty-six were non-WSN. The number of non-WSN exceeded the number of WSN teams in 2008.

Furthermore, in 2006, among the sixteen WSN teams, fifteen completed the inquiry activity and seven won awards. Of the ten non-WSN teams that year, only eight finished the five-week inquiry activity and only three won awards. In 2007, thirty-two teams were WSN: twenty-five finished the inquiry process and seven won awards. In the same year, twenty-two teams were non-WSN: fifteen completed the process and only four won awards. Before 2008, then, the WSN teams generally outperformed the non-WSN teams, but 2008 was a turning point. In that year, forty-five teams were WSN: thirty-five completed the process and seven won awards. In the same year, forty-six teams were

non-WSN: thirty-five completed the inquiry process and seven won the award, the same as the number of WSN teams winning it.

Each year, all teams were reviewed by a committee, and teams with superior results were selected and given awards. According to the statistics listed in Figure 4, the fifth-grade students are the greatest number of awards over the three-year period, meaning that over-all they demonstrated the greatest capability for weather science learning on the TWIN platform. As for the poor showing of the ninth-grade students, it must be borne in mind that in Taiwan ninth graders are under great pressure due to senior high school entrance examinations, and they are less likely to spend time on such activities.

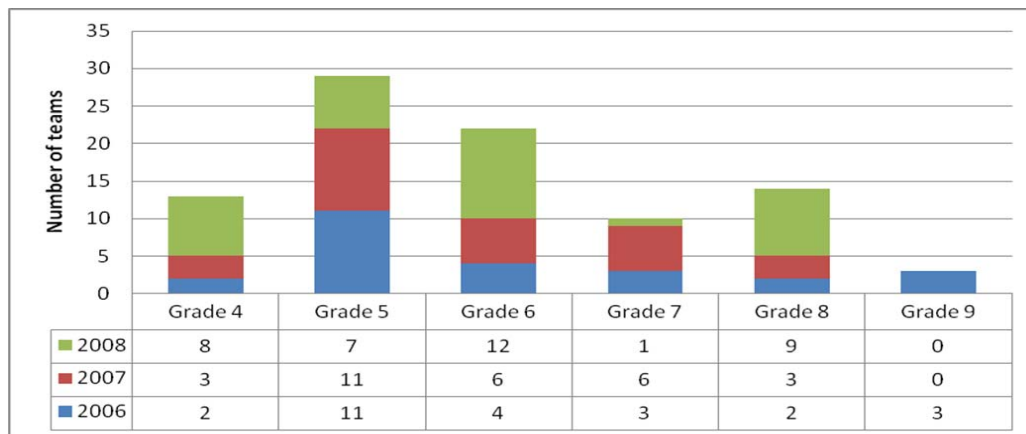


Figure 4. Awarded teams by grade level and number of students in 2006-2008

Analysis of student weather science learning abilities

To examine students' performance when they used the TWIN platform from 2006 to 2008, a rubric was proposed to score student inquiry abilities. This rubric was modified from the Official Scientific Inquiry Scoring Guide-Grades 6, 7, and 8 (Official of Teaching and Learning, n.d.) of the Oregon Department of Education, based on the transcripts of student worksheets, and then validated by the three experts (one science educator and two high school teachers currently in Ph. D. programs in science education). This rubric included four kinds or phases of inquiry ability: questioning, planning, analyzing, and interpreting. Each phase was coded in terms of three dimensions: application of scientific knowledge, communication, and the nature of scientific inquiry. Therefore, each phase included three constructs. The researchers gave each construct a scale of 0 to 3 points. Table 3 presents the rubric.

Questioning. The researchers coded the transcripts in Worksheet I in three dimensions. The *application of concepts* construct was placed in the application of scientific knowledge dimension, the *interpretation of topics* construct in the communication dimension, and the *inference of topics* construct in the nature of scientific inquiry dimension. The researchers scored *application of concepts* from 0 to 3 points according to how clearly the applied concepts were described and their relevance to the question. They scored *interpretation of topics* from 0 to 3 points according to the relevance of the question to a given topic and how clearly the students described the factors in the question. Inference of topics was scored from 0 to 3 points according to how correctly the students described the scientific meaning or relevance of the possible answers to the question.

Planning. The researchers coded the transcripts in Worksheet II in three dimensions. The *manipulation of investigation* construct was in the application of scientific knowledge dimension, the *completeness of proposal* construct was in the communication dimension, and the *appropriateness of proposal* construct was in the nature of scientific inquiry dimension. The researchers scored manipulation of investigation from 0 to 3 points, according to how clearly students listed the data items they wanted to collect and elaborated the relationships among or between the data. Completeness of proposal was scored from 0 to 3 points according to how completely they organized and structured the investigation proposal and detailed procedures; appropriateness of proposal was scored from 0 to 3 points according to how clearly students answered questions using sufficient data and reasoned using appropriate diagrams.

Analyzing. The researchers coded the transcripts in Worksheet III in three dimensions. The *processing of data* construct was in the application of scientific knowledge dimension, the *presentation of data* construct was in the communication dimension, and the *transformation of data* construct was in the nature of scientific inquiry dimension. For the processing of data, the researchers gave a score of from 0 to 3 points according to how properly students answered questions based on measurements or observations, and on how errors could be reduced. For data presentation, the researchers gave the students scores from 0 to 3 points according to how appropriately they converted the logged data into graphics or/and tables. For transformation of data, the researchers scored the students from 0 to 3 according to how clearly they transformed the data to support results.

Interpreting. The researchers coded the transcripts in Worksheet IV in three dimensions. The *explanation of data* construct was in the application of scientific knowledge dimension; the *making a conclusion* construct was in the communication dimension; and the *examination and evaluation* construct was in the nature of scientific inquiry dimension. Explanation of data was scored from 0 to 3 points according to how clearly students explained the relationships between and among variables or/and trends based on the data. Making conclusions was scored from 0 to 3 points according to how clearly students presented results and how correctly they drew conclusions. Examination and evaluation was scored from 0 to 3 points according to how clearly students explained important limitations and sources of error and pointed out possible directions for improvement.

Table 3. Four phases and three dimensions of scientific inquiry

Phase	Application of Scientific Knowledge (a)	Communication (c)	Nature of Scientific Inquiry (n)
Questioning	Q-a: Application of concepts	Q-c: Interpretation of topics	Q-n: Inference of topics
Planning	P-a: Manipulation of investigation	P-c: Completeness of proposal	P-n: Appropriateness of proposal
Analyzing	A-a: Processing of data	A-c: Presentation of data	A-n: Transformation of data
Interpreting	I-a: Explanation of data	I-c: Making conclusions	I-n: Examination and evaluation

The subjects for analysis of student inquiry abilities were those students who had participated in annual weather science learning tournaments from 2006 to 2008. They filled out and submitted four worksheets (worksheets I, II, III and IV listed in Table 1), in teams, once a week. After excluding invalid subjects, twenty-three, forty and seventy teams participated in 2006, 2007, and 2008 respectively (see Table 2). Two raters randomly chose five teams each year (fifteen teams in total) for coding based on the rubric mentioned above, and the inter-rater reliability reached 0.88.



Figure 5. Descriptive analysis of student inquiry abilities from 2006 to 2008

a: Application of Scientific Knowledge; c: Communication; n: Nature of Scientific Inquiry

The purpose of the coding scheme was to define the important aspects of a task and to provide guidance for assessing student inquiry abilities. After the student answers in the four worksheets were coded based on the rubric shown in Table 3, the analytical results showed that the student performances in most of the constructs improved slightly from 2006 to 2008, presumably because the students could review worksheets from the previous year and learn from them,

and also because the teachers had become more familiar with TWIN and were better at using it with the students. However, the students continued to perform poorly in the fourth phase, the interpreting phase, including explanation of data, making conclusions, and examination and evaluation, over the three-year period (see Figure 5). This outcome suggests that students need support and guidelines when interpreting tables and figures they generated, in making conclusions, and in evaluating results.

Detailed analysis of the answers to the worksheets indicated that the students performed well in several constructs. For instance, they could manipulate several variables and understand the relationships among them under controlled conditions. They also demonstrated organization and planning skills. The answers below from two groups (G2007-4-9 and G2007-4-3) that participated in 2007 showed that they planned to collect the data regarding the variables related to humidity based on their understanding of the relationships between these variables.

We prepared to collect data on precipitation, station locations, humidity and terrain. We thought that temperature could affect humidity, and humidity could affect precipitation. We wondered whether the different terrain would affect precipitation (G2007-4-9).

In twelve chosen districts, we randomly selected two stations in each area, a total of twenty-four stations. The hourly data from 2004 to 2006 were used for data analysis. In July, there often were thunderstorms in the afternoons. This was caused by specific conditions regarding air pressure, wind direction, humidity, and terrain (G2007-4-3).

In the past three years, most of the students could convert data into appropriate diagrams in order to present the results clearly. The following is an example from a group in 2008 (G2008-1-3, see Table 4).

Table 4. A summary of averages for three months (March, April, and May) (G2008-1-3)

	Hua-Jiang Elementary school	Tai-Ping Elementary school	Yan-Ping Elementary school	Sho-Zhi Elementary school	Zhou-Mei Elementary school	Kuan-Tu Elementary school	Average
Average temperature	17.26°C	17.40°C	17.65°C	17.55 °C	17.27°C	17.7°C	17.47°C
Average pressure	1017.82hPa	1017.82hPa	1015.60hPa	1017.59hPa	1016.92hPa	1017.25hPa	1017.17hPa
Average rainfall	3.61mm	3.61mm	3.07mm	3.69mm	3.21mm	2.72mm	3.32mm
Average humidity	71.31%	71.51%	72.40%	72.39%	73.37%	77.94%	73.15%
Humidity place	6	5	4	3	2	1	

Overall, the findings indicated that the students performed well in scientific inquiry with the TWIN platform except for the interpreting phase. Regarding the latter, most students could not explain data based on theories and often drew conclusions unrelated to their questions. One team (G2007-5-8) in 2007 interpreted their results based on their life experiences, and another team (G2006-2-8) in 2006 could not draw a meaningful conclusion because they did not control other relevant variables.

It was quite suitable to play or to go for a walk in the countryside at the beginning of July and at the end of August, because the ultraviolet index was quite low (G2007-5-8).

There was no certain pattern in humidity associated with terrain. Humidity was higher in mountainous areas sometimes and humidity was higher in a plain sometimes (G2006-2-8).

Discussion and Conclusions

Participation in science learning can provide students the opportunity to develop general inquiry abilities, to acquire specific investigation skills, and to understand science concepts and principles (Edelson, Gordin & Pea, 1999).

Technology, especially mobile and wireless, can be applied in science learning. In 2004, a city-wide wireless weather sensor network named TWIN (Taipei Weather Science Learning Network) composed of sixty weather sensor nodes was deployed in sixty Taipei City elementary schools. TWIN provides updated weather data for various points in Taipei City every five minutes. This data is saved at a central server and is open to the public. TWIN proved to be very useful in giving elementary and junior high school students actual and instant weather data, allowing them to explore this data in a geographically free and open environment, providing them with an effective, task-oriented learning activity, and enabling them to prepare a digital archive. A series of annual weather science learning tournaments was held in 2006-2008 to encourage the teachers and students to use the TWIN resources. Thus far 171 teams, including 220 teachers and 447 students, have participated in the tournaments. For both teachers and students this was a new experience.

According to the three-year tournament data shown in Table 2 regarding the participation rate, completion rate, and higher-achievement teams, in 2006 the WSN teams performed better than the non-WSN teams. The difference between the WSN and non-WSN students in 2007 was very small, and the WSN students had slightly better results than the non-WSN students. In 2008, the WSN students and non-WSN students performed almost equally. This indicated that all students, even if their school lacks a sensor node, can perform well. The data also indicates that most of the teams can complete the weather science learning activity. The overall data for the three-year tournaments shows that the TWIN platform has an at least acceptable degree of usability and effectiveness.

The analysis of data regarding student weather science abilities, as described in the analysis of the student weather science learning abilities section, indicated that the students in general could perform well in the questioning phase, planning phase, and analyzing phase, but not in the interpreting phase. Another interesting statistic concerns the number of teams that quit the tournaments. In 2006, three teams gave up. Among them, one team gave up in the planning phase, one team in the analyzing phase, and one team in the interpreting phase. In 2007 fourteen teams gave up, two in the questioning phase, one in the planning phase, four in the analyzing phase and seven in the interpreting phase. In 2008, the number of teams leaving before the end of the tournament soared to twenty-one: six gave up in the questioning phase, one in the planning phase, five in the analyzing phase and nine in the interpreting phase. The interpreting phase score is lower than that for any of the other three phases, and the greatest number of teams also quit during the interpreting phase. These data suggest that interpreting the findings was challenging for the students. While it was found that students' weather science ability was generally improved during the questioning, planning and analyzing phases, interpretation is a very important skill as it involves giving the data meaning. Clearly there needs to be more emphasis on helping weather science students to learn how to interpret data. It is therefore suggested that coaches and teachers need to attend workshops which can help them learn strategies for facilitating students' interpretive skill.

The preliminary data for the tournaments does show the positive effects of using the TWIN platform in weather science learning. However, further studies are needed to analyze the process of interpretation, and more generally of meaning-making in the context of student group interaction. In addition, another contest event that on the theme of weather forecast will be took placed in the near future to investigate whether it can deepen students' abilities on data analyzing and interpretation, widen their knowledge coverage and viewpoints of weather science, as well as their interests on meteorology and climatology learning.

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Constructivist Instruction: Success or Failure?

(Book Review)

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Introduction

Constructivism may address a broad range of disciplines, from philosophy to education, from psychology to sociology. From a philosophical viewpoint, constructivism is an epistemology, a theory of knowledge representing an essential part of contemporary philosophical culture. What does knowledge mean? How does the process of knowledge take place? What is the relation between knowledge and reality? Constructivist is also a referential learning theory for some psychologists and pedagogists. How is our mind structured? How do we learn? Moreover, constructivist is an instructional paradigm, a set of teaching techniques. How to teach? What are the characteristics of an effective teaching? There is not yet a strong, unique instructional model based on the constructivist framework and the debate among researchers is still hotly open. Plus, some researchers call the effectiveness of the constructivist didactics into question and suggest that explicit instruction is superior.

Constructivist Instruction: Success or Failure? is a book which well represents the actual debate related to constructivism and education. The main purpose of this book is to discuss the present status of constructivism, applied to teaching and to development of instructional materials. The volume was stimulated by the 2007 annual convention of the American Educational Research Association, which was an occasion for constructivists and advocates of explicit instruction ("instructionists") to debate about both theoretical and practical issues. Particular relevance for animating the debate was related to the Kirschner, Sweller and Clark's paper *Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching* (2006).

The book is organized in chapters which present detailed views from both sides of the controversy. The first part of the volume is introductive. The second part is dedicated to chapters by constructivists, whilst the third part is devoted to chapters by instructionists. The fourth part is prepared by researchers concerned with content and application areas. The fifth tries to offer a summary of the main issues debated and to define a possible common research agenda.

Part I. Introduction

In the first chapter, *The Success or Failure of Constructivist Instruction: An Introduction*, Tobias and Duffy trace a brief outline of the theoretical debate related to the constructivism and provide some background information about the history of constructivism as a learning theory, with some reference to researchers who influenced the field.

The authors suggest that, even if a solid base for the current interest to constructivism can be related to the work of Vygotsky (1978), Dewey (1929), Piaget (1952), and Bruner (1966), a strong input for the growth of constructivist theory and its application to instruction can be tied to some recent researches. In particular, Brown, Collins, and Duguid (1989) argued that knowledge is situated and is a product of the interaction with its context and its culture. Resnink (1987) examined situated learning which takes place outside the school. Lave and Wenger (1991) extended

the study of situated learning to communities of practices.

At the end of this chapter, the authors present a detailed overview of the entire volume.

Part II. The Evidence for Constructivism

In the second chapter, *Reconciling a Human Cognitive Architecture*, Jonassen provides a general overview of the constructivist positions. The author agrees with Kirschner et al.'s (2006) about the collaborative articulation and construction of cognitive architecture, but he takes issue with the theory definition of learning as a change in long-term memory. Jonassen claims that a cognitive architecture must account for the context, the learner, and the social and cognitive process of cognition in order to explain or predict cognitive activities.

In the third chapter, *Constructivism in an Age of Non-Constructivist Assessments*, Schwartz, Lindgren, and Lewis suggest that constructivist instruction may not be suitable for all learning purposes. The authors propose that constructivist teaching may be superior for situations in which current learning is a preparation for future learning, rather than for sequential problem solving. If the objective of instruction is for immediate problem solving, the authors suggest that constructivist instruction may not be ideal.

In the fourth chapter, *Taking Guided Learning Theory to School: Reconciling the Cognitive, Motivational, and Social Contexts of Instruction*, Herman and Gomez explore the implications of guided learning theory for schooling. The authors claim that critics of constructivist instruction ignore such critical components of the instructional process as motivation, the social context of the classroom, and other aspects of the dynamics of instruction. They then discuss their work on supporting students' reading in science and describe tools developed to guide student's reading in that domain.

In the fifth chapter, *Beyond More Versus Less: A Reframing of the Debate on Instructional Guidance*, Wise and O'Neill argue that experimental "high versus low guidance" studies cannot provide a valid basis for making assumptions about the fundamental merits of constructivist teaching. The quantity of guidance is just one dimension along which guidance can be usefully characterized. Two additional concerns that have to be considered are context and timing of guidance especially in ill-defined problem domains.

In the sixth chapter, *Constructivism: When It's the Wrong Idea and When It's the Only Idea*, Spiro and DeSchryver claim that constructivist instruction may be more or less effective depending on the domain in which it is adopted to support teaching and learning. It may lead to superior results in ill-structured domains such as medical diagnoses, whilst it may be less effective in well-structured domains such as mathematics, for example. In such domains, explicit instructional approaches may be more effective.

Part III. Challenges to the Constructivist View

In the seventh chapter, *What Human Cognitive Architecture Tells Us About Constructivism*, Sweller argues that some constructivist approaches, namely discovery, problem-based, or inquiry learning, seem to imply that evolutionary secondary knowledge, such as intentional school learning, can occur as easily as evolutionary primary knowledge, such as learning to speak or listen. The author argues that reading, writing, and other evolutionary secondary subjects taught in school have evolved relatively recently, and therefore have to be taught explicitly.

In the eighth chapter, *Epistemology or Pedagogy, That Is the Question*, Kirschner affirms that children differ from adult experts in many ways and that children do not have many of the cognitive abilities of adult experts, such as their context knowledge, their conditionalized knowledge, or their ability to retrieve knowledge rapidly.

In the ninth chapter, *How Much and What Type of Guidance is Optimal for Learning?*, Clark focuses on guidance and instructional support provided to learners and suggests that guidance should provide accurate and complete demonstrations of how and when a task should be performed. Further, when transfer to a new situation is required, guidance must provide the practice and declarative knowledge permitting learners to function in that situation. The author maintains that guidance should involve application of procedures with immediate corrective feedback.

In the tenth chapter, *Constructivism as a Theory of Learning Versus Constructivism as a Prescription for Instruction*, Mayer suggests that there is a difference between behavioral activity and cognitive activity. While the first one does little to advantage learning, the second one is vital for learning. The author suggests that in discovery learning constructivists tend to confuse the two, leading to considerable confusion since the behavioral activity seen in discovery learning does little to promote learning.

In the eleventh chapter, *The Empirical Support for Direct Instruction*, Rosenshine reviews classical findings developed by process-product studies of students' learning from classroom instruction. That research is composed of both experimental and correlational work, and has largely been ignored with the advent of constructivist approaches. The author suggests that those findings are still valid and should be taken into consideration.

Part IV. An Examination of Specific Learning and Motivational Issues

In the twelfth chapter, *Learning and Constructivism*, Kintsch remarks that there is confusion between the commonly accepted notion that all knowledge is constructed by the individual, and the constructivist approaches to instruction, such as discovery, problem-based, and other instructional approaches.

In the thirteenth chapter, *From Behaviorism to Constructivism: A Philosophical Journey from Drill and Practice to Situated Learning*, Fletcher overviews the philosophical and psychological roots of both constructivist and, to a small, explicit instruction. This chapter suggests the importance of "drill and practice" and the use of simulated environments for situated learning.

In the fourteenth chapter, *What's Worth Knowing about Mathematics?*, Gresalfi and Lester deal with instructional issues from the perspective of mathematics education. The authors suggest that a constructivist approach should see learning as a change in social activity that integrates what is known with how one came to know it, and emphasizes understanding of math and when to apply that understanding.

In the fifteenth chapter, *"To every thing there is a season, and a time to every purpose under the heavens" What about Direct Instruction?*, Klahr describes his research on the control of variables strategy trying to clarify how direct instruction differ from discovery learning, when direct instruction should be used and what aspects of disciplinary practice should be included in early science education.

In the sixteenth chapter, *Beyond the Fringe: Building and Evaluating Scientific Knowledge Systems*, Duschal and Duncan oppose instructionists' position regarding science education. The authors emphasize that science education is not only knowing "what" is known, but also knowing "how" and "why" is known.

Part V. Summing Up

In the seventeenth chapter, *An Eclectic Appraisal of the Success or Failure of Constructivist Instruction*, Tobias analyzes the issues in the book from an eclectic viewpoint and claims that, whenever possible, it is important to support the theoretical debate with research results.

In the eighteenth chapter, *Building Lines of Communication and a Research Agenda*, Duffy focus on the failure in communication between the constructivist researchers and the direct-instruction researchers. The first ones seem to ignore that information processing plays an important role in the learning process, whilst the second ones seem to ignore that extensive guidance may be provided in constructivist environments.

Final comments

This volume effectively presents some crucial aspects related to the actual theoretical debate in the research of learning theory. The initial question – *"Constructivism and the Designing of Instruction: Success or Failure?"* – seems to find not an unique answer. A variety of positions are expressed in this volume by different researchers. The

debate arose from the chapters of this volume helps to spotlight many of the issues and clarify the underlying rationale for the different perspectives.

An interesting feature of the book is the dialogue built into it between the different positions. In fact, each chapter ends with discussions in which two authors with opposing viewpoints make questions about the chapter, followed by the author(s)' clarifications to those questions; for some chapters there are several cycles of questions and answers. Such as interactive dialogue among researchers with different background and perspectives allows to have some points further discussed and clarified by the author(s).

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