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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.

- Educational system developers and artificial intelligence (AI) researchers are sometimes unaware of the needs and requirements of typical teachers, with a possible exception of those in the computer science domain. In transferring the notion of a 'user' from the human-computer interaction studies and assigning it to the 'student', the educator's role as the 'implementer/ manager/ user' of the technology has been forgotten.

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 The articles should be original, unpublished, and not in consideration for publication elsewhere at the time of submission to *Educational Technology & Society* and three months thereafter.

The scope of the journal is broad. Following list of topics is considered to be within the scope of the journal:

Architectures for Educational Technology Systems, Computer-Mediated Communication, Cooperative/ Collaborative Learning and Environments, Cultural Issues in Educational System development, Didactic/ Pedagogical Issues and Teaching/Learning Strategies, Distance Education/Learning, Distance Learning Systems, Distributed Learning Environments, Educational Multimedia, Evaluation, Human-Computer Interface (HCI) Issues, Hypermedia Systems/ Applications, Intelligent Learning/ Tutoring Environments, Interactive Learning Environments, Learning by Doing, Methodologies for Development of Educational Technology Systems, Multimedia Systems/ Applications, Network-Based Learning Environments, Online Education, Simulations for Learning, Web Based Instruction/ Training

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Submissions are invited in the following categories:

- Peer reviewed publications: Full length articles (4000 - 7000 words)
- Book reviews
- Software reviews
- Website reviews

All peer review publications will be refereed in double-blind review process by at least two international reviewers with expertise in the relevant subject area. Book, Software and Website Reviews will not be reviewed, but the editors reserve the right to refuse or edit review.

For detailed information on how to format your submissions, please see:
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Submission procedure

Authors, submitting articles for a particular special issue, should send their submissions directly to the appropriate Guest Editor. Guest Editors will advise the authors regarding submission procedure for the final version.

All submissions should be in electronic form. The editors will acknowledge the receipt of submission as soon as possible.

The preferred formats for submission are Word document and RTF, but editors will try their best for other formats too. For figures, GIF and JPEG (JPG) are the preferred formats. **Authors must supply separate figures** in one of these formats besides embedding in text.

Please provide following details with each submission: ▪ Author(s) full name(s) including title(s), ▪ Name of corresponding author, ▪ Job title(s), ▪ Organisation(s), ▪ Full contact details of ALL authors including email address, postal address, telephone and fax numbers.

The submissions should be uploaded at http://www.ifets.info/ets_journal/upload.php. In case of difficulties, please contact **kinshuk@ieee.org** (Subject: Submission for Educational Technology & Society journal).

Journal of Educational Technology & Society

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Book Reviews

Guest Editorial: Grand Challenges and Research Directions in e-Learning of the 21th Century

Nian-Shing Chen and Wei-Chieh Fang

National Sun Yat-sen University, Taiwan //
nschen@mis.nsysu.edu.tw // wfjohnny@staff.nsysu.edu.tw

E-learning has received much attention over the past decade. Its affordability has made educational technologies prevalently available in educational system. However, there exit some challenges. First, there has been a discrepancy between the latest development of learning technologies and the adoption of them in schools. Second, there have been questions about the effective implementation of learning technologies in the current educational system. Third, there have been barriers that slow down the integration of learning technology into school curriculum within formal educational systems.

In response to these challenges in e-Learning research, Prof. Nian-Shing Chen and Prof. Chin-Chung Tsai co-organized the World Submit Forum and Asia-Pacific Submit Forum on e-Learning research trends in September 7-8, 2011, Taipei, Taiwan. The two submits invited many internationally well-known scholars to present their ideas and research findings focusing on research trends in e-Learning. A grand panel was also conducted with all the speakers to facilitate two-way interactions and exchanges with the audiences. To share meeting results with more researchers in this field, we also invited five editors to write articles to share their visions and experiences regarding their concerned issues from five major international peer-reviewed journals in the field of e-Learning as follows:

- Dr. Chin-Chung Tsai, editor of Computers & Education
- Dr. Nick Rushby, editor of British Journal of Education Technology
- Dr. Michael Spector, editor of Educational Technology Research & Development
- Dr. Kinshuk, editor of Educational Technology & Society
- Dr. Joseph Psotka, editor of Interactive Learning Environments

Through the participation of many internationally well-known scholars, this special issue not only provides opportunities for international cooperation and communication in e-Learning studies, but also constitutes a further step in e-Learning research field. This special issue includes seven articles:

Kinshuk et al. manually explored the trends of the highly cited articles published in the Journal of Educational Technology and Society from 2003 through 2010. They investigated the research topics, international collaboration, participant levels, learning domain, research method and frequent author keywords. Since the ET&S journal not only includes empirical studies but also studies with innovative system and model design, this article may give both system designers and researchers a research overview over the past years and thoughts for future research.

Spector gives insights into the emerging technologies and research directions by analyzing two reputable publications, "Horizon Report" and "A Roadmap for Education Technology," along with two sources, "IEEE Technical Committee on Learning Technology's report" and "European STELLAR project." The author points out the barriers to progress in adopting educational technologies as well as the critical factor in improving learning and instruction with technologies. This paper may help not only the designers but also practitioners and policy makers in adopting educational technologies.

Chai et al. reviewed papers that had investigated ICT integration using technological pedagogical content knowledge (TPACK), a framework for the design of teacher education programs. They found positive results in enhancing teachers' capacity to integrate ICT for instructional practice. Based on the papers reviewed, a revised TPACK frame work was also proposed for future study.

Rushby first reports key issues in educational technology in the past and further proposed three visions of the future learning technology. In one of his visions, he suggests Georffrey Moore's innovation curve can be applied to explain "how rapidly these [educational] technologies will emerge and how they can be deployed in education and training." His analysis took an approach different from the content analysis.

Lim et al. addressed two gaps, a usage gap and an outcome gap, in educational uses of technology. They first examined the gaps between technology trends and the use of technology, in terms of success of technology implementation and effective teaching, and then discussed the causes of them. They also provided suggestions to close these gaps.

Psotka suggests that education has been slow in adopting disruptive technologies such as educational games and virtual reality environments. He urges that education should not be limited to classroom but can be extended to informal settings, such as home and Internet, where disruptive technologies can be the access point for new information and knowledge other than school. Benefits of disruptive technologies are exemplified in the article.

Tsai et al. suggests that educational technologies are essential in supporting knowledge creation. They proposed a conception of design epistemology, which emphasizes the dynamic, social and creative aspects of knowing and knowledge construction, to develop students' epistemic repertoires, or ways of knowing. With the proposed idea of design epistemology, ICT can serve as an epistemic tool for instruction so learners are encouraged to evaluate perspectives, information and knowledge acquired from ICT-supported environments.

Trends in Educational Technology through the Lens of the Highly Cited Articles Published in the Journal of Educational Technology and Society

Kinshuk[1], Hui-Wen Huang[2*], Demetrios Sampson[3] and Nian-Shing Chen[4]

[1]Athabasca University, Canada // [2]Wenzao Ursuline College of Languages, Taiwan // [3]Centre for Research and Technology – Hellas (CE.R.T.H.), Greece // [4]National Sun Yat-sen University, Taiwan // Kinshuk@athabascau.ca // huiwen422@gmail.com // sampson@iti.gr // nschen@mis.nsysu.edu.tw
[*]Corresponding author

ABSTRACT

The advent of the Internet, World-Wide Web and more recently, advanced technologies such as mobile, sensor and location technologies have changed the way people interact with each other, their lifestyle and almost every other aspect of life. Educational sector is not immune from such effects even if the rate of change is far slower than many other sectors. Researchers have been continuously exploring new ways of using technologies in education and the field is continuously progressing. This paper looks at this progress by analyzing the highly cited articles published in the Journal of Educational Technology and Society, in order to identify various trends and to ponder on the future ahead.

Keywords

Educational technology, Journal of Educational Technology and Society, Highly cited papers, Web of Science, Social Sciences Citation Index, Research trends

Introduction

The term "educational technology" has been used for quite some time; as early as 1960s when Lawrence Lipsitz first started Educational Technology magazine. It is difficult to define what educational technology actually means but researchers and practitioners have typically attributed this term to indicate use of various sorts of technologies to facilitate educational processes.

With the explosive growth of computers in academia in later half of last century and for individual use in early eighties, and emergence of the Internet in mainstream education in nineties, educational technology has become somewhat synonymous to computer based learning and online education.

Journal of Educational Technology and Society came into existence in 1998. This paper aims to provide a vision for future of educational technology through a systematic analysis of the highly cited papers in the journal, identifying the themes that survived, those that short-lived, and those that have seen growing popularity over the years.

This bird's eye view of educational technology through the lens of the Journal of Educational Technology and Society provides some interesting afterthoughts for both future of education and predictions about the direction educational technology is taking in coming years.

The next section will describe the rationale behind initiating the journal, its main purpose and a brief introduction of the key founders. This will be followed by an extensive analysis of various trends that have emerged during past several years.

Historical background

Since late seventies and early eighties, education sector had started to harness the power of continuously improving communication technologies, with the computer as its front end. The inter-activity and the inter-connectivity offered by these technologies promised to have an unprecedented impact on Education - to the extent that Educational Technology could be talked of as a discipline in its own right, combining the lessons learnt in the diverse fields of "Artificial Intelligence," "Educational Psychology," "Educational Sociology," and not the least, "Educational Management."

The new found benefits of technology in education caught interest of not only researchers but also of governments and funding agencies. Millions of dollars were poured in, mostly in America and Europe, with hope that computer systems would be able to help students in the learning process, hence reducing teachers' workload. The result was that research in educational technology touched such advanced issues as intelligent tutoring, simulations, advanced learning management systems, automatic assessment systems and adaptive systems. However, practitioners, dealing with real-life academic environment, could not take advantages of all that research with equally fast pace and the implementation legged seriously behind.

A serious issue emerged with the widening gap of research and implementation that contributed significantly to further dividing the research and practitioners communities. As evident from the work presented in conferences and journals in last two to three decades, there has been very little input from actual practitioners in the research process. Most research in educational technology area has been undertaken by computer scientists and alike. The academics from other disciplines have been brought from time-to-time in the process of researching advanced systems and technologies, but mostly to elicit their knowledge so that the systems and technologies could replace them.

Once a learning system is developed, it becomes like a black box to any outsider (including the academics of the disciplines for which that particular system is developed). There is very little possibility of customization in the system on the part of the implementing teacher (the one who is expected to use it in his/her curriculum) except perhaps few pedagogical rules and the chunks of knowledge (learning objects). System designers (primarily computer science academics) somehow perceive that because they teach their students, they know how to teach, and therefore the systems developed by them would and should be acceptable by any other teacher, regardless of the discipline.

This gap between researchers and practitioners was identified in late nineties and as a result, the International Forum of Educational Technology & Society (IFETS) (http://ifets.ieee.org/) evolved in May 1998 during an informal discussion at De Montfort University, United Kingdom. The focus of the forum was on the communication gap which existed between educational system developers and the educators who adopt such systems.

The main purpose of the IFETS forum has been to encourage discussions on the issues affecting the educational system developer (including artificial intelligence researchers) and educator communities. While recognizing that this brief might be seen as too broad, it was proposed to conduct multiple discussion threads on more specific topics. This approach helped in developing specific aspects concerning the design and implementation of integrated learning environments while sharpening the overall vision about the purpose and processes of education.

To provide a synthesis of the discussions held in the forum and to articulate the thinking of both communities, Journal of Educational Technology & Society was conceived as an archival entity, which could bring exposure to everyone's perspectives, and hopefully provide at least a platform for justifying the differences if not to diffuse those differences.

The first issue of the journal was published in October 1998. Since then, the journal has been published quarterly and is a focal point to record on-going discussions in the discipline, on implementation projects, present invited viewpoints and perspectives from experts in diverse fields and also to encourage peer-reviewed articles providing a more detailed treatment of the various aspects of educational technology, its objectives and its contexts. Journal of Educational Technology and Society is meant to be the mouth piece of the diverse membership of both researchers and practitioners community and each group is strongly encouraged to make their voice heard. Through dialogue and specialization, journal aims to maintain 'unity within diversity.'

Analysis of highly cited papers

Generally, the advancement of knowledge is driven by a variety of contributions. The highly cited articles are considered to play important roles in knowledge contribution because researchers tend to cite high quality articles that are useful for their own research (Aylward, Roberts, Colombo, & Steele, 2008; Lee, Wu, & Tsai, 2009). Identifying the highly cited articles seems to be a reliable and objective means because it shows valuable research topics in the profession (Flores et al., 1999). When one article is cited by many subsequent papers, it means that this article has its influence and contribution in a particular field (White & White, 1977). The research trends can be

highlighted through examining research topics among the highly cited articles. In addition, a list of the highly cited articles gives novice researchers a direction to focus on the highly influential articles during a specific period of time and develop their own research interests.

Several scholars stated the importance of reviewing journal publications. For example, White and White (1977) pointed out that "the importance of a journal is determined by the overall quality of the articles it carries" (p. 301). Analyzing the publication history of a specific journal can reveal a more accurate view of the publication pattern. The action of reviewing journal publications can "provide the editors of the journal an opportunity to reflect on the consistency of their publication decisions in relationship to the journal's mission statement and policies" (Taylor, 2001, p. 324). To understand the publication pattern, Garfield (1983) proposed citation analysis to explore the frequencies, patterns, and graphs of citations in articles and books. It measures the importance of particular journals or authors in a scholarly community (Flores et al., 1999; Rourke & Szabo, 2002; Taylo, 2001).

According to Chiu and Ho (2007), the impact or visibility of an article can be identified by the number of citations. Previous studies have reviewed the highly cited articles in different fields (Aksnes, 2003; Allen, Jacobs, & Levey, 2006, Blessinger & Hycaj, 2010). However, little research has been conducted regarding the review of the characteristics of the highly cited articles in the field of educational technology. Through a systematic analysis, the present study provides insight to the research trends and basic citation trends of the highly cited articles published in the *Journal of Educational Technology and Society* (ET&S).

The purpose of the current study has been twofold. First, the authors explored the distribution of major research topics among the highly cited articles published in the ET&S during 2003-2010. Second, the authors examined the emerging trends after reviewing the highly cited empirical studies in the ET&S. The reason to focus on empirical studies with high citation counts was that such information would provide important insight for junior researchers to plan their research topics from theory to practice. In addition, to avoid a disadvantage of recently published articles with less citation counts in a long time frame, the authors compared the highly cited empirical studies published within a four-year time interval, i.e., 2003-2006 and 2007-2010.

In order to provide researchers who are interested in submitting journal papers to the ET&S, the authors systematically analyzed the highly cited articles in the journal to provide valuable information about using these articles as guides for their own studies. Thus, the research questions addressed by this study are as follows:
1. What research types were identified from the highly cited articles published in the ET&S during 2003-2010? What were their variations between the first four years (2003-2006) and the second four years (2007-2010)?
2. What were the characteristics of the highly cited empirical studies published in the ET&S during 2003-2010? What were their variations between the first four years (2003-2006) and the second four years (2007-2010)?
3. What were the emerging research trends of the highly cited empirical studies published in the ET&S during 2003-2010? What were their variations between the first four years (2003-2006) and the second four years (2007-2010)?

Related work

Citation analysis is a useful tool to provide a direct and objective means of analyzing influences in a certain research field (Garfield, 1955; Smith, 1981). Shih, Feng and Tsai (2008) claimed that "articles with more citation frequencies are usually those that are better recognized by others in related fields. They probably present more fundamental ideas about the issues for future research" (p. 960). Many studies on citation analysis reviewed highly cited articles in different disciplinary fields, such as science (Aksnes, 2003), ecology and ecological economics (Leimu & Koricheva, 2005), geomorphology (Doyle & Jlian, 2005), nursing (Allen, Jacobs, & Levey, 2006), software engineering (Wohlin, 2007), e-learning (Shih et al., 2008), instructional design (Ozcinar, 2009), computer-assisted language learning (Uzunboylu & Ozcinar, 2009), library and information science (Blessinger & Hycaj, 2010) and knowledge management in education (Uzunboylu, Eris, & Ozcinar, 2011). These studies showed raw citation count to identify the influence of scholarly work.

Previous studies have attempted to describe the development of educational technology research in different time periods using content and citation analysis. For example, Klein (1997) analyzed 100 articles published in the *Educational Technology Research and Development* between 1989 and 1997. Taylor (2001) conducted a content

analysis of all articles submitted to *Adult Education Quarterly* from 1989 to 1999. Rourke and Szabo (2002) analyzed articles published in *Journal of Distance Education* during 1986-2001. Lee, Driscoll and Nelson (2004) examined 383 articles published in four professional journals in the field of distance education from 1997 to 2002 using content analysis. Tsai and Wen (2005) reviewed the research papers in science education during 1998 to 2002 using manual coding. Aylward, Roberts, Colombo, and Steele (2008) used citation analysis to examined documents with a large number of citations in a specific journal from 1976 to 2006. Shih et al. (2008) reviewed 444 articles related to the topic of cognition in e-learning from 2001 to 2005. Ozcinar (2009) examined 758 documents regarding the topic of instructional design during 1998-2008, retrieved from the Web of Science database, to conduct content analysis and citation analysis. These researchers illustrated insightful information to examine trends and patterns in scholarly documents.

According to Noyons and van Raan (1998), splitting the publication data into two periods can help in better understanding the relationship between the two different periods in terms of monitoring research trends of the identified topics. Lee et al. (2009) analyzed highly cited science education articles published during 1998-2002 and 2003-2007, and found a dynamic shift in the research topic. Tsai, Wu, Lin, and Liang (2011) selected 228 empirical papers to examine the research trends regarding science learning in Asia during 2000-2004 and 2005-2009. These studies helped readers to visualize dynamic trends in different periods of time.

Recently, studies on using author keywords to analyze the research trends have shown that this method can effectively predict the research tendency (Chiu & Ho, 2007; Mao, Wang, & Ho, 2010; Li et al., 2009; Ozcinar, 2009). The purpose of author keywords analysis is to identify their frequency and discover directions of scientific research. To find the most frequently appeared words, McNaught and Lam (2010) used Wordle, a web-based word clouds program, to analyze the transcriptions of six focus-group meetings. They claimed that word clouds can be a supplementary research tool in conducting content analysis. Word clouds can present what the most common words are with their size reflecting their frequency.

Although several articles mentioned above have conducted studies on content and citation analyses regarding educational technology research, the citation analyses examined in the highly cited articles in a specific journal have not been examined in detail. Hence, the current study systematically analyzed the research type, research topic, first author's country, international collaboration, participant levels, learning domain, research method, and frequently appearing keywords among top 20 highly cited articles in the ET&S during 2003-2010.

Method

Materials

The data were based on the highly cited articles published in the ET&S from 2003 to 2010. The ET&S was chosen for two reasons. First, the ET&S has a high impact factory of 1.066 in Thomson Scientific 2010 Journal Citations Report, from the Web of Science database. Second, the ET&S is one of the leading Social Science Citation Index (SSCI) journals in the field of educational technology. The ET&S, a quarterly journal, began publishing referred journal articles in 1998, and has been on the SSCI list since 2003. All the journal's articles are freely accessing online at http://www.ifets.info.

The search period was set during 2003 to 2010 because the ET&S was not indexed in the Web of Science database until 2003. It is important to note that the articles in the Web of Science database show more consistency in quality under restrict peer-review and an objective evaluation process (Braun, Schubert, & Kostoff, 2000; Wohlin, 2007). Hence, identifying the characteristics of the highly cited articles published in the ET&S during the past eight years will provide a macroscopic and systematic examination for readers to have a holistic and accurate interpretation of the research influence in the field of educational technology.

The Web of Science database (http://www.isiknowledge.com/), published by the Institute for Scientific Information (now Thomson Reuters), was the literature source in this study. The reason to use the Web of Science database was that it is the most important and frequently used source database in conducting bibliometric studies in various research fields (Gil-Montoya et al., 2006; Lee, Wu, & Tsai, 2009; Li et al., 2009; Mao, Hwang, & Ho, 2010; Ozcinar, 2009; Tsai & Wen, 2005).

Procedures

The authors went through three steps to analyze the characteristics of the highly cited ET&S articles. In the first step, the authors searched the name of the ET&S journal in the Web of Science database for the timespans 2003-2010, 2003-2006, and 2007-2010, respectively. Afterwards, the authors refined the search by specifying *articles* under the category of document types. The database produced total citation numbers of articles published in the ET&S in different time intervals, using the update data as of November 30, 2011. Since this study focused on examining the highly cited articles until 2010, a calculation of the number of citations per article was computed by subtracting the citations of the year 2011. The criterion for selecting the highly cited articles was those articles published in the ET&S and cited at least 15 times.

In the second step, the authors identified research types, research topics, first author's country, participant level, learning domain, research methods, and frequently appearing keywords among all the articles obtained from the results of the first step. The process of classifying research type and research topics was jointly coded by two raters (one of the authors and one research assistant with master's degree in cognitive psychology). The two raters first discussed the coding criteria, and then separately coded three articles listed on the highly cited articles during 2003-2010. The agreement rate between raters for all coding results was 90%, suggesting that the coding classification used in this study was stable and reliable. Disagreements were resolved via three face-to-face discussions between the two raters.

In the final step, the authors used word clouds (http://www.wordle.net) to validate the previous analysis in manual coding implemented in the second step. Wordle is a web-based visualization program to generate word clouds. The authors first typed all the keywords listed on the highly cited empirical studies, and the program automatically generated a graphic on a new web page.

Data analysis

In addition to manual coding, the authors used word clouds to be a supplementary research tool to support traditional content analysis methods (McNaught & Lam, 2010). Word clouds reveal the frequencies of the different words within the body of text. The more frequent the word, the more important is the concept (McNaught & Lam, 2010). Since word clouds deal with each word as the unit of analysis, the authors used this supporting tool to validate the finding of research topics obtained from manual coding.

Results

Identification of the highly cited articles published in the ET&S

The results of the citation analysis of the top 20 highly cited articles from the years 2003-2010, 2003-2006, and 2007-2010 included self-citations. Appendix-1, Appendix-2 and Appendix-3 present the results, which have been ranked in order by the number of citations, in different time intervals. This yielded 20, 20, and 23 articles for the periods 2003-2010, 2003-2006, and 2007-2010, respectively. The reason for retrieving more than 20 articles was the tied number of citations among the last four highly cited articles. A detailed list of the highly cited articles in rank order by total number of citations can be found in the Appendix.

Research types

All the data retrieved from the Web of Science database were identified into four categories: system and/or model design, empirical study, theoretical paper, and other. The four categories were modified from those suggested by Lee et al. (2009). The category of system and/or model design included articles that report a new system and/or model applied in a new learning context, without statistical analyses. Empirical study category included articles that report results obtained from what the research methods were (quantitative, qualitative, or mix-method), who the participants were, what the participants did, and what measures were utilized. Theoretical paper category included articles that propose "a new theory or theoretical framework" in the field of educational technology (Lee et al., 2009, p. 2002).

Since some articles could not meet the definition of the three categories, they were classified into the category "other." Table 1 presents the frequencies and percentages of research types after the two coders manually classified the top 20 highly cited articles in different time intervals. During 2003-2010, 40% ($n = 8$) were under the category of system and/or model design, 30% ($n = 6$) were empirical studies, 15% ($n = 3$) were theoretical papers, and 15% ($n = 3$) were under the category of other. From 2003 to 2006, 38.1% ($n = 8$) were system and/or model design, 23.8% ($n = 4$) were empirical studies, 14.3% ($n = 3$) were theoretical papers, and 23.8% ($n = 5$) were under the category of other. During 2007-2010, 17.4% ($n = 4$) were system and/or model design, 52.2% ($n = 12$) were empirical studies, 8.7% ($n = 2$) were theoretical papers, and 21.7% ($n = 5$) were under the category of other. The comparison of different research types in highly cited articles is presented in Figure 1.

Table 1. Frequencies and percentages of research types in top 20 highly cited articles during 2003-2010, 2003-2006, and 2007-2010

Research types	Frequencies (Percentages)		
	2003-2010	2003-2006	2007-2010
System and/or model design	8 (40%)	8 (38.1%)	4 (17.4%)
Empirical study	6 (30%)	4 (23.8%)	12 (52.2%)
Theoretical paper	3 (15%)	3 (14.3%)	2 (8.7%)
Other	3 (15%)	5 (23.8%)	5 (21.7%)
Total	20 (100%)	20 (100%)	23 (100%)

(a)

(b)   (c)
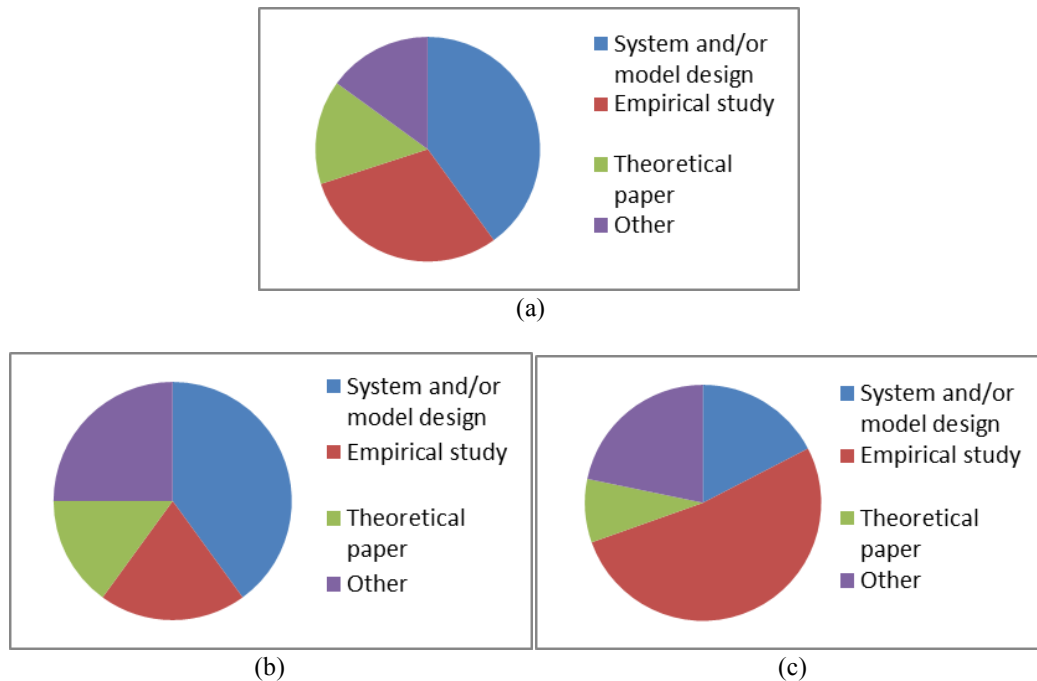
Figure 1. (a) Distribution of the research types during 2003-2010; (b) Distribution of the research types during 2003-2006; and (c) Distribution of the research types during 2007-2010

Co-authorship

The results indicated that the vast majority of the highly cited articles were co-authored with one or more collaborations. For example, the percentages of co-authored articles with either the same country or different country were 90% ($n = 18$), 80% ($n = 16$), and 83% ($n = 19$) for the periods 2003-2010, 2003-2006, and 2007-2010, respectively.

During 2003-2010, 85% ($n = 17$) of the highly cited articles were written by more than one author. Yang (2006) from Taiwan, Liu (2005) from Taiwan, and Nichols (2003) from New Zealand were the only three single authors among

the highly cited ET&S articles. To divide different time intervals, the authors found that four highly cited ET&S articles were written by single authors between 2003 and 2006. They were: Yang (2006) from Taiwan, Nichols (2003) from New Zealand, Liu (2005) from Taiwan, and Anohina (2005) from Latvia. Four highly cited ET&S articles were also written by single authors from 2007 to 2010, namely Paquette (2007) from Canada, Dron (2007) from UK, Liu (2007) from Taiwan and Yang (2009) from Taiwan.

International collaboration

Of the top 20 highly cited articles published in the ET&S during 2003-2010, 20% (*n* = 4) articles had international co-authorship. The articles with international collaboration were: Koper and Olivier (2004) between The Netherlands and U.K. with 84 citation counts, Aroyo and Dicheva (2004) between The Netherlands and U.S.A. with 29 citation counts, Avgeriou et al. (2003) between Greece and Cyprus with 25 citation counts, and Aroyo et al. (2006) among The Netherlands, Germany, Belgium, Sweden, and Austria with 18 citation counts. Researchers from the Netherland were the most active to collaborate with scholars with other countries in publishing internationally co-authored articles.

The results of four highly cited ET&S articles in international collaboration during 2003-2006 were identified to those of the articles between 2003 and 2010. The four articles were: Koper and Olivier (2004), Aroyo and Dicheva (2004), Avgeriou et al. (2003), and Aroyo et al. (2006). Four highly cited ET&S articles during 2007-2010 were identified with international collaboration. They were: Jovanovic et al. (2007) between Serbia and Canada with 12 citation counts, Teo, Luan, and Sing (2008) between Singapore and Malaysia with 9 citation counts, Hastie, Chen, and Kuo (2007) between Australia and Taiwan with 9 citation counts, and Chen, Kinshuk, and Wei (2008) between Taiwan and Canada with 7 citation counts. Researchers from Canada and Taiwan were the most active to engage in international collaboration in publishing articles.

Research topics under system and/or model design articles

To further analyze research topics in highly cited articles under system and/or model design during 2003-2010, the authors identified that research topics were adaptive learning (Karampiperis & Sampson, 2005; Henze, Dolog, & Nejdl, 2004; Aroyo et al., 2006), mobile and ubiquitous learning (Yang, 2006; Kravcik et al., 2004), e-learning (Aroyo & Dicheva, 2004), and collaborative learning (Yang, Chen, & Shao, 2004).

During 2003-2006, the research topics were mobile and ubiquitous learning (Yang, 2006; Kravcik et al., 2004), adaptive learning (Karampiperis & Sampson, 2005; Henze, Dolog, & Nejdl, 2004; Aroyo et al., 2006), e-learning (Aroyo & Dicheva, 2004), collaborative learning (Yang, Chen, & Shao, 2004), and assessment criteria (Yin et al., 2006).

During 2007-2010, three research topics were identified: ontology (Jovanovic et al., 2007; Boyce & Pahl, 2007), personalized learning (Wang et al., 2007), and ICT integration (Wang & Woo, 2007).

Characteristics of the highly cited empirical studies published in the ET&S

The following content analyses of the highly cited empirical studies were identified on the basis of research topics, author's country, participant level, learning domain, research methods, and frequently appearing author keywords.

Research topics

Based on the highly cited empirical studies during 2003-2010, the authors used manual coding to identify four research topics. Table 2 shows the four research topics: collaborative learning (Hernandez-Leo et al., 2006; Zurita et al., 2005), game-based learning (Holzinger et al., 2008; Virvou et al., 2005), mobile learning and ubiquitous learning (El-Bishouty et al., 2007), and technology adoption (Sugar et al., 2004).

Table 2. Distribution of research topics of the highly cited empirical studies published in the ET&S during 2003-2010

Author/Year	Research topic	Citation counts
Hernandez-Leo et al. (2006)	Collaborative learning	36
Holzinger et al. (2008)	Dynamic media	30
Virvou et al. (2005)	Game-based learning	28
Zurita, et al. (2005)	Collaborative learning with mobile devices	22
Sugar et al. (2004)	Technology adoption	20
El-Bishouty et al. (2007)	Ubiquitous learning	15

After manually coding four highly cited empirical studies during 2003-2006, the authors found three main research topics: collaborative learning (Hernandez-Leo et al., 2006; Zurita, et al., 2005), game-based learning (Virvou et al., 2005), and technology adoption (Sugar et al., 2004) (Table 3).

Table 3. Distribution of research topics of the highly cited empirical studies published in the ET&S during 2003-2006

Author/Year	Research topic	Citation counts
Hernandez-Leo et al. (2006)	Collaborative learning design	36
Virvou et al. (2005)	Game-based learning	28
Zurita et al., (2005)	Collaborative learning	22
Sugar et al., (2004)	Technology adoption	20

Several research topics were classified in the highly cited empirical studies during 2007-2010. The authors categorized mobile and ubiquitous learning (El-Bishouty et al., 2007; Chen & Hsu, 2008; Liu, 2007), e-learning (Yukselturk & Bulut, 2007; Demetriadis & Pombortsis, 2007), dynamic media (Holzinger et al., 2008), forum analysis (Hou et al., 2008), technology adoption (Teo et al., 2008), blended learning (Delialioglu & Yildirim, 2007), Web 2.0 (Yang, 2009), and collaborative learning (Huang et al., 2009) (Table 4).

Table 4. Distribution of research topics of the highly cited empirical studies published in the ET&S during 2007-2010

Author/Year	Research topic	Citation counts
Holzinger et al., (2008)	Dynamic media	31
El-Bishouty et al., (2007)	Ubiquitous learning	15
Chen & Hsu (2008)	Mobile learning	11
Teo et al., (2008)	Technology adoption	9
Hou et al., (2008)	Forum analysis	9
Yukselturk & Bulut (2007)	e-learning	8
Liu (2007)	Mobile learning	8
Yang (2009)	Web 2.0	7
Delialioglu & Yildirim (2007)	Blended learning	7
Demetriadis & Pombortsis (2007)	e-learning	6
Makri & Kynigos (2007)	Web 2.0	6
Huang et al., (2009)	Collaborative learning	6

Authors' Countries

Table 5 shows the frequencies of all authors' countries over different time intervals. Based on author's country, the following countries were identified in the highly cited empirical studies during 2003-2010: Spain, Austria, Greece, Chile, U.S.A., and Japan. Among four highly cited empirical studies during 2003-2006, the authors originated from Spain, Greece, Chile, and U.S.A. With regard to 12 highly cited empirical studies during 2007-2010, 41.7% ($n = 5$) of the authors' country were from Taiwan, followed by Greece and Turkey, both of them with two highly cited empirical studies. There was one international co-authored empirical study conducted by researchers from Singapore and Malaysia during 2007-2010.

Table 5. Frequencies of author's country in highly cited empirical studies during 2003-2010, 2003-2006, and 2007-2010

Country	Frequencies		
	2003-2010	2003-2006	2007-2010

Spain	1	1	0
Austria	1	0	1
Greece	1	1	2
Chile	1	1	0
Taiwan	0	0	5
U.S.A.	1	1	0
Japan	1	0	1
Singapore	0	0	1 (international collaboration)
Malaysia	0	0	1 (international collaboration)
Turkey	0	0	2
Total	6	4	12

Participant levels

As revealed in Table 6, all highly cited empirical studies involved post-secondary students and elementary school students. No other educational levels of participants, such as junior high and senior high students, were found. The educational levels of the participants involved in six empirical studies published during 2003 to 2010 were: elementary school level (50%) and college level (50%). During 2003-2006, two empirical studies (Hernandez-Leo et al., 2006; Sugar et al., 2004) involved college students and two empirical studies (Virvou et al., 2005; Zurita et al., 2005) used elementary school students. Interestingly, 11 empirical studies during 2007-2010 involved college students whereas only one study (Liu, 2007) used elementary school students.

Table 6. Frequencies of participant level in highly cited empirical studies during 2003-2010, 2003-2006, and 2007-2010

Participant level	Frequencies		
	2003-2010	2003-2006	2007-2010
College	3	2	11
Elementary school	3	2	1
Total	6	4	12

Learning domain

Table 7 presents different learning domains applied in the highly cited empirical studies over different time intervals. During 2003-2010, two articles were classified into education domain and two articles were science domain (including computer and engineering). The two remaining empirical studies were about math and geography. During 2003-2006, two empirical studies (Hernandez-Leo et al., 2006; Sugar et al., 2004) were conducted in education domain, and the two remaining studies were about math (Zurita, et al., 2005) and geography (Virvou et al., 2005). During 2007-2010, six empirical studies were conducted in science domain. Four studies (Chen & Hsu, 2008; Teo et al., 2008; Yang, 2009; Makri & Kynigos, 2007) were identified into education domain, and the two remaining studies were classified into math (Liu, 2007) and business (Hou et al., 2008) domains.

Table 7. Frequencies of learning domain in highly cited empirical studies during 2003-2010, 2003-2006, and 2007-2010

Learning domain	Frequencies		
	2003-2010	2003-2006	2007-2010
Education	2	2	4
Geography	1	1	0
Math	1	1	1
Science (including computer and engineering)	2	0	6
Business	0	0	1
Total	6	4	12

Research method

Table 8 shows different research methods applied in the highly cited empirical studies over different time intervals. During 2003-2010, among highly cited empirical studies (*n* = 6), four empirical studies utilized mixed method and two used quantitative method. During 2003-2006, three empirical studies (Hernandez-Leo et al., 2006; Virvou et al., 2005; Sugar et al., 2004) used mixed method, followed by one empirical study (Zurita et al., 2005) with quantitative method. No empirical study using qualitative method was found in the two intervals. During 2007-2010, five empirical studies (Hou et al., 2008; Liu, 2007; Yang, 2009; Delialioglu & Yildirim, 2007; Makri & Kynigos, 2007) utilized qualitative method, followed by four studies (Chen & Hsu, 2008; Yukselturk & Bulut, 2007; Demetriadis & Pombortsis, 2007; Huang et al., 2009) with mixed method and three studies (Holzinger et al., 2008; El-Bishouty et al., 2007; Teo et al., 2008) with quantitative method. Interestingly, the number of empirical studies using qualitative method obviously increased in the period of 2007-2010.

Table 8. Frequencies of research method in highly cited empirical studies during 2003-2010, 2003-2006, and 2007-2010

Research method	Frequencies		
	2003-2010	2003-2006	2007-2010
Mixed method	4	3	4
Quantitative	2	1	3
Qualitative	0	0	5
Total	6	4	12

Frequent author keywords

According to Mao, Wang, and Ho (2010), author keywords analysis provides researchers with "the information of research trend" (p. 813). The authors used word clouds to present the frequently used author keywords obtained from the highly cited empirical studies during 2003-2010, 2003-2006, 2007-2010, respectively.

The Wordle program automatically generated three graphics (Figure 2(a), 2(b), and 2(c)) after the authors typed all the keywords listed on the empirical studies in different periods of time. The results indicated that "learning" was the top keyword that appeared in empirical studies over the different time intervals. During 2003-2010, the word clouds showed that frequently appeared keywords were: collaborative learning, computer-supported collaborative learning, dynamic media, and educational technology (Figure 2(a). It is important to note that the Wordle program shows single words, and in this analysis, those words were combined as per the keywords provided by the authors in order to obtain meaningful analysis. Only four empirical studies were identified during 2003-2006. The frequently appeared keywords were: computer-supported collaborative learning and educational technology (Figure 2(b)). During 2007-2010, the word clouds showed that mobile learning, media learning, blended learning, online learning, instructional technology, and language learning using blog (Figure 2(c)).

(a)

(b)   (c)
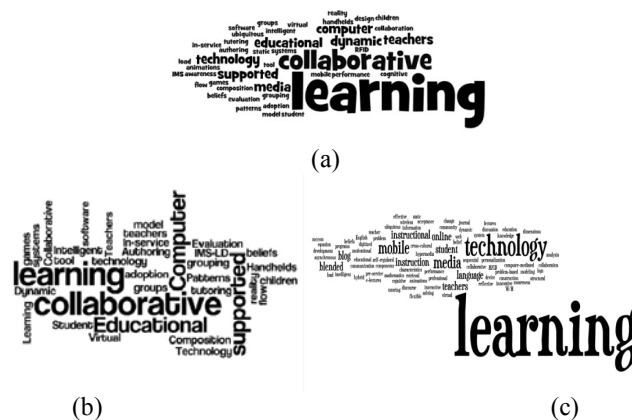
Figure 2. (a)Word clouds of the keywords listed on empirical studies during 2003-2010; (b) Word clouds of the keywords listed on empirical studies during 2003-2006; and (c) Word clouds of the keywords listed on empirical studies during 2007-2010

Discussion

The purpose of the current study was to explore the characteristics of the highly cited articles published in the ET&S during 2003-2010. Appendix-1 presents the top 20 highly cited articles published in the ET&S from 2003 through 2010. Obviously, Appendix-1 demonstrates that the top 20 highly cited articles were mostly about system and/or model design (40%, $n = 8$) during 2003-2010. It is not surprising to obtain such findings because most researchers in the field of educational technology conducted system/model design in a short period of time to report how the system/model worked in a learning setting.

The distribution of highly cited empirical studies during 2003-2006 and 2007-2010 was quite different. The results indicated that only four (23.8%) empirical studies were found in the top 20 highly cited articles from 2003 to 2006. On the other hand, 12 (52.2%) empirical studies were retrieved within the top 20 highly cited articles from 2007 to 2010. The reason could be that the ET&S did not receive many high quality empirical studies before 2007. As a result, fewer empirical study articles were cited by other scholars during 2003-2006.

The impact or visibility of an article can be identified by the number of citations (Chiu & Ho, 2007). The overall quality of the highly cited articles published in the ET&S over the past years appeared to be good due to an increase in mean citation count every year (impact factor in 2010 = 1.067) shown on the Web of Science database. The numbers of internationally co-authored articles in different time intervals were the same. They did not increase in recent years. One of the reasons may be that it is difficult to find common research topics among researchers from different countries. Moreover, it would be reasonable to assume that participants' different characteristics and English proficiencies may hinder the possibilities of conducting international collaboration. To increase more international collaborations in research fields, the policy makers may provide consistent financial support for those researchers who are interested in publishing international co-authored articles while allocating national funding.

From Appendix-1, it is evident that will be the key trends in the near future. Further, mobile learning technology and ubiquitous collaborative learning with mobile devices, and game-based learning, and ubiquitous learning were the core research topics, based on the six highly cited empirical studies during 2003-2010. This is in line with the 2011 Horizon Report (http://wp.nmc.org/horizon2011/). In this report, the application of mobile devices and game-based learning learning are new research topics with great potential in academia (Hwang & Tsai, 2011; Liu & Hwang, 2010). Hence, the three core research topics definitely echo these researchers' statements and indicate a future direction in the field of educational technology.

After splitting into two different time intervals, the authors found different results. During 2003-2006, among four frequently cited empirical studies, collaborative learning was the hot research topic in this time frame. During 2007-2010, mobile/ubiquitous learning, e-learning, and Web 2.0 were identified to be the trends in citations among the 12 highly cited empirical studies. Particularly, the topic of collaborative learning became less representative in recent years. It is possible that the findings of collaborative learning studies have matured in the educational technology field, which in turn affects the citation counts of these articles. On the other hand, mobile/ ubiquitous learning and other technology-based learning have become popular research topics over the recent years. For example, two studies related to mobile/ubiquitous learning conducted by El-Bishouty et al. (2007) and Chen & Hsu (2008) received 16 and 11 citation counts respectively (as of November 30, 2011). It is therefore not surprising that the results of the present study are consistent with the 2011 Horizon Report due to the fact that mobile devices have become affordable and wireless network connections are accessible for the public.

The researchers in the field of educational technology generally conduct empirical studies in different learning domains. The results of analyzing highly cited empirical studies indicated that the research of using technology in science classes and education programs showed their impact during 2007-2010. In particular, 50% (6 out of 12) of the highly cited empirical studies during 2007-2010 were found in science curriculum (including computer and engineering). The studies of using technology in the science classroom published in the ET&S obtained more attention from the researchers over the past four years. Based on the findings, it is predicted that using technologies in different learning domains will be foreseeable.

In terms of research methodology, mixed-method was found to be the major research method in highly cited empirical studies over 2003-2010. By analyzing the research methods used in highly cited empirical studies, the

authors concluded that mixed-method was popularly applied in the field of educational technology. For researchers, the reason to apply mixed method design is to collect both quantitative and qualitative data in order to present complete pictures and in-depth explanation about the findings.

The increase of using qualitative method in educational technology research was observed at different time intervals. No papers with qualitative research were found during 2003-2006, whereas five (42%) qualitative research papers were identified during 2007-2010. It suggests that the findings in educational technology research need more in-depth exploration to investigate users' thoughts and concerns.

Interestingly, the results of using word clouds to present the frequently used author keywords were similar to the findings obtained from manual coding. For instance, in analyzing empirical studies, the authors found that ubiquitous learning, mobile learning, and collaborative learning were highlighted in Wordle.

The findings of this study are constrained by some limitations, which similar studies in future should address. First, selecting a single journal to analyze the highly cited articles might be skewed towards a certain research field due to the small number of published articles. It might not be truly representative of the total literature of educational technology. Analyzing different journals in the same field may have different results regarding the characteristics identified in this study. Second, the analysis on research topics obtained from the highly cited empirical studies could be extended to analyze research topics from all articles published in the ET&S. Third, the highly cited articles were analyzed by total citation counts obtained from 2010 Journal Citation Report. Future study may analyze the h index in the highly cited articles by comparing individual authors' h indices and their papers cited in the field of educational technology. Finally, the citation counts used in this study included self-citations. Use of indications (rather than indicators, such as citation counts) to evaluate the quality of the highly cited articles lends itself to further investigation (Aksnes, 2003).

The way forward

It has been very interesting journey through time to see how educational technology has progressed as reported in the highly cited papers in the Journal of Educational Technology and Society. The field has matured immensely in certain areas and new directions are opening up. Still, the issue of "learning" has stayed on the top and hopefully, we would be sensible enough to keep it that way.

The major goal of the journal, since when it was started, has been to open up dialog between those who design the educational technology and those who use it. The analysis seems to endorse progress in that area even if a lot of work still to be done. Interestingly, the patterns emerged during the analysis align with the analyses of other prominent initiatives, such as the Horizon Reports published by the New Media Consortium (http://www.nmc.org), and the roadmap for education technology compiled by Woolf (2010). For example, Horizon Reports have over past few years consistently identified research areas related to mobility, collaboration, social media and personalization, as some of the technologies with the best chances of adoption. Woolf (2010)'s roadmap also identified these as promising areas to overcome various challenges that are experiences in today's educational environment. Findings of the study presented in this paper agree with these analyses and provide indication of a healthy research progress for the advancement of these educational technology research areas worldwide.

In terms of the coverage of the issues, concerns related to the impact of ICT were very predominant at earlier stage but later declined, as Web-based learning has more and more integrated into mainstream education and teething problems have started to sort out.

Educational paradigms and concerns for individual students have continued to dominate the field and the trend indicates that it will continue to do so.

Infrastructure issues and associated technologies have featured continuously but there is a rapid shift in the field. Earlier issues of the journal featured areas like hypermedia but the focus then shifted to more advanced entities such as collaborative technologies, social media, mobile learning and collaborative technologies, and the trend seems to continue for a foreseeable future.

Overall, the analysis indicates that the field of educational technology is a rapidly evolving field. Both educational paradigms and technological advancements are affected. However, the changes in technology are at much faster pace compared to the shifts in educational paradigms. It would be very interesting to see how the landscape develops in next few years, when the true effects of globalization and ever improving connectivity based technologies, such as ubiquitous and augmented reality technologies mature.

Conclusions

The distribution of research topics in highly cited empirical studies identified in this study provides insights for educators and researchers in the educational technology field to develop their future research interests. Moreover, the results might lead researchers in educational technology to focus their manuscript submissions on the hot research topics found in this study.

To monitor the research trends in the field of educational technology, the authors used word clouds to analyze author keywords listed in the highly cited empirical studies and made a cross-validation with the research topics found in this study. The authors could conclude that the future research direction of educational technology is mobile learning, ubiquitous learning, and game-based learning. The findings provide directions to better understand the future potential research topics.

Two questions were worthy of re-thinking after the authors finished this study. Why did the highly cited articles published in the ET&S with single author receive high citation rates? Future studies might ask the author(s) about their comments. Another question is that international collaboration illustrates a contribution factor for the highly cited articles. How did these authors from different countries find their common research topics? The current study has set the footing and foundation of guiding future studies on these issues.

Acknowledgements

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Appendix 1

Top 20 highly cited ET&S papers (by citation counts in total, as of November 30, 2011) during 2003-2010

Rank	Citation counts	Title	Author(s)	Country	Published year /page number	Research type
1	84	Representing the learning design of units of learning	Koper, R., Olivier, B.	The Netherlads, U.K.	2004/7(3), 97-111	Theoretical paper
2	45	Context aware ubiquitous learning environments for peer-to-peer collaborative learning	Yang, S. J. H.	Taiwan	2006/9(1), 188-201	System evaluation
3	36	COLLAGE: A collaborative learning design editor based on patterns	Hernandez-Leo, D., Villasclaras-Fernandez, E. D., Asensio-Perez, J. I., Dimitriadis, Y., Jorrin-Abellan, I. M., Ruiz-Requies, I., Rubia-Avi, B.	Spain	2006/9(1), 58-71	Empirical study (mixed method)
4	36	Adaptive learning resources sequencing in educational hypermedia systems	Karampiperis, P., Sampson, D.	Greece	2005/8(4), 128-147	System evaluation
5	31	Dynamic media in computer science education, content complexity and learning performance: Is less more?	Holzinger, A., Kickmeier-Rust, M., Albert, D.	Austria	2008/11(1), 279-290	Empirical study (quantitative method)
6	30	Reasoning and ontologies for personalized e-learning in the semantic web	Henze, N., Dolog, P., Nejdl, W	Germany	2004/7(4), 82-97	System evaluation
7	29	The new challenges for e-learning: The educational semantic web	Aroyo, L., Dicheva, D.	The Netherlands, U.S.A.	2004/7(4), 59-69	System introduction
8	28	Combining software games with education: Evaluation of its educational effectiveness	Virvou, M., Katsionis, G., Manos, K.	Greece	2005/8(2), 54-65	Empirical study (mixed method)
9	25	Towards a pattern language for learning management systems	Avgeriou, P., Papasalouros, A., Retalis, S., Skordalakis, M.	Greece, Cyprus	2003/6(2), 11-24	Other
10	24	Ontology enabled annotation and knowledge management for collaborative learning in virtual learning community	Yang, S. J. H., Chen, I. Y.-L., Shao, N. W. Y.	Taiwan	2004/7(4), 70-81	System evaluation
11	22	Dynamic grouping in collaborative learning supported by wireless handhelds	Zurita, G., Nussbaum, M., Salinas, R.	Chile	2005/8(3), 149-161	Empirical study (quantitative method)
12	20	Criteria, strategies and research issues of context-aware ubiquitous learning	Hwang, G.-J., Tsai, C.-C., Yang, S. J. H.	Taiwan	2008/11(2), 81-91	Other
13	20	Examining teachers' decisions to adopt new technology	Sugar, W., Crawley, F., Fine, B.	U.S.A.	2004/7(4), 201-213	Empirical study (mixed method)
14	19	A theory for eLearning	Nichols, M.	New	2003/6(2), 1-	Theoretical

				Zealand	10	paper
15	19	Using mutual information for adaptive item comparison and student assessment	Liu, C.-L.	Taiwan	2005/8(4), 100-119	Other
16	18	Mobile collector for field trips	Kravcik, M., Kaibel, A., Specht, M., Terrenghi, L.	Germany	2004/7(2), 25-33	System evaluation
17	18	Interoperability in personalized adaptive learning	Aroyo, L., Dolog, P., Houben, G.-J., Kravcik, M., Naeve, A., Nilsson, M., Wild, F.	The Netherlands, Germany, Belgium, Sweden, Austria	2006/9(2), 4-18	System and model evaluation
18	16	An ontology-based framework for bridging learning design and learning content	Knight, C., Gasevic, D., Richards, G.	Canada	2006/9(1), 23-37	Theoretical paper
19	16	A particle swarm optimization approach to composing serial test sheets for multiple assessment criteria	Yin, P.-Y., Chang, K.-C., Hwang, G.-J., Hwang, G.-H., Chan, Y.	Taiwan	2006/9(3), 3-15	System design
20	16	PERKAM: Personalized knowledge awareness map for computer supported ubiquitous learning	El-Bishouty, M.M., Ogata, H., Yano, Y.	Japan	2007/10(3), 122-134	Empirical study (quantitative method)

Emerging Educational Technologies and Research Directions

J. Michael Spector

Department of Learning Technologies, University of North Texas, USA // jmspector007@gmail.com

Abstract

Two recent publications report the emerging technologies that are likely to have a significant impact on learning and instruction: (a) New Media Consortium's *2011 Horizon Report* (Johnson, Smith, Willis, Levine & Haywood, 2011), and (b*) A Roadmap for Education Technology* funded by the National Science Foundation in the USA (to download the report see http://www.cra.org/ccc/edtech.php). Some of the common technologies mentioned in both reports include personalized learning, mobile technologies, data mining, and learning analytics. This paper analyzes and synthesizes these two reports. Two additional sources are considered in the discussion: (a) the IEEE Technical Committee on Learning Technology's report on curricula for advanced learning technology, and, (b) the European STELLAR project that is building the foundation for a network of excellence for technology enhanced learning. The analysis focuses on *enablers* of (e.g., dynamic online formative assessment for complex learning activities) and *barriers* to (e.g., accessibility and personalizability) to sustained and systemic success in improving learning and instruction with new technologies. In addition, two critical issues cutting across emerging educational technologies are identified and examined as limiting factors – namely, political and policy issues. Promising efforts by several groups (e.g., the National Technology Leadership Coalition, the IEEE Technical Committee on Learning Technology, Networks of Excellence, etc.) will be introduced as alternative ways forward. Implications for research and particular for assessment and evaluation are included in the discussion as means to establish credible criteria for improvement.

Keywords

Accessibility, Emerging technology, Network of excellence, Online assessment, Personalization

Introduction

New and more powerful information and communications technologies (ICT) continue to emerge at a rapid pace. Their use in business, government, and the entertainment sectors is widespread and the impact remarkable. E-commerce continues to grow at a rate of about 20% globally and is expected to approach a trillion US dollars in 2013 (JP Morgan, 2008). E-government is now well established at many levels in both developed and developing countries around the globe and particularly critical in times of national and international crisis (United Nations Public Administration Netwrok, 2010). The entertainment industry is perhaps the leader in ICT innovations as demonstrated by the popularity of animated 3D feature-length movies and massively multi-player games on smart phones. Given the growth and impact of ICT in other sectors, it is reasonable to wonder what impact emerging educational technologies will have on learning and instruction and how research might be directed to explore that impact.

As it happens, scholars have been exploring the issue of emerging educational technologies and their impact for years. Two recent sources will be discussed in this paper: (a) the New Media Consortium's (2011) *2011 Horizon Report* (Johnson et al, 2011), and (b) *Roadmap for Education Technology* commission by the National Science Foundation in 2010 (Woolf, 2010). In addition to these two highly regarded sources, two projects that have been exploring emerging educational technologies will also be examined and included in the discussion: (a) the European STELLAR project that is developing a network of excellence for technology enhanced learning (see http://www.stellarnet.eu/), and, (b) the IEEE Technical Committee on Learning Technology's effort to recommend curricula for advanced learning technologies (Hartley, Kinshuk, Koper, Okamoto, & Spector, 2010).

The analysis will focus on enablers and barriers for systemic and sustained improvements in making effective use of ICT in learning and instruction. The paper concludes with the role that politics and policy play as enablers of and barriers to technology enhanced learning, along with recommendations for research agendas to promote technology enhanced learning.

The 2011 Horizon Report

The New Media Consortium, a globally-focused not-for-profit consortium, (see http://www.nmc.org) established the Horizon Project in 2002 to identify and describe emerging technologies that seemed likely to have a significant

impact on a variety of sectors around the world. Potential impacts on teaching, learning and creative inquiry have been a focus from the very first *Horizon Report*. The *2011 Horizon Report* (Johnson et al., 2011) includes sections on key trends, critical challenges and technologies to watch. The report identifies six technologies to watch in three time-to-adoption contexts: one year or less, two to three years, and four to five years. In addition to the primary report, there are reports on specific sectors (e.g., K-12) and regions (e.g., Australia). To gain a complete understanding of the report, it is a good idea to look at previous reports and use the new Navigator tool to explore the huge sets of data used to develop the various Horizon Reports; these are available to the general public at no cost on the NMC Website.

Key trends

The *2011 Horizon Report* identified four key trends, all of which also appeared in the *2010 Horizon Report*. First, the massive amount of resources and relationship opportunities afforded by the Internet create a continuing need to re-examine the role of an educator with regard to sense-making, coaching, and credentialing. Second, people continue to expect to work, learn and study at their convenience in terms of time and place. Third, work is increasingly collaborative which creates a need to [re-]structure student projects to reflect authentic and realistic contexts likely to be encountered outside study environments. Fourth, technologies are increasingly cloud-based. Taken together, these trends suggest that learning environments should be more collaborative and that they should make use of tools, technologies, processes and resources likely to be encountered in the workplace. While this is not ground-shaking news to educational technologists and researchers, the implications for schools really are ground-shaking in the sense that significant transformations need to occur if schools are to be responsive to such trends.

Critical challenges

Four critical challenges are also identified in the *2011 Horizon Report* (Johnson et al., 2011). First and foremost, digital media literacy is again ranked as the most important challenge. In order to maintain currency with emerging technologies and the trends previously described, being literate in the area of digital media is vital. Digital literacy is a multi-faceted skill that covers the ability to find, use, interpret, modify, and create a variety of digital media. Falling behind in this area contributes to the digital divide, which is widening just when accessibility and resources are expanding. A second significant challenge is in the area of evaluation metrics, which was noted in 2010 as well. The challenge in this area is in part because much of the research being conducted is designed for earlier forms of education resulting in no significant differences being found for new forms of education. Third, economic pressures associated with new media are challenging traditional forms of education to compete in novel ways. In response to the trend for teaching and learning anywhere and anytime, online universities and programs are attracting increasing numbers of students causing traditional universities to compete for students who would have been presumed to prefer traditional universities. Fourth, due to the proliferation of information, resources, tools and devices, it is increasingly difficult for teachers and students to maintain their knowledge and skills. As would be expected, the challenges are closely connected with the trends noted earlier. It is worth noting here that the challenge of developing appropriate evaluation metrics, along with associated assessments, is especially important in the sense that without such metrics, progress in any of the areas mentioned is merely speculative. This issue arises in the NSF Roadmap to be discussed in a subsequent section.

Technologies to watch

In the near term (one year or less), the report identifies two technologies, consistent with findings in previous years: *electronic books* and *mobile devices*. Both of these are well known and have already made their way in educational contexts. Moreover, they are consistent with the trends and challenges presented previously. Electronic books add to the wealth of information and resources available on the Internet, but they may not be accessible to everyone. Mobile devices do allow people to learning almost anywhere at their convenience, but keeping pace with new mobile devices is a challenge and there are places where the devices or the networks to facilitate their use are not accessible or affordable.

In the two-to-three year time horizon, two technologies are identified that have significant but not yet fully realized potential to impact learning and instruction: *augmented reality* and *game-based learning*. Both of these technologies are now part of mainstream popular culture in many parts of the world, but their potential to impact education is not yet fully realized. Augmented reality consists of computer generated sensory input to supplement human perception. A simple example is a mobile device used museums to assist visitors; the device might show a movie clip or play an audio file to enhance the exhibit viewer's experience. Game-based learning is not new, of course, but what is relatively new is the strength of interest in massively multiplayer games as evident at the serious games Website (see http://www.seriousgames.org/). While there is great interest in digital games and games are becoming increasingly sophisticated and popular, there is not strong evidence of improved learning on account of game-based learning experiences, although there are notable exceptions (Tobias & Fletcher, 2011). This deficiency points to the importance of the challenge for improved evaluation metrics, and for the need to connect game and education goals. While the devices to support educational gaming have become quite sophisticated, there is again the issue of access to and knowledgeable use of those devices, which in many cases detracts from the learning experience. In this author's opinion, an example of an effective educational game is one created using a validated system dynamics model that allows learners to collaboratively interact, formulate hypotheses, make decisions, and develop policies to guide future decisions (Milrad, Spector, & Davidsen, 2003).

In the four to five year time horizon, the two technologies identifies as most likely to impact learning and teaching are *gesture-based computing* and *learning analytics*. Gesture-based computing extends input from keyboard and mouse to include body and eye movements. The goal is to make interaction more intuitive and natural, although the evidence in this area is not convincing, at least not in terms of improved learning and instruction. The devices themselves are quite popular and are quite likely to continue to gain interest in entertainment contexts. The one area where gesture-based computing is likely to be directly effective is with simulators that are intended to behave like their real-world counterparts – in such cases, it is possible to make the interaction experience quite authentic and realistic, which is likely to impact learning. The other longer-term technology to watch is learning analytics. The notion of analytics is to mine very large sets of data in near-real time in order to configure an experience for a user that is likely to be relevant and of interest. Commercial e-commerce sites already do this to suggest to buyers additional purchases based on things already selected by them that matched with additional things that similarly profiled users selected. In an educational context, the notice of learning analytics can build on meaningful evaluation and assessment metrics (a challenged noted earlier) to configure particular learning experiences in a personalized learning context. For example, assume that profiles are kept on learners that include interests, preferences and previous performance. When a particular learner is struggling with a unit of instruction, the learning analytics module could search a database of similarly profiled learners who struggled with that same unit of instruction but who subsequently succeeded when given an opportunity to interact with a supporting unit of instruction. Then, the personalized learning system presents a customized learning activity based on the output of the learning analytics. Such a system is realistic and may be closer than four or five years from realization and impact in actual instructional contexts.

The NSF roadmap for education technology

In 2009, the US National Science Foundation commissioned a report on the future of educational technology. A number of meetings and workshops were convened that included leaders in several different disciplines who were tasked with making recommendations for a research agenda and future federal funding. The report from these meetings and workshops was published in 2010 (Woolf, 2010). The report focused on the role and impact of computing and technology in education, and it included research recommendations and a vision for education the year 2030. Seven grand challenges were identified followed by seven technology recommendations. In the next two sections, the grand challenges and technology recommendations are briefly characterized. The report contains a rationale for each of these challenges and recommendations, and readers are directed to the report for elaboration. In the context of this paper, the overlap with the *Horizon Report* will be emphasized, as there is a great deal of convergence, which adds credibility to both reports as they were constructed independently without overlapping authors.

Grand challenges

These grand challenges form the basis for specific research recommendations made in the *Roadmap*, some of which will be discussed in a subsequent section, and are connected with the vision for education in 2030 (that vision is not elaborated here as the emphasis here is on emerging technologies and their implications for education and research in the next few years).

- Personalizing education—a one-method fits all approach does not match up with a diverse population and the potential of new technologies; moreover, finding in cognitive psychology and new technologies make it possible to create effective learning activities to meet individual student needs and interests; this challenge fits quite well with trends and challenges cited in the *Horizon Report*.
- Assessing student learning—there is a need for effective assessments of students and teachers, not only for accountability and promotion (summative) but in order to improve learning and instruction (formative); the focus in assessment should be on improving learning, especially from a perspective of life-long learning and literacy in the information age; assessments should be seamless and ubiquitous (woven into learning activities unobtrusively); this challenge matches directly with the elaboration of evaluation metrics in the *Horizon Report*.
- Supporting social learning—supporting meaningful and collaborative learning activities is more important than ever before, partly due to requirements in the workplace to work collaboratively and partly due to the affordances of new Web 2.0 technologies; this challenge fits well with the *Horizon Report* trend pertaining to increasing collaboration and the challenges pertaining to digital media literacy and traditional models of the university.
- Diminishing boundaries—traditional boundaries between students and teachers, between and among personal abilities and types of learning, between formal and informal learning, and between learning and working are changing and becoming blurred in the 21st century; this creates a need to recognize the significance of informal learning and different learner abilities and interests; this challenge matches quite well with all of the *Horizon Report* trends and challenges.
- Developing alternative teaching strategies—the teacher is no longer the sole source of expertise in classroom settings due to the widespread availability of networked resources; this creates a need to change instructional approaches and train teachers accordingly; this challenge fits well with the challenge of new models of education and the trends cited in Horizon Report.
- Enhancing the role of stakeholders—stakeholders in education systems need to develop trust that those systems are adequately preparing students for productive lives in 21st century society; as a consequence, there is a need to regularly consult with employers, parents, administrators, teachers and students to ensure that all stakeholders have confidence that the education system is working well; this challenge matches well with the Horizon Report challenge pertaining to economic and pedagogical pressures on traditional forms of instruction.
- Addressing policy changes—the knowledge society requires flexibility on the part of an informed population; educational inequities and the digital divide can challenge the stability of a society and need to be addressed; as with the other challenges, this one matches will with several trends and challenges cited in the *Horizon Report*.

It is obvious that these challenges are interrelated, as is the case with the trends and challenges in the *Horizon Report*. It is not possible to address just one without taking into consideration the others. The *Roadmap* includes a discussion of these interrelationships along with a table that maps the grand challenges to technology features and the vision of education in 2030. Readers are referred to the *Roadmap* for additional details.

Technology recommendations

Seven information and communications technologies areas are discussed in the Roadmap that are likely to have a significant impact on learning and instruction. Each is briefly characterized so that the overlap with the *Horizon Report* can be illustrated.

- User modeling—dynamic modeling of student competencies and prior learning is an important area in which ICT can contribute to improved learning and instruction, particularly through formative assessment and personalized instruction; pursuing new methods and tools to support user modeling fits well with the *Horizon Report* trends and challenges as well as with other technology recommendations in the *Roadmap*.
- Mobile tools—new mobile devices are increasing access to and use of ever more resources to support learning activities; integrating these smart and flexible tools into education context is a priority for the future; this

recommendation matches directly with the *Horizon Report* elaboration of mobile technologies and ubiquitous access.

- Networking—access to networked resources in essential in order to maintain progress in learning and instruction in the 21st century; these resources can democratize education and help minimize the digital divide if other challenges are met; this recommendation matches directly with the Horizon Report trend pertaining to cloud-based computing.
- Serious games—the notion of fun within the context of learning has long been recognized in primary education; the role of an education game to promote motivation and interest are gaining traction in secondary and post-secondary settings; serious games are those games that have an explicit and carefully planned educational purpose; more massively parallel, multi-player online games should be pursued and designed for transfer of learning to real-world environments; this recommendation is a direct match the *Horizon Report* emphasis on game-based learning.
- Intelligent environments—the research and development of intelligent tutoring environments in the 1980s and 1990s have matured and can now be applied to many contexts with more effective student modeling to effectively support personalized learning; the recommendation is to pursue adaptive systems in a wide variety of domains consistent with the other technologies mentioned in the *Roadmap*; there is no direct match with this recommendation in the *Horizon Report* although it is consistent with nearly all of the trends and technologies elaborated in that report.
- Educational data mining—it is now possible to record, store and retrieve a great deal of education data pertaining to individual and groups of learners that can be used to provide formative assessment and personalize learning, which is the recommendation of the *Roadmap* in this area; this recommendation is a direct match with the emphasis in the *Horizon Report* on learning analytics, and links with the other technologies cited in both reports.
- Rich interfaces—rich interfaces include those technologies that can sense, recognize, analyze and react to human interaction, and these, coupled with more open-ended learning environments, can be used to promote learning and instruction in a wide variety of contexts; the recommendation is to pursue rich interfaces that are responsive to affective as well as cognitive interaction, that support augmented realities, and that can serve as personal learning companions; this recommendation matches quite well with the *Horizon Report* emphasis on gesture-based computing and augmented reality.

As was the case with the grand challenges, these technologies to watch are interrelated and should be pursued in combinations rather than as single points of emphasis in research and development agendas. Some of the specific research recommendations in the Roadmap will be elaborated in a subsequent section.

The IEEE learning technology technical committee report on curricula

The IEEE Technical Committee on Learning Technology (TCLT) established a Working Committee to develop specifications for new curricula for advanced learning technologies as a response to the demands and potential of new and emerging technologies (Hartley, Kinshuk, Koper, Okamato, & Spector 2010).The Working Committee adopted and developed a competency-based approach with regard to curricula and assessments to cover undergraduate, postgraduate and training contexts. The competences were elaborated and assembled as a framework consisting of competence domains, classes and tasks which should be useful to educators and practitioners in adopting a broader multi-disciplinary approach, and in developing greater skill and understanding when applying new technologies to improve education and training. The effort reported here represents a three-year effort that culminated in the 2010 report (Hartley et al., 2010). The reason for including a summary of this report is that it again highlights the consistency found in the Horizon Report and the Roadmap – another indication that there is broadly based convergence on a global scale of the ideas represented in those two reports. This convergence will be further emphasized in the STELLAR project to be discussed in a subsequent section of this paper.

The Working Committee agreed with Melton (1997) that developments in technology are placing growing demands on the educational system, which are necessitating changes to curricula, pedagogies and assessment procedures. Existing curricula in informatics, learning technology and instructional design are confronting serious challenges in meeting the requirements of the workplace and society in general. The effort resulted in a competency framework that included five competency domains with associated sub-domain competence classes, which are more specific competencies that provide an elaboration of each competency domain; the reader is encouraged to examine the final

report for details of competencies classes as that is beyond the scope of this paper. The five competency domains (competency clusters) are briefly characterized as a context for the thirteen advanced learning technology curricula topical areas aimed at preparing instructional technologists and educational information scientists of the 21st century.

- Knowledge competence domain—this domain includes those competences concerned with demonstrating knowledge and understanding of learning theories, of different types of advanced learning technologies (including those cited in the *Roadmap* and *Horizon Report*), technology based pedagogies, and associated research and development.
- Process competence domain—this domain focuses on skills in making effective use of tools and technologies to promote learning in the 21st century; a variety of tools ranging from those which support virtual learning environments to those with pertain to simulation and gaming are mentioned.
- Application process domain—this domain concerns the application of advanced learning technologies in practice and actual educational settings, including the full range of life-cycle issues from analysis and planning to implementation and evaluation.
- Personal and social competence domain—consistent with the emphases cited in the *Roadmap* and *Horizon Report*, the report emphasize the need to support and develop social and collaboration skills while developing autonomous and independent learning skills vital to lifelong learning in the information age.
- Innovative and creative competence domain—this domain specifically recognizes that technologies will continue to change and that there is a need to be flexible and creative in making effective use of new technologies; becoming effective change agents within the education system is an important competence domain for instructional technologists and information scientists; this competency cluster is especially consistent with the *Horizon Report* challenge pertaining to the changing nature of education systems and the emphasis in the *Roadmap* on enhancing the role of stakeholders and addressing policy changes.

The Working Committee report (Hartley et al., 2010) identified thirteen topical areas that might be included in curricula in the future, each of which is elaborated in more detail in the report. The purpose here is simply to suggest a convergence of emphasis in the various reports pertaining to emerging technologies and the implications for learning, teacher preparation and research. The topical areas include the following:

- Introduction to advanced learning technologies—an historical overview of the evolution of learning technologies to provide a grounding in lessons learned from past efforts.
- Introduction to human learning in relation to new technologies—an elaboration of the contributions of cognitive psychologists and instructional designers in recent years.
- Foundations, evolution and developments in advanced learning technologies—emphasis on the affordances of new technologies, especially those pertaining to social networking, mobile devices and adaptive technologies (all of which are mentioned in the *Horizon Report* and the *Roadmap*).
- Typologies and key approaches to advanced learning technologies—elaboration of the links between and among taxonomies of technologies, technologies affordances, pedagogical approaches, and learning goals and objectives.
- User perspectives of advanced learning technologies—detailed treatment of the roles, expectations, and responsibilities of the various users involved with education systems involving new and emerging technologies.
- Learner perspectives of advanced learning technologies—elaboration of how various learners view and use new and emerging technologies for a variety of purposes.
- System perspectives of advanced learning technologies—emphasis on a systems level understand of new technologies and a holistic view of how effective technology integration can and does take place.
- Social perspectives of advanced learning technologies—emphasis on collaborative work, multi-disciplinary groups, and organizational and management issues involved in making effective use of new technologies.
- Design requirements—development of competence in the area of identifying critical design issues and creating effective plans to meet the challenges of user modeling, adaptive systems, and access to networked resources (again these are all technologies identified in the *Horizon Report* and the *Roadmap*).
- Design processes and development lifecycles—development of competence in such areas as needs assessment, requirements analysis, interface design, and authoring tools.
- Instructional design and the learning objects approach—up-to-date treatment of instructional design with emphasis on creating and using learning objects and flexible packaging of reusable and open-source components.
- Evaluation models and perspectives—emphasis on the need to construct and conduct comprehensive formative and summative evaluations in order to systematically improve learning and instructional systems; this topical

area is particularly well matched the emphasis in the *Horizon Report* on evaluation metrics the emphasis in the *Roadmap* on assessments.

- Emerging issues in advanced learning technologies—explicit recognition that technologies change and new ones will emerge, creating new challenges and an ongoing need to be flexible and creative in making effective use of learning technologies.

While these thirteen topical areas are generally well matched with the trends, challenges and technologies discussed in the *Horizon Report* and the *Roadmap*, they are particularly pertinent in emphasizing the need to properly prepare the teachers, instructional designers and information scientists of the future. It is clear that powerful educational technologies exist and will continue to emerge. What is not clear is how well we will be able to make effective use of those technologies. Without proper training of teachers and others, it is likely that new technologies will suffer the fate of so many educational technologies of the past – little impact on learning and marginal adoption rates. We can and should do better with these powerful new technologies, and serious and seriously changed curricula are required in order to do so.

A network of excellence for technology enhanced learning

A fourth source to emphasize the convergence of thinking about emerging educational technologies is the STELLAR Project that is developing a network of excellence in the area of technology enhanced learning (see http://www.stellarnet.eu). This three-year European project that will end in 2012 has already developed a number of resources that are available to the general public. In addition, networks to support advanced graduate students and connect TEL (Technology Enhanced Learning) scholars and researchers around the world are in place. The STELLAR Project identified five grand challenges (see http://www.stellarnet.eu):
- Provide a unifying framework for research;
- Engage the TEL community in scientific debate and discussion to develop awareness of and respect for different theoretical and methodological perspectives;
- Build TEL knowledge;
- Developing an understanding of how Web 2.0 technologies can support the construction of knowledge and research; and,
- Develop strategies for TEL instruments to feed and fuel ongoing developments.

The elaboration of these challenges is quite consistent with those discussed in the *Horizon Report* and the *Roadmap*, although the language used to express the challenges is somewhat different. Again we find emphasis on technologies (e.g., Web 2.0 technologies) mentioned in the other reports. The third and fourth challenges mentioned above are completely consistent with the Working Committee report on curricula for advanced learning technologies. The convergence with the previous reports discussed is even more obvious when three STELLAR guiding themes are considered:
- Connecting learning through networked learning and learner networks; this brings to mind the *Horizon Report* emphasis on cloud-based computing, the *Roadmap* emphasis on supporting social learning and the Working Committee report with its personal and social competence domain.
- Orchestrating learning with an emphasis on the role of teachers, the importance of meaningful assessments, and a focus on higher order knowledge and skills; this them is directly aligned with the *Horizon Report*'s discussion of the changing roles of educators, evaluation metrics, and new education systems, the *Roadmap*'s discussion of personalized education, assessing student learning, and alternative teaching methods, and the Working Committee's curricula recommendations in many competence areas.
- Contextualizing virtual learning environments and instrumentalizing learning contexts with an emphasis on novel experiences, new technologies, the mobility of learners and standards for interoperability; this theme aligns well with the emphasis in the other reports on augmented reality, alternative teaching methods, evaluation metrics, learning analytics, mobile technologies, and so on.

In summary, the convergence in these four sources of thinking about new and emerging technologies and their potential impact on learning and instruction is quite remarkable. The trends, challenges, and technologies discussed in these four sources are not all that new. They might be summarized as follows: (a) there will be smaller, more portable and more flexible devices to support learning; (b) there will be larger and more powerful information and

learning repositories to use in constructing learning experiences, assessing learning, and supporting personalized instruction; (c) educational environments will continued to become richer in terms of interaction, collaboration, media modalities, connectivity, collaboration, assessment; (d) learning activities will become increasing focused on problem solving and critical reasoning skills in authentic contexts; and (e) more holistic approaches (e.g., collaborative learning, emphasis on both affective and cognitive aspects of learning, etc.) to learning and instruction will displace traditional atomistic approaches that focus on individual learners and simpler learning tasks (e.g., declarative knowledge and simple, decontextualized procedures (Spector, 2000; Spector & Anderson, 2000).

Given such convergence among the academic community, one wonders if the recommendations and visions will materialize. What might stand in the say of realizing the potential of new and emerging technologies? What are the likely enablers and barriers?

Enablers and barriers

Enablers of successful integration of new technologies to improve learning and instruction are easily linked with barriers to success, and they fall mainly into two categories: (a) technology and infrastructure, and (b) human use and adoption. There is no shortage of powerful new technologies and many are quite affordable. For the technologies discussed in this paper to have an impact, access and supporting infrastructure are critical factors. Widespread, affordable and unfettered access to the Internet is basic. Without access to what the *Horizon Report* called *cloud-computing* and other reports simply referred to as the Web, very little progress or change is possible. Internet access and the supporting infrastructure are essential enablers of ongoing progress. Lack of such access becomes a barrier to progress and will serve to widen the digital divide. Simply stated, the technology and infrastructure barriers can be overcome with a modest investment of resources, and they must be overcome in order to ensure progress in the area of technology enhanced learning.

The issue of human use and adoption of new technologies is much more complex and challenging, as noted in several reports. Humans, both individuals and groups, are not always rational. Being rational involves being able to (a) articulate clearly stated goals, (b) identify and assess alternative means of achieving those goals, (c) follow-through with consistent and determined action consistent with the goals, and (d) evaluate progress and make appropriate adjustments. Such rationality requires a willingness to examine evidence, especially evidence that may be counter-intuitive or not well-aligned with one's predispositions. Consistent with many examples of concerted human behavior in many different domains, it is perhaps reasonable to conclude that humans are only intermittently rational. Some will resist integrating new technologies as doing so may seem to threaten practices that have become comfortable routines. Others may resist new technologies as they worry that students will be more adept with those technologies than they are. Still others may simply believe that what worked for them and famously successful people of their generation should be good enough for anyone. Other patterns of resistance to change and the adoption of new technologies can be cited as well. The Working Committee report emphasized the need for educational technologists and information scientists of the future to become effective advocates of change. This is a skill that is not easily or readily acquired, and in addition to the difficulty of developing skills of change agency, there is a need to be recognized as a legitimate source of expertise. Again this emphasizes the need to properly prepare people to function in an atmosphere of rapidly changing technologies with resistant populations and limited budgets. There are a few cases where human use and adoption issues have been addressed at a national level with remarkable success (e.g., Ireland, Japan, and South Korea). The larger and more diverse the society involved is, the more serious are the challenges posed by human use and adoption. Still, this area should be addressed, as suggested by all four sources discussed above.

On the human side of barriers and enablers, politics and policies stand out as perhaps the greatest challenge. Policies are developed and implemented at multiple levels, ranging from the school and district level, to the state, regional and national level. When policies are viewed as constraining and restrictive by teachers and learners, it is not likely that progress will occur, in spite of adequate technology and infrastructure. This is the case in many places in the USA where state-mandated testing in accordance with the national No Child Left Behind (NCLB) law is viewed as interfering with ongoing learning activities. In many schools in the USA, learning is interrupted for a week or longer devoted to preparing for and taking the mandated tests. Moreover, those tests seldom serve the constructive purpose of improving learning and instruction or encouraging specific educational practices. Rather, they are viewed as punishing poorly students, teachers and schools. If this personal assessment of NCLB is at all accurate, then the

conclusion is that this is a case of a policy serving as a barrier to progress even though it was intended to be an enabler.

Research directions

The *Roadmap* addresses research directions throughout the report with too many recommendations to discuss in this short paper. Because assessment is an area cited by all of the sources as a critical factor in improving learning and instruction with technologies, the focus here is on research in the area of assessment. The *Roadmap* and the IEEE Working Committee both cite competencies as a focal point for assessment. This is a traditional view of assessment – namely that assessments should be aligned with objectives. However, all of the sources emphasize formative assessments. The *Roadmap* discusses the importance of assessments that are useful to all parties. From a learner's perspective, this amount to a formative assessment that identifies a particularly difficult area along with recommended activities and resources that might help improve progress (Shute, 2008). In addition, formative assessments that are dynamic and occur in the context of specific learning activities are quite useful. As a consequence, the *Roadmap* encourages research aimed at developing dynamic, formative assessments, especially for learning activities that involve complex learning tasks.

Two specific advanced assessment technologies are worth mentioning that are specifically aimed at supporting the goals and visions of learning with advanced technologies discussed in this paper. The first of these involves using an annotated and dynamic concept map technology developed by Pirnay-Dummer, Ifenthaler, and Spector (2010). The general notion is that when a learner is confronted with a challenging, ill-structured problem (e.g., engineering design, environmental planning, technology integration), it is possible to elicit how the learner is conceptualizing the problem space, compare that representation with how highly experienced persons have conceptualized the same problem space, dynamically analyze similarities and differences, and use that analysis to encourage the learner to consider alternative solution approaches or perhaps to focus on a previously overlooked aspect of the problem.

The second technology is to make use of stealth assessments—that is to say, collect data on student performance in the course of a student or group of students working online on a problem solving activity. Such data may be log data from a computer system, for example. An analysis can be conducted on such files to determine what was done or not done. The stealth assessment system might then prompt the student to consider an alternative course of action or explore some part of the system previously ignored based on the analysis of the log file.

Both stealth assessment and dynamic concept map assessment have been demonstrated to be effective in a variety of learning situations. Both technologies exist but require funding support to become mainstream educational assessment tools available at low cost for widespread use throughout an education system. In addition, there are many important research questions worth investigating with regard to both of these representative emerging assessment technologies, including when it makes sense to interrupt the learner given a variety of situations, how learning advice is most effectively offered (e.g., suggestive vs. directive), and why learners follow or fail to follow advice offered by such assessment agents.

Conclusion

Four highly reputable sources of views and perspectives on new and emerging educational technologies have been reviewed and discussed. What is evident from this review and the discussion is that powerful technologies continue to emerge that can have significant impact on learning and instruction. What is not clear is to what extent the recommendations for research and the visions for education will be realized. Significant barriers remain, including budgetary matters, social perspectives that do not always place high value on education, and natural human tendencies to resist change. We have the means and wherewithal to transform learning and instruction and to make education affordable and accessible for nearly everyone on this planet. Will that happen? If one judges the future based on the past, the conclusion is that such transformations are not likely to happen on a global basis, although they will surely occur on a limited and local basis. It is perhaps unwise to place faith in educational progress in the technologies alone, regardless of how powerful and promising they are. Perhaps we ought to place our faith in properly trained, persistent, and dedicated teachers, designers, administrators, policy makers and parents—that is this author's conclusion.

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A Review of Technological Pedagogical Content Knowledge

Ching Sing Chai[1]*, Joyce Hwee Ling Koh and Chin-Chung Tsai[2]

[1]Nanyang Technological University, 1 Nanyang Walk, Singapore // [2]Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, #43, Sec.4, Keelung Rd., Taipei, 106, Taiwan //
Chingsing.chai@nie.edu.sg // Joyce.koh@nie.edu.sg // cctsai@mail.ntust.edu.tw
*Corresponding author

ABSTRACT

This paper reviews 74 journal papers that investigate ICT integration from the framework of technological pedagogical content knowledge (TPACK). The TPACK framework is an extension of the pedagogical content knowledge (Shulman, 1986). TPACK is the type of integrative and transformative knowledge teachers need for effective use of ICT in classrooms. As a framework for the design of teacher education programs, the TPACK framework addresses the problem arising from overemphasis on technological knowledge in many ICT courses that are conducted in isolation from teachers' subject matter learning and pedagogical training. The present review we have conducted indicates that TPACK is a burgeoning area of research with more application in the North American region. Studies conducted to date employed varied and sophisticated research methods and they have yielded positive results in enhancing teachers' capability to integrate ICT for instructional practice. However, there are still many potential gaps that the TPACK framework could be employed to facilitate deeper change in education. In particular, we suggest more development and research of technological environments base on TPACK; study of students' learning conception with technology; and cross fertilization of TPACK with other theoretical frameworks related to the study of technology integration.

Keywords

Technological pedagogical content knowledge (TPACK), ICT, teacher education

Introduction

While ICT is becoming prevalent in schools, and children are increasingly growing up with ICT, teachers' use of ICT for teaching and learning continue to be a concern for educators (Jimoyiannis, 2010; Polly, Mims, Shepherd, & Inan, 2010). Integrating ICT into classroom teaching and learning continue to be a challenging tasks for many teachers (Shafer, 2008; So & Kim, 2009). Teachers feel inadequately prepared for subject-specific use of ICT and robust theoretical framework is lacking (Brush & Saye, 2009; Kramarski & Michalsky, 2010). To address the challenges, an important theoretical framework that has emerged recently to guide research in teachers' use of ICT is the technological pedagogical content knowledge (TPACK).

The notion of technological pedagogical content knowledge (TPACK) formally emerged in the literature of education journal in 2003 (Lundeberg, Bergland, Klyczek, & Hoffman, 2003). In 2005, several seminal articles appear concurrently (see Angeli & Valanides, 2005; Koehler & Mishra, 2005a; Niess, 2005). Originally given the acronym of TPCK, the acronym has recently been changed to TPACK for the ease of pronunciation (see Thompson & Mishra, 2007–2008). Since 2005, TPACK has been a burgeoning focus of research especially among teacher educators who are working or interested in the field of educational technology. To date, we have identified more than 80 journal articles written with reference to the TPACK framework. However, TPACK still needs to be further understood and developed into an actionable framework that can guide teachers' design of ICT interventions. This warrants a need to review and assess the directions of current TPACK research. This study therefore aims to consolidate the collective emerging trends, findings, and issues generated in TPACK research, and to identify its current gaps. It also proposes a revised TPACK framework to guide possible areas for future research that address the current research gaps.

Method

Identifying journal articles

The literatures were identified in May 2011 by first exploring the Web of Science database, follow by Scopus database. The keyword employed was "technological pedagogical content knowledge" and "TPACK OR TPCK." As a result, a total of 40 full articles were located. A further search was conducted using Education Research Complete and ERIC as databases in the EBSCOhost. The search yielded 75 journal articles. Combining the searches and

eliminating duplicates, a total of 82 journal articles were collected. We removed 5 book reviews for the *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* (AACTE, 2008) and three position papers with one or two paragraphs advocating that the TPACK framework should guide future work in ICT integration. These position papers were assessed as not adding much to this area of study and were thus not included. The remaining 74 articles were read, analyzed and coded using a spreadsheet program.

Coding scheme employed

The coding scheme were adapted from the structured/systemic approach to literature review as advocated by Lee, Wu and Tsai (2009; see also Tsai & Wen, 2005). For this review, four main categories were employed to allow the researchers to make sense of the articles. They are listed as follow:
• Basic data: authors, year of publication, journals, localities of study
• Research methods: research approach, method, theme, data collected, method of analyses, research outcomes
• Content analyses: technology, pedagogy, content area and the designed pathway (i.e., how the researchers/teacher educators design their program according to the TPACK framework)
• Discussion: issues discussed, future directions, personal comments

These four areas of coding allow the researchers to systematically study the emerging trends, issues and possible future research directions. The personal comments were memo of the researchers' emerging query and understanding about the literature. All codes were accepted based on consensus among the researchers and each paper was coded twice. As the codes are relatively objective, we do not have many disputes in reaching consensus. In the following sections, we will delimit the 7 dimensions of TPACK before we proceed to present the findings of the review.

Delimiting TPACK and its constituents

TPACK refers to the synthesized form of knowledge for the purpose of integrating ICT/educational technology into classroom teaching and learning. The core constituents of TPACK are content knowledge (CK), pedagogical knowledge (PK), and the technological knowledge (TK). The interaction of these three basic forms of knowledge gives rise to pedagogical content knowledge (PCK), technological content knowledge (TCK), technological content knowledge (TPK) and the TPACK. As a form of knowledge, TPACK has been described as situated, complex, multifaceted, integrative and/or transformative (Angeli & Valanides, 2009; Harris et al., 2009; Koehler & Mishra, 2009; Manfra & Hammond, 2008). As a framework, it has been employed to unpack ICT-integrated lessons, teachers work with ICT, to design teacher education curriculum, to design classroom use of ICT and to frame literature review pertaining to ICT or educational technology (Polly et al., 2010). In essence, this is a powerful framework which has many potential generative uses in the research and development related to the use of ICT in education. Figure 1 below shows the diagrammatic depiction of the relations among the seven constructs.
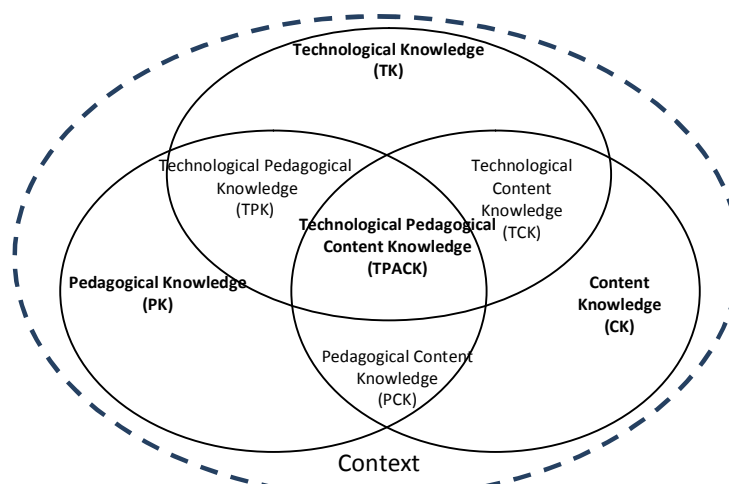
Figure 1. TPACK Framework (Koehler & Mishra, 2009; p. 63)

Confusion about TPACK constructs

Due to the overlapping nature of the framework, concerns about the confusion among the constructs have been highlighted by researchers such as Cox and Graham (2009) and researchers interested in measuring teachers' self-reported perception of TPACK (Archambault & Barnett, 2010; Lee & Tsai, 2010). Cox and Graham (2009) emphasize the notion of independence when classifying the forms of knowledge. For example, when discussing knowledge pertaining to TPK such as the principles of the use of online forum for discussion, there should be no reference towards the subject matters (CK). Their suggestion seems very appropriate in helping researchers to delimit the constructs. Based on their suggestion, some loose use of terms in the literature can be detected. For example, Archambault and Barnett (2010) commented that two teachers interpret their item 1d "My ability to decide on the scope of concepts taught within my class" (p.1959) as pertaining to the PCK while they intended it to be representing CK. The item is unclear as content scoping may involve a pedagogical decision, which could be properly classified as PCK. Polly et al. (2010) consider "using technology to address specific academic standards" and the design of "technology-rich units" (p. 866) as work in the area of TCK. As academic standards are usually set for education purpose, they may be designed with implicit pedagogical intentions. In such cases, the materials should properly be classified as TPACK. On the other hand, while software such as Google Earth and SPSS can be undoubtedly classified as TCK since they are designed for general usage without consideration towards pedagogy, digitization of print based materials can hardly be classified under TCK as such digitization can be carried out for all content.

Other areas that may require some clarifications are in the areas of TK and TCK. While it is legitimate to include knowledge of operating overhead projectors and many other traditional forms of technology as technological knowledge (see Schmidt et al., 2009), in the context of TPACK research, it would only serve to cloud the focus. Confining the discussion of TK to skills and knowledge in using technologies associated with computers would be more appropriate and meaningful (see Cox & Graham, 2009).

Synthesizing from the literature we reviewed (Cox & Graham, 2009; Koehler & Mishra, 2009; Mishra & Koehler, 2006), Table 1 below attempts to provide the succinct definition of each construct accompany with some examples.

Table 1. Definition and examples of TPACK dimensions

TPACK Constructs	Definition	Example
TK	Knowledge about how to use ICT hardware and software and associated peripherals	Knowledge about how to use Web 2.0 tools (e.g., Wiki, Blogs, Facebook)
PK	Knowledge about the students' learning, instructional methods, different educational theories, and learning assessment to teach a subject matter without references towards content	Knowledge about how to use problem-based learning (PBL) in teaching
CK	Knowledge of the subject matter without consideration about teaching the subject matter	Knowledge about Science or Mathematics subjects
PCK	Knowledge of representing content knowledge and adopting pedagogical strategies to make the specific content/topic more understandable for the learners	Knowledge of using analogies to teach electricity (see Shulman, 1986)
TPK	Knowledge of the existence and specifications of various technologies to enable teaching approaches without reference towards subject matter	The notion of Webquest, KBC, using ICT as cognitive tools, computer-supported collaborative learning
TCK	Knowledge about how to use technology to represent/research and create the content in different ways without consideration about teaching	Knowledge about online dictionary, SPSS, subject specific ICT tools e.g. Geometer's Sketchpad, topic specific simulation
TPACK	Knowledge of using various technologies to teach and/represent and/ facilitate knowledge creation of specific subject content	Knowledge about how to use Wiki as an communication tool to enhance collaborative learning in social science

Findings of this review

In the following sections, findings of this review are presented in three main sections according to the basic data analyses, research methods analyses, and content analyses. Findings from the analyses of discussion such as identified issues, gaps in research and insights that emerged are incorporated into the findings.

Findings from the basic data analyses

General publication trend

Figure 2 below documents the growth of publication since the first article was published in 2003.
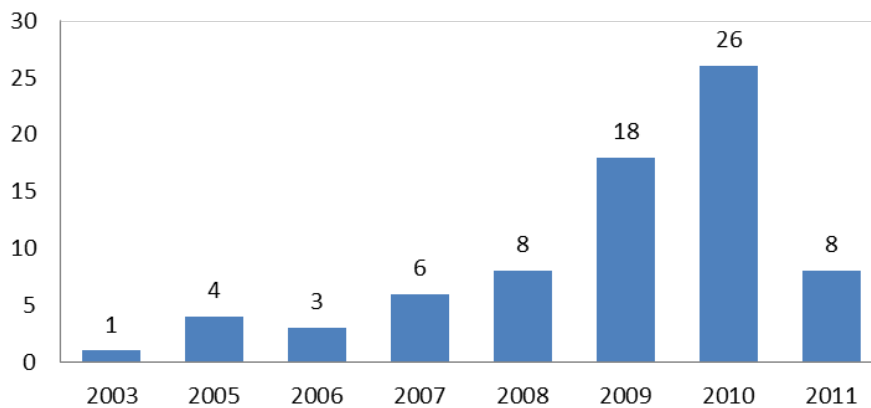
Figure 2. Growth of publication since 2003 to May 2011

The trend as reflected clearly indicates a growing interest in applying the framework. While at this point of time we cannot assess if the 2011 figure indicates a drop in publication in this area, we conjecture that the framework will continue to receive attention from educators. The integration of ICT into curriculum inevitably involves the three basic dimensions of TPACK, i.e., the TK, PK, and CK. It is difficult if not impossible to label a lesson as ICT integrated if any of the basic element is missing.

Site of Studies

In terms of the sites of study, most of the studies were conducted in the North America (65%, n = 49). The next region is from Europe and Mediterranean, accounting for 16.7% (Turkey, 4; Israel, 3; Cyprus, 2; Finland, Norway, Greece, Spain 1 each). The Asia Pacific region started to contribute to the literature in 2008 accounting for the rest (17.6%) of the contribution (Singapore, 5; Taiwan, 4; Australia, 3; Malaysia, 1). The figures suggest that many more studies can and perhaps should be carried out beyond the US. It is worth noting that theoretical papers have only been written by the US-based researchers. Researchers beyond US could perhaps contribute to theorizing the framework, based on the different cultural contexts and thus the experience in developing teachers for ICT integration. Currently, the TPACK framework is adopted in cross cultural context without questions.

Types of journals

To date, 44 journal titles published article employing the TPACK framework. Forty seven of the articles (64%) are published in educational technology journals (e.g., *Australasia Journal of Educational Technology, Computers & Education*). Eight articles (10.8%) are published in cross discipline journals (e.g., *Journal of Technology and Teacher Education, Journal of Science Education and Technology*). Seven articles (9.5%) are classified as published

in subject based journals (e.g., *English Education, Journal of Geography*) , 6 in general pedagogy journals (e.g., *Instructional Science*), 4 in teacher education journals (e.g., *Teaching and Teacher Education*), and one in general education magazine (*California Readers*). This distribution indicates that the TPACK framework is more readily accepted by education technologists rather than content specialists. It further implies the need for education technologists to further publicize the frameworks among content specialists.

Findings from the research method analyses

Out of the 74 papers, 55 are data driven research while the other 19 papers are non-data driven. The nineteen papers are classified as theoretical paper (9), worked example (9) and an editorial paper. To qualify as data driven papers, the papers need to have an explicitly method section that addresses data collection and data analyses. We report the non-data driven papers below before findings about the data driven papers are reported.

Theoretical papers

The nine theoretical papers reviewed uniformly argued for relevance of TPACK as a guiding framework for teachers' acquisition of knowledge for ICT integration (Cox & Graham, 2009; Hammond & Manfra, 2009b; Harris, Mishra, & Koehler, 2009; Kereluik, Mishra, & Koehler, 2011; Koehler & Mishra, 2005b; 2009; Pierson & Borthwick, 2010; Robin, 2008; Swenson, Young, McGrail, Rozema & Whitin, 2006). Cox and Graham's (2009) paper deals with precising definitions of the TPACK constructs. The other 8 papers discussed how TPACK framework can be used to guide educators' effort in dealing with the challenges on teaching and learning that are brought forth by rapidly changing technologies. For example, Harris et al. (2009) suggested helping social studies teachers by providing 42 forms of activity type that could integrate ICT to enhance instruction. Kereluik et al. (2011) points out that teaching is complex problem solving while Koehler and Mishra (2005b) highlights TPACK as repurposing technology through teachers' design effort.

In his review of the AACTE (2008) handbook, Hewitt (2008) suggested that there is a lack of critical perspectives among the authors who have contributed. Similar remarks may be also appropriate for these theoretical papers as none of them reflexively challenges the TPACK framework. Perhaps the gaps for further theorizing may be found in the comprehensiveness of the framework or the contextual influences bearing on teachers' TPACK (see later section).

Worked examples

Other than the theoretical papers, there are 9 papers classified as worked examples. These papers report schools or the researchers' effort in applying the TPACK framework to structure learning in institutional settings (Brush & Saye, 2009; de Olvieria, 2010, Guerrero, 2010; Kersaint, 2007; Lambert & Sanchez, 2007, Lee & Hollebrands, 2008) or creating resources and examples for ICT integration (Bull, Hammond & Ferster, 2008; Harris et al., 2010; Toth, 2009). The last non-empirical paper is an editorial paper written by Bull et al. (2007). They discussed ICT integration as "wicked problems" and the needs for further research on effective ICT integration to subsequently inform teachers and policy makers. In sum, the publication of these papers indicates that educators perceive strong needs for the sharing of resources, examples, best practices and further studies for ICT integration. In the following section, we dwell more into depth on the data driven research.

Data driven research

Based mainly on the explicit classification of the research methods reported by the authors, the 55 data driven papers can be classified into 3 types of research approaches (31 qualitative, 13 quantitative, and 11 mixed approach papers) and 7 categories of research methods. The research methods and the number of studies include artifact evaluation (2), software development (1), case study (10), intervention study (32), document analysis (1), survey study (4), and instrument validation (5). Table 2 below provides a summary of these studies.

Table 2. Summary of empirical research papers

References	Research method	Research approach	Theme of research
Oster-Levinz & Klieger, 2010; Valtonen, Kukkonen, & Wulff, 2006	Artifact evaluation	Qualitative	Online courses website evaluation
Wu, Chen, Wang, & Su (2008)	Software development	Mixed	Development of game-based environment for computer engineering course
Doering & Veletsianos, 2008; Hammond & Manfra, 2009a; Manfra & Hammond, 2008; Schul, 2010a; Schul, 2010b	Case study	Qualitative	Students' perception and practice of learning with technology
Almas & Krumsvik, 2008; An & Shin, 2010; Hofer & Swan, 2008			Teachers' perception and practice of teaching with ICT integration in classrooms
Wilson & Wright, 2010			Teachers' development (5 years) of TPACK from preservice to inservice stage
Khan, 2011		Mixed	University teachers and students' perception of the pedagogical use of simulation for learning chemistry
Allan, Erickson, Brookhouse, & Johnson, 2010; Angeli & Valanides, 2009; Doering, Veletsianos, Scharber, & Miller, 2009; Hardy, 2010a, 2010b; Koehler & Mishra, 2005; Mishra & Koehler, 2006; Özmantar, Akkoç, Bingölbali, Demir, & Ergene, 2010; Tee & Lee, 2011	Intervention studies	Mixed	Reports of courses designed to the improved teachers (pre-service, inservice, university faculty) TPACK.
Akkoç, 2011 ; Archambault, Wetzel, Foulger, & Williams, 2010; Bowers & Stephens, 2011; Groth, Spickler, Bergner & Bardzell, 2009; Haris & Hofer, 2011; Holmes, 2009; Jang, 2010; Jang & Chen, 2010; Koh & Divaharan, 2011; Lundeberg et al., (2003); Nicholas & Ng, 2010; Niess, 2005; Richardson, 2009; Shafer, 2008; So & Kim, 2009; Jimoyiannis, 2010		Qualitative	
Angeli & Valanides, 2005; Chai, Koh & Tsai, 2011a; Chai, Koh & Tsai, 2010; Graham et al., 2009; Koehler, Mishra & Yahya, 2007; Kramarski & Michalsky, 2010; Kramarski & Michalsky, 2009		Quantitative	
Lee & Tsai, 2010; Archambault, & Barnett, 2010; Koh, Chai & Tsai, 2010; Sahin, 2011; Schmidt et al., 2009	Instrument validation	Quantitative	Creation of survey to measure the various TPACK dimensions
Greenhow, Dexter & Hughes, 2008	Survey studies	Mixed	Survey of teachers' view and use of ICT with reference to TPACK constructs
Banas, 2010; Ozgun-Koca, 2009		Qualitative	
Jamieson-Proctor, Finger, & Albion, 2010		Quantitative	
Polly et al., 2010	Document analysis	Qualitative	Review of PT3 project reports and journal papers

Artifacts evaluation

Valtonen, Kukkonen, and Wulff (2006) evaluated 13 high school teachers created online courses for virtual high school employing the TPACK framework, with focus towards Jonassen, Peck and Wilson (1999) meaningful learning framework. The online activities were classified according to the five aspects of the meaningful learning framework (active authentic, intentional, constructive and cooperative), for example completing drill-and-practice as a form of active learning (which is disputable from our perspective). The evaluation essentially mapped out the various forms of TPK of the online activities. Frequency of subject matter (CK) that employs online activities were then computed to reflect the forms of TPACK that teachers adopted. Their analysis indicates that the courses foregrounded active learning over the rest of the dimensions, and the courses are teacher centric in nature with drill-and-practice and self-assess assignment as the predominant online activities. Oster-Levinz and Klieger (2010) also reported that they have created an instrument based on the TPACK framework for the evaluation of online tasks and it was used to evaluate 53 online tasks. The quality of the PK and PCK reflected in the designed online task was assessed with three point scales (high, medium, low). For example, choosing appropriate representations of the curricular is an indicator for assessing the PCK.

Efforts in developing of rubrics for assessing the quality of instruction according to the various TPACK constructs may be a meaningful area of study. It offers a comprehensive ways of evaluating designed ICT integrated lessons, thereby helping educators to identify weaknesses and strengthen course design.

Software development

The TPACK framework can be a powerful framework for software development but it has thus far been only reported once. Wu, Chen, Wang, and Su (2008) developed a role-playing game-based learning environment for undergraduate computer majors and map out the features of the environment in relation to the TPACK framework. They also identified the difficulties that they faced in the all seven TPACK constructs and identified possible solutions to address the problems. For example, based on literature review, they selected role playing as the appropriate pedagogy (PK) for learning of software engineering curriculum. They then identified the difficulties that they faced as articulating the details of professional skills involved for all the characters involved in the game, and they proposed to seek experts in the real world for help in this aspects. The designed environment was pilot tested with a group of 34 students and students' feedback affirmed the usefulness of the designed gaming environment.

Wu et al.'s (2008) work provides an example of how the TPACK framework can be employed for the development of content-based technological environment that addresses identified pedagogical challenges. Design, development and evaluation of learning environments is an important area if technology is going to contribute more to education and the TPACK framework should be further exploited in this important area. Well-designed educational environment based on the TPACK framework could reduce the effort teachers need to integrate ICT. Emerging technologies that have been advocated as pedagogically powerful include mobile technologies, multi-touch collaborative software, multi-users virtual environment etc. The TPACK framework could be employed to steer and enhance these learning environments.

Case studies of students and teachers' practices and perception

As shown in Table 2, there are 9 case studies reported to date. The themes of research cover mainly teachers' and students' perception and practice of teaching and learning given some forms of technological tools (e.g., movie makers) or environment (e.g., simulation or 1-1 laptop). These case studies were conducted in real world setting, thus providing the readers a sense of how TPACK are enacted and the perceptions of the teachers and learners. The five studies reporting students' perception contribute to educators' understanding of the effects of TPACK on students (Hammond & Manfra, 2009a; Khan, 2011; Manfra & Hammond, 2008; Schul, 2010a, 2010b). Hammond and Manfra interviewed students after they have completed their digital documentary making for history. They reported that students' prior conception of technology and their preferences influences their experiences. For example, some students viewed PrimaryAccess (the software for creating digital documentary) as not so useable and inflexible and some students disliked recording their own voices. In addition, the digital documentaries produced mimic authoritative sources of information such as the textbook and teachers' presentation, implicitly reflecting the

students' conception of learning history as reproducing accurate information. The study points to the importance of understanding students' perspectives.

When teachers are able to design TPACK integrated lesson, students learning could be enhanced. Khan (2011) reported that the students view simulation software (TCK) as effective in helping them to understand Chemistry after they went through 11 cycles of generate-evaluate-modify (a form of PCK instructed by the teacher) relationships between variables. Doering and Veletsianos (2008) also reported that students who learn Geography using geospatial technology and real time authentic data provided by scientist station in the Artic develop a better "sense of place." On the other hand, Schul (2010a; 2010b) utilize both the Cultural Historical Activity Theory (CHAT) and the TPACK framework to study how TPACK activities evolve over time and shape the students' learning practices. He asserts that the two studies show that students are developing empathy for history and are acting like historian. The approach of utilizing CHAT and TPACK can be expanded to study how teachers' TPACK shape the classroom activities and impact on other activity systems within the schools; and how such reciprocal interactions play out socio-historically over time.

Interestingly, except for Khan's (2011) study that was focused on undergraduate chemistry students, students' learning was investigated mainly by researchers in the field of social studies (history, geography). More investigations about students' learning in general and for specific content areas such as mathematics and language art are needed. Asian students' perception of learning with technology could be another area worth exploring. In addition, current investigations of students' learning are qualitative in nature. Quantitative research especially in terms of students' learning processes and achievements should be conducted.

With regards to the teachers' perception and practices about the use of ICT for teaching, Almas and Krumsvik's (2008) findings indicate that while the two teachers they observed and interviewed see ICT as integral to their work especially for administration, their teaching practices did not change much. ICT was used to support teacher lectures and students' homework. The teachers' TPACK is emerging but national examinations are still their key concerns. Manfra and Hammond (2008) studied how teachers' pedagogical aims influence their practices and students' learning practices as reflected in their final products. They reported that one of the teachers adopted traditional stance and the students' learning practice are closely aligned to reproductive learning. For the other teachers who are more constructivist oriented, the students exhibited more sense making and creativity in their work.

In other words, there is a need to distinguish TPACK that is teacher-centric or student-centric. These studies (Almas & Krumsvik, 2008; Khan, 2011; Manfra & Hammond, 2008) reveal that teachers' pedagogical beliefs, facilitation and technological skills are important factors that influence the enacted TPACK in classroom, which subsequently shape students' practice and perception. The teachers' pedagogical beliefs and skills can be classified as intra-mental factors while examination requirements, time constraints and technological environments can be seen as institutional and physical factors (see also An & Shin, 2010). The TPACK models may need to be expanded (see last section) in order to explain the types of ICT integration practices enacted in the classrooms. In addition, more studies on how teachers' belief shape their TPACK and classroom practices are needed to clarify the relationships between beliefs, knowledge and skills, and contextual affordances and constraints. Ethnographical research, which has not been employed to date, could provide important insights needed to unpack the complexities involved.

Intervention studies

There are 32 intervention studies that examine course effectiveness and these studies employ the TPACK framework to structure professional development programs for pre-service (17 studies), in-service (10 studies) and/or higher education teachers (5 studies). Among these studies, seven were classified by the respective authors as case studies. In addition, five were categorized as design-based research by the authors (Angeli & Valanides, 2005; Bowers & Stephens, 2011; Mishra & Koehler, 2006; Tee & Lee, 2011; Shafer, 2008). However, as the purpose of these studies was oriented toward course effectiveness; we believe it is clearer for them to be categorized as intervention studies. It is worth noting at this point that the in-service and higher education studies normally involved small number of participants (around 20) and therefore they employed mainly qualitative (12) or mixed methods (3). It seems desirable to have large scale quantitative study among in-service teachers. In addition, while preschool and other more specialized education teachers may also be using ICT, we did not find any study conducted for these teachers.

The design-based research involves iterative design of the learning environment which is informed by the implementation and analyses from authentic classroom context. It is intervention by nature but it does not treat the effects as summative (Angelia & Valanides, 2005). On the whole, they are rigorous and they provided strong evidences of the effectiveness of the TPACK framework. For example, Mishra and Koehler (2006) reported six case studies that allow them to iteratively design and study how graduate students (mostly inservice teachers) and faculties, who were involved in collaborative design of online courses or other technology-based learning environment, were able to deepen their understanding of technology, pedagogy and content and also the overlapping areas (i.e. TCK, TPK, PCK and TPACK). Their study affirmed the fruitfulness of the TPACK framework. Angeli and Valanides (2005) reported three cycles of intervention employing different pedagogical approaches (case-based learning and an instructional design model based on ICT-related PCK); to enhance teachers TPACK. The pre-service teachers were assessed based on their ability to identify a) topics to be taught with ICT; b) representation to transform content; c) teaching strategies and d) to infuse ICT activities in classroom teaching. The results showed that the ICT-related PCK model was superior.

Except for Lundeberg et al. (2003) who employed action research to help pre-service science teachers to learn about the use of simulation; and Doering et al. (2009) who trained 20 teachers through workshop on how to use the GeoThentic environment, all intervention studies required the teachers to plan or design lessons for ICT integration as an important part of the course. This approach has been generally referred to as learning by design (see Koehler & Mishra, 2005b; 2009). Lundeberg's study was conducted before the learning by design approach was publicized. The GeoThentic environment, on the other hand, is a well-designed 3D environment that could be used directly without much additional design effort from the teachers. Regardless of the approach for the intervention studies, 28 out of these 32 studies reported positive outcomes and while 4 reported mixed outcomes. Among the studies that reported positive outcomes, some also reported achieving good effect sizes (Chai et al., 2010; Chai et al., 2011a; Kramarski & Michalsky, 2010; Tee & Lee, 2011). Together, these studies which involve different research approaches provide firm foundation for the effectiveness of engaging teachers in learning by design, undergirded by the TPACK framework.

More recent intervention studies have identified additional factors and issues associated with facilitating teachers' development of TPACK. Kramarski and Michalsky (2009, 2010) highlighted the metacognitive demands of design work, specifically in terms of self-regulation. They therefore created question prompts supporting the various aspects of self-regulation. The studies conducted indicate that it is important to provide metacognitive support to pre-service teachers when they are tasked to design ICT lessons. Tee and Lee (2011), on the other hand, employed the SECI (Socialization, Externalization, Combination, Internalization) model to structure a master course to develop teachers' TPACK. The SECI model is based on the knowledge spiral framework (Nonaka & Takeuchi, 1995), which is a model of knowledge creation. In other words, Tee and Lee (2011) see TPACK development as a form of knowledge creation within the teachers' professional community. The SECI model points to the importance of community and the social dimensions of knowledge creation. Similar recognition and utilization of community's resources is also an implicit feature of a number of intervention studies (e.g. Chai et al., 2011a; Mishra & Koehler, 2006; Koehler et al., 2007). It seems that research in TPACK can be further expanded from the perspective of knowledge creation. Paavola, Lipponen, and Hakkarainen (2004) highlighted three models of knowledge creation, of which CHAT (see Schul, 2010a, b) and knowledge spiral have been employed in relation to TPACK research. Perhaps the knowledge building model could also be applied to enhance teachers' TPACK by helping teachers to build theories about ICT integration.

The four intervention studies which reported mixed results (Groth et al., 2009; Nicholas & Ng, 2010; Niess, 2005; So & Kim, 2009) point to other factors that need to be considered to facilitate deeper and wider integration of ICT in classrooms. For example, two out of five teachers from Niess (2005) study expressed doubts in the usefulness of technology in facilitating students' learning even though the yearlong program provided multiple opportunities and formal lessons on the use of ICT. So and Kim (2009) detected gaps between knowledge, beliefs and action related to ICT among Singaporean pre-service teachers. While the pre-service teachers demonstrate good understanding of problem-based pedagogy and have adequate ICT skills, they perceived difficulties in designing authentic and engaging problems and appropriate scaffolds for their subject matter. They also tend to think that using problem-based learning with ICT are too time consuming. With such perception, the teachers may not be willing to design and implement ICT-based problem-based pedagogy. Their study again reinforces our earlier suggestion about the importance of teachers' beliefs, competencies and context. In sum, enhancing teachers' TPACK is a necessary but insufficient condition for widespread pedagogical use of ICT. The intrapersonal factors such as teachers' beliefs and

their creative capacity in designing appropriate problems or scenarios need to be addressed. Institutional problems that surface in these studies include insufficient curriculum time, time for planning and examination constraints (Groth et al., 2009; Haris & Hofer, 2011; Nicholas & Ng, 2010). While the TPACK framework seems to provide some solutions, perhaps additional effort should be devoted in helping the teachers to deal with contextual constraints and addressing their beliefs.

Beside both intra-and-extra personal contextual that may need attention, the epistemic nature of learning by design also require further consideration. Engaging teachers in learning by design helps to move teachers away from traditional epistemology which is primarily concern with true/false values of knowledge claims. Learning by design promotes designerly ways of thinking (Cross, 2007), solving wicked problems through the criteria of satisficing. We argue that it is very important for teachers to be experienced in this form of thinking. Designing a new way of learning with technology is essentially a form of contextualized knowledge creation. It may open up teachers' perspective on what teaching and learning should be and what knowledge creation is about; beyond the view that creating knowledge refers exclusively to establishing truth claims. Equip with both traditional and design epistemology, teachers would be able to better engage students to learn with technology. How teachers' experience of "learning by design" changes their epistemological and/or pedagogical beliefs and practices in classroom could be the focus of future research. In addition, while current studies indicate engaging teachers in learning by design is fruitful, it may not be sufficient in providing evidence about the level of design expertise that teachers' acquire. What level of design expertise should teachers attain if they are to be able to continuously renew teaching practices as new pedagogical affordances emerge with new technologies? The intervention studies reviewed in this paper typically involve a single course in engaging teachers to learn by design. Such single pass approach may be insufficient. Weaving multiple courses to reinforce and strengthen teachers' design competencies is likely to be more fruitful.

Document analysis

There is only one document analysis that employed the TPACK framework. Polly et al. (2010) analyze 26 "Preparing Tomorrow teachers to teach with technology (PT3)" reports together with 10 journal articles published based on PT3. Their general conclusion support the foregoing section in that they also found that most intervention produced positive outcomes, especially for TK and pre-service teachers' willingness to use ICT. As illustrated by their work, the TPACK framework can be a common conceptual framework for many more review studies. For example, one can employ the TPACK framework to study how medical educators employ ICT for teaching and learning of pathology. In addition, we suggest that TPACK could also be used to analyze policy documents to examine whether there is a shift towards the use of overlapping constructs such as TPK, TCK and TPACK to formulate policies or standards, which could reflect a deeper understanding among policy makers.

Survey studies

To date, there are 4 survey studies that claim to employ the TPACK framework. Jamieson-Proctor et al. (2010) surveyed 345 Australian pre-service teachers with 2 scales (Learning with ICT, 20 items; Technological Knowledge 25 items). The findings indicate that while access to computers and Internet were very high, about 33% of the teachers indicate that they are not confident in using ICT in classroom. The survey also indicates low competence in web page development and multimedia authoring among pre-service teachers. Banas (2010) coded 225 reflective essays written by in-service teachers on their attitude towards technology. Only 13% of the teachers were facilitating students learning *with* technology. The majority of teachers were getting students to learn *from* technology. The necessity of enhancing teachers' TPACK knowledge for more adventurous learning seems obvious. Ozgun-Koca (2009) obtained open-ended survey responses and conducted group interview with 27 Turkish pre-service teachers with regards to the role of graphing calculator. While about 88% of the teachers indicated that using the graphing calculator save time, most teachers did not elaborate much on doing more interpretive work or building deeper conceptual understanding with the saved time. In addition, only one third of the pre-service teachers indicated using the graphing calculator as discovery tool. Greenhow et al. (2008) compare the differences between in-service and pre-service teachers' thinking about ICT integration problem elicited through online multimedia problem solving scenarios. As expected, in-service and pre-service teachers are different with regards to the process and the content of their instructional decision. The pre-service teachers are more superficial and uncritical as compared to their

counterparts. However, both groups lack consideration about the relative advantage/disadvantages between different options of ICT tools.

In sum, these studies point to the need of helping pre- and in-service teachers to build deeper understanding about TPACK, especially for constructivist-oriented student centered learning where technologies are employed to scaffold sense making. We would argue that more surveys that compare pre- and in-service teachers TPACK could be helpful in identifying the gaps in their TPACK and teacher educators can then plan how to support the continuous development of TPACK. In addition, survey studies of other educators beyond K-12 in higher education setting should be carried out to understand their notion of TPACK. This is especially so for the faculties in higher education as they are likely to be the most important people to help form the pre-service teachers' TPACK.

Instrument validation

Five studies have been written on the creation and validation of self-report surveys. The first reported 7-factors survey was created by Schmidt et al. (2009), assessing primary school teachers' TPACK in different subject areas. Schmidt et al. analyzed the 7 factors individually, perhaps because of the small sample size (N = 124). Sahin (2011) also created a 7 factors survey and analyzed the factors individually (N = 348). Both surveys reported good reliability coefficients. However, they cannot be considered as fully validated.

Lee and Tsai (2010) and Archambault and Barnett (2010) have both created surveys to measure teachers TPACK related constructs with reference to web-based environment. Archambault and Barnett created a 7 factors 24 items survey and obtained responses from 596 K-12 American teachers involved in online teaching. Factor analyses yielded a 3 factors instead of 7. The non-technology constructs (CK, PK and PCK) loaded as one factor, while 3 technology-related constructs (TPK, TCK, and TPCK) formed the other factor. Items from TK form the last factor.

Lee and Tsai (2010) created a 6 factors 30-items survey to study Taiwanese teachers' self-efficacy of web-based TPACK (N = 558). The 6 factors are web-general, web-communicative, web-pedagogical knowledge, web-content knowledge, web-pedagogical-content knowledge, and attitudes towards web-based instruction. They obtained five factors after factor analysis, with web-pedagogical-content knowledge and web-pedagogical knowledge and combined into one factor.

Similarly, Koh et al.'s (2010) attempt to factor analyzed the adapted Schmidt et al.'s (2009) survey among Singaporean preservice teachers (N = 1185) also faced problems. Exploratory factor analysis generated five factors labeled as TK, CK, Knowledge of teaching with technology (KTT), Knowledge of Pedagogy (KP), and knowledge from critical reflection (KCR). KTT comprises items from TCK, TPK and TPACK. KP comprises of items from PK and PCK. The three studies to date indicate that items belonging to technology-related factors tended to group together while non-technology related pedagogical items formed another group. They also indicate that teachers are not quite able to distinguish the 7 factors of TPACK.

It is obvious further work in designing valid instrument is necessary. This work would allow educators to understand and compare teachers' TPACK employing demographic variables such as teaching experience, content areas, gender etc. To this end, Chai, Koh and Tsai (2011b) have been able to design a survey and identify all seven factors through exploratory and confirmatory factor analyses for Singaporean pre-service teachers. The questionnaire they created were contextualized towards constructivist pedagogy (PK), and constructivist used of ICT. Further adaption of this survey or the creation of new surveys that are contextualized towards specific subject matter, pedagogy and technology is an important area for future research in TPACK. For example, survey can be created for problem-based learning (PK) supported by simulation (TK) for Earth Science (CK). Such specific instrument can allow the researchers to have more confidence in measuring the contextualized TPACK constructs and it may be easier to identify the 7 factors. They also provide more specific information for course design and evaluation.

Findings from content analysis

This study also analyzed the articles based on the three foundational dimensions of TPACK framework: The content, technology and pedagogy. As some papers do not make clear reference to technology, pedagogy and subject matter,

which make it impossible to see how TPACK or ICT integration is formed, papers that do not address any one of the three TPACK aspects are excluded in this part of analysis. In addition, the subject matter for pre/in-service teachers who are in courses that prepare them to use ICT are lumped under instructional technologies. Instructional technologies or educational technology is an established discipline and therefore should be treated as one. Based on these criteria, 54 studies were analyzed and the outcomes are provided below. Table 3 provides a summary of the content analysis.

Table 3. Content analyses of content, pedagogy and technology

Reference	Pedagogical Approach	Subject domain (number of studies)	Technology
Nicholas & Ng, 2010	Constructivist	Engineering (2)	Picaxe microchips programming
Wu, Chen, Wang, & Su (2008)			Game-based software engineering education system
Doering & Veletsianos, 2008		Geography (2)	Geospatial software
Doering, Veletsianos, Scharber, & Miller, 2009			Geothentic online system
Niess, 2005		Instructional Technology (17)	Multiple ICT tools
Kramarski & Michalsky, 2010			Hypermedia
Kramarski & Michalsky, 2009			Web-based learning environment
Koh & Divaharan, 2011;			IWB (IWB)
Kereluik, Mishra & Koehler, 2011; Mishra & Koehler, 2006; Chai et al., 2010, 2011a; So & Kim, 2009; Tee & Lee, 2011; Angeli & Valanides, 2005, 2009; Koehler et al., 2007; de Oliveria, 2010			Multiple ICT tools (e.g. Moodle, Office package, Wikipedia, Dreamweaver etc)
Archambault, Wetzel, Foulger, & Williams, 2010			web 2.0; social networking tools
Koehler & Mishra, 2005a, 2005b			Web-based learning environment, I-video
Lambert & Sanchez, 2007		Interdisciplinary (3): Language art and social studies	Multiple ICT tools, e-mail and video conferencing
Hofer & Swan, 2008		Interdisciplinary: History and language art	Digital documentary making (i.e. digital movie maker I-movie/ photostory)
Robin, 2008		Interdisciplinary: History, language, 21st century skills	Digital story telling
Hardy, 2010a; 2010b		Mathematics (12)	Tablet PC, Blackboard, PowerPoint presentation, Geo sketchpad, graphing, spreadsheet
Lee & Hollebrands, 2008			Video case of using students using ICT tools for learning Mathematics
Richardson, 2009			Virtual manipulative, graphing calculator, simulation software, GeoGebra.
Groth, Spickler, Bergner & Bardzell			graphing calculator
Holmes, 2009			IWB
Bowers & Stephens, 2011; Shafer, 2008			Geometer Sketchpad (GSP)

Kersiant, 2007			Graphing calculator; applets
Guerrero, 2010			GSP, Cabri Geometry etc
Özmantar, Akkoç, Bingölbali, Demir, & Ergene, 2010			Graphic calculus
Akkoç, 2011			Cabri Geometry and Geogebra
Jang & Chen, 2010		Science (8)	Multimedia authoring, presentation, social networking, collaboration, mapping, blog
Jimoyiannis, 2010			Simulation, modelling tools, spreadsheet, Web resources, Web 2, LMS, Webquest
Graham et al., 2009			Digital microscope, Google earth, GPS
Lundeberg, Bergland, Klyczek, & Hoffman (2003)			Simulation (Case It!), Web-based posters, conferencing tools
Khan, 2011; Toth, 2009			Simulation, virtual laboratory
Jang, 2010			IWB
Allan et al., 2010			EcoScienceWorks, Simulation and programmable simulation
Haris & Hofer, 2011		Social studies (9)	Multiple ICT tools
Schul, 2010a; 2010b		Social studies: history	Digital documentary making (photostory 3/ Imovie), online archives
Manfra & Hammond, 2008			Digital documentary making: PrimaryAccess
Brush & Saye, 2009			Multiple ICT tools, video case; Google earth overlay; blog, e-portfolio
Hammond & Manfra, 2009a			PrimaryAccess and/or PowerPoint presentation
Bull et al., 2008			Web 2.0 tool: PrimaryAccess, digitize historical artifacts, online movie with PrimaryAccess
Hammond & Manfra, 2009a; Harris et al., 2009	Mixed (Constructivist and traditional)	Social studies	Multiple ICT tools
Harris et al., 2010		Multiple subjects (1)	

The pedagogy employed or advocated

The first common theme that emerges from the analysis is that out of the 54 papers, 51 can be described as advocating or practicing generally constructivist-oriented pedagogy. Project-based or inquiry-based learning were common among qualitative case studies that investigate students' perception reported earlier. Earlier section has also reported that most intervention studies adopted the learning by design approach, which is also essentially constructivist in nature. The three papers that presented both constructivist and traditional strategies are theoretical papers or worked examples (Hammond & Manfra, 2009b; Harris et al., 2009; Harris et al., 2010). Given the common pedagogical approach, the TPK involved would also be constructivist oriented. The common TPK is characterized by emphasis on bringing in authentic problems through technological representation (simulated environment, raw data, video-cases, etc.); engaging students in active sense making with the aid of technology as cognitive tools in collaborative groups. The emphasis of constructivist-oriented learning with technology is not surprising as constructivism forms a strong theoretical foundation for the use of technology (see for example Jonassen et al., 1999).

The content knowledge

Table 3 depicts the distribution of subject matter that the 54 papers were focused on. Not surprisingly, the biggest share of the studies is devoted to instructional technology (31%). TPACK was originated by teacher educators and instructional technology is the main course to help teachers in the use of ICT for classroom teaching. Science, mathematics and engineering, which can be considered as hard disciplines, together account for 41% of the distribution. Soft disciplines such as geography and social studies (6 of which are about history) combined with interdisciplinary studies occupied about 28% of the distribution. The distribution seems to reinforce the opinion that the use of technology is more akin to the mathematics and science subjects. Surprisingly, no study is targeted exclusively towards language learning and also literature. Interdisciplinary project-based learning that crosses the hard/soft discipline also seems rare. In addition, the TPACK framework has also not been employed in many more specialized subject matters such as economy, visual arts, music, accounting etc. More studies in these content areas are desirable.

The technology involved in TPACK research

The technologies reported in TPACK research can be generally classified into two categories: subject general technology corresponding to the TK dimension; and subject-specific technology corresponding more toward TCK. There are 34 studies that employed subject general technologies which can be used for many content areas such as web-based environments, learning management system, office tools, hypermedia authoring and interactive whiteboard (IWB). The 17 studies classified under instructional technology typically involved more than one form of these general technologies except for Koh and Divaharan (2011) that focused on IWB. One study that involved multiple subject matters (Harris et al., 2010) and three interdisciplinary studies (Hofer & Swan, 2008; Lambert & Sanchez, 2007; Robin, 2008) also employ general technologies. Social studies (9) constitute the next content area that employs general technologies. Five studies in this group focus on digital documentary making involving tools like photo-story, i-movie etc. especially for the study of history. Other subject-based TPACK studies that employ general technology include mathematics (2); and science (2). While technologies created for general purpose could be adapted for teaching and learning, these forms of technologies are demanding on teachers' design capacity to repurpose the tools.

For subject-specific technologies (i.e., TCK), a total of 20 studies were reported covering four areas. There are 10 studies that employ TCK in mathematics (Akkoç, 2011; Bowers & Stephens, 2011; Groth et al, 2009; Guerrero, 2010; Hardy, 2010a, 2010b; Kersaint, 2007; Özmantar et al., 2010; Richardson, 2009; Shafer, 2008). The mathematics-based technologies include Geometer Sketch Pad, graphing calculators, Cabri Geometry, GeoGebra and applets for simulation. For science subjects, there are 6 studies that employed simulations (Allan et al., 2010; Jimoyiannis, 2010; Khan, 2011; Lundeberg et al., 2003, Toth, 2009) and specialized technology such as digital microscope (Graham et al., 2009). Four other uses of TCK were reported for engineering course (Nicholas & Ng, 2010; Wu et al., 2008) and Geography (Doering & Veletsianos, 2008; Doering et al., 2009). Bowers and Stephens (2011) have rightly pointed out that TCK was less researched for TPACK framework. The analyses also show that TCK is more employed for hard disciplines. Given that technology are very important for the advanced study of almost all subjects, teachers in K-12 settings should be using more specialized form of technology in the near future. It may also be that when TCK is involved in teaching, the research is published in specialized journals and the researchers may be subject matter experts who are not familiar with the TPACK framework. Reviewing the use of TCK in specialized field of study from the TPACK framework could be an important step forward for the inclusion of these technologies into K-12 education.

The possible pathways to foster TPACK

Within this study, we attempted to analyze the sequence in which educators draw upon the aspects of TPACK to foster teachers or students' ability to teach or learn with ICT. Twenty nine out of the 55 data driven papers provide sufficiently clear information for us to map out the sequences that the authors employed. Among the 29 papers, 17 described engaging the teachers or learners starting from the overlapping aspects of TPACK such as PCK (7 papers), TPACK (5), TCK (4) and TPK (1 paper). The other paper started describing the intervention with CK (5), PK (4) and TK (3). After the starting point, diverse approaches are taken. For example, Harris et al. (2010) advocate that

teachers begin with identifying activity types suitable for the learning of specific topics, which can be classified as PCK, and look for relevant technology to support the activity types. Jang (2010) describes beginning his intervention by discussing TPACK theories first, followed by identifying topics that traditional teaching were not effective (i.e., PCK) and understanding how IWB could help (TPK). Many PT3 projects (Polly et al., 2010) started with enhancing technological knowledge or providing technical skills training, follow up with discussion on how the technologies can be used in teaching and learning (TPK), transforming content into some digital forms of representation (TCK) and finally designing some projects for specific subject matter (TPACK). Two studies from Singapore (Chai et al., 2010; Chai et al., 2011a) started building pre-service teachers TPACK from pedagogical knowledge about the meaningful learning framework (see Jonassen et al., 2008); followed by how technology (TK/TCK) could enhance meaningful learning (TPK). The teachers then applied the knowledge to design a TPACK lesson for a specific topic (CK). Lastly, the two studies from Angeli and Valanides (2005; 2009) began by identifying topics (CK) for technology integration and proceed into the technology mapping processes where all constituents of the TPACK knowledge based are considered in a situated manner to transform the curriculum into TPACK units.

In short, there are diverse ways to employ the various aspects of TPACK to design ICT integrated lessons. Our analysis indicates that the sequence of drawing upon the TPACK aspects to finally build TPACK lessons are dependent on contextual factors such as the availability of technological solutions, the learners familiarity with the software and the instructors' pedagogical reasoning. As most studies yield positive results, it seems that sequence does not matter. However, interested researchers could perhaps conduct research to compare if different sequence of instruction drawing on different aspects of TPACK would result in different learning trajectories.

In addition, it seems to make sense to begin from one of the overlapping constructs such as PCK, which is the most common starting point, and proceed to other constructs. For example, Akkoç (2011) and Wu et al. (2008) both started by understanding students' difficulties in learning the subject matter (PCK) and seek technological representations (TCK) that could help to address students' problem. Doering and Veletsianos (2008) identified geospatial technology (TCK) and adopt appropriate constructivist-oriented pedagogy (PK) to enhance students' learning. Many simulation packages have the advantage of representing TCK and this make ICT integration less problematic. We would argue that the design of educational technologies that encompass all aspects of TPACK, i.e., TPACK ready, is essential in encouraging teachers to use ICT. While on the one hand it is essential to enhance teachers' competency to design TPACK lessons, it is unreasonable to expect teachers to spend much time on designing ICT integrated lesson.

Concluding remarks

The TPACK framework is a generative framework with many more possible future applications. In this paper, we have reviewed a sizable and representative set of studies and pointed out many possible directions for future research. Based on our review, we would propose a revised representation of the TPACK framework to guide future research as depicted in Figure 3 below.

Figure 3. The revised TPACK with TLCK framework
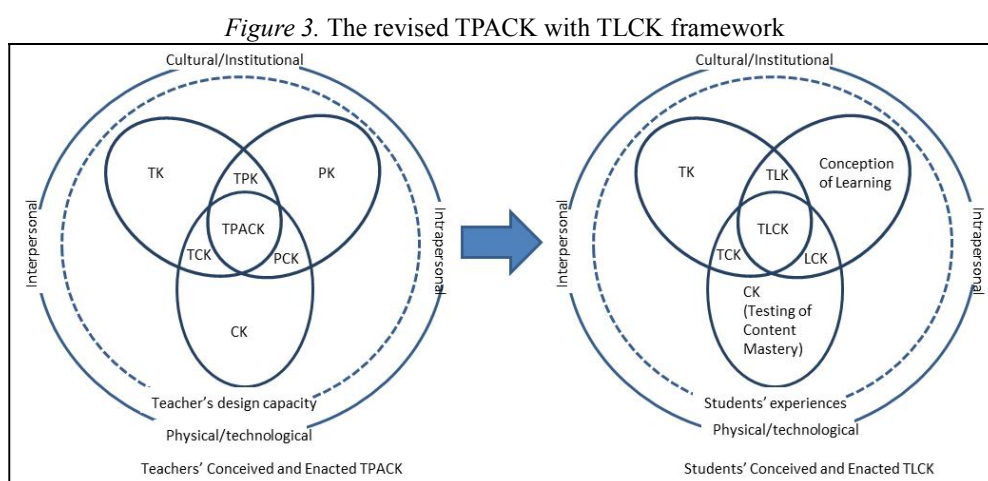
The first revision we have made to the original conception is to make explicit the contextual factors that would influence the TPACK integrated lessons designed by educators. TPACK are highly situated form of designed knowledge and many researchers employing the TPACK framework are acutely aware of the importance of context in shaping the manifestation of TPACK in classrooms (e.g., Doering et al., 2009; Pierson & Borthwick, 2010). The contextual factors are elaborated below.

Based on the literature reviewed, we identified four interdependent contextual factors that are to a certain extent distinctive. The intrapersonal dimension of context refers to the epistemological and pedagogical beliefs that teachers hold. These beliefs have been identified as influencing teachers' instructional decision (e.g., Tsai, 2007). In the context of creating TPACK lessons, teachers have to assume the epistemic agency and appropriate "design literacy", which characterized by flexibility and creativity (Kereluik et al., 2011). Most of the time, however, teachers are more acquainted with being the authority in the classrooms who deals with verified knowledge. The epistemic roles involved are at odd with each other. For the interpersonal dimension, Koehler et al. (2007) study indicates its importance especially in terms of collaborative design. Given that design work is best carried out in group, the interpersonal dimension should be carefully considered. Cultural/Institutional factors such as the prevalent view of seeing schools as places for cultural reproduction and the emphasis on paper-and-pencil tests and examinations can be daunting barriers that exert strong influence on if and how teachers use technology (Almas & Krumsvik, 2008; Groth et al., 2009). Lastly, the physical/technological provision in schools obviously influences teachers' decisions. Polly et al. (2010) highlighted that insufficient provision may cause beginning teachers to regress towards not using technology. If the provision for the use of technology is not ubiquitous and teachers have to make special arrangement to use technology such as bring students to computer laboratories, the additional effort is likely to deter teachers' willingness when there exist simpler solution.

From students' perspective, how students' conceptions of learning are related to the way they use technology to learn specific CK could provide a check on the effects of teachers' TPACK implementation. Conceptions of learning refer to how students perceive or interpret their learning experiences toward specific CK (e.g., science, mathematics) or in certain contexts such as technology-enhanced learning environments (Marton, Dall'Alba, & Beaty 1993; Tsai et al., 2011). These conceptions are found to guide students' approaches to learning and are associated with learning outcomes (Bliuc et al., 2010, 2011; Yang & Tsai, 2010). We believe the TPACK research can be further enhanced by investigating more refined constructs, such as the extension of the ideas about conceptions of learning. We suggest to investigate how students' notion of learning of particular content (LCK corresponding to PCK), learning with technology (TLK corresponding to TPK), and technological content knowledge could help to inform teachers about what can or should be done in the classrooms. For example, students may have good understandings or conceptualizations about how some game-based learning could enhance and impede their learning (TLK). Teachers can draw on such notion and facilitate students learning with technology. In addition, if students' LCK formed through prolonged exposure to certain pedagogical practices, for example learning for tests, they may resist new pedagogy such as that involving knowledge co-construction (see for example Hammond & Manfra, 2009a). Similar to framework of TPACK, the ideas of TLCK (Technological Learning Content Knowledge) are proposed in this review. For successful implementation of ICT in teaching practice, in addition to teachers' thorough understandings toward TPACK, it also requires students' awareness of TLCK-related constructs (such as more sophisticated conceptions of learning, TLK, LCK and TLCK), as illustrated in Figure 3. Understanding students' perceptions in these areas would help teachers and designers to design better lessons and programs. More importantly, students' academic achievement given the TPACK integrated lessons has not been reported by any of the study we reviewed. This is a clear gap that needs attention. In addition, survey studies about students' perception of learning with technology could also provide important information to help ministry and schools in planning education programs.

Finally, we would like to point out the possibility of cross fertilizing some older framework for the study of ICT integration with the TPACK framework. Established framework such as the technology acceptance model, concern-based adoption model and the three models of knowledge creation(i.e. SECI, expansive learning and knowledge-building) as reviewed by Paavola et al., (2004) could be brought to bear on TPACK. For instance, researchers can possibly envision the acceptance of certain emerging technology by analyzing its TPACK properties and the possible stages of concern that would follow when the technology is implemented. The SECI, expansive learning and knowledge-building approach can also be synthesized to inform teachers on how new TPACK integrated lessons can be designed. More studies that meaningfully merges complimentary framework could be a promising way forward.

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The Future of Learning Technology: Some Tentative Predictions

Nick Rushby
Editor, British Journal of Educational Technology, UK // nick.rushby@dsl.pipex.com

ABSTRACT
This paper is a snapshot of an evolving vision of what the future may hold for learning technology. It offers three personal visions of the future and raises many questions that need to be explored if learning technology is to realise its full potential.

Keywords
Future trends, History, Innovation, Technology life cycle, Visions

Introduction

Some twenty one years ago I quoted an old Chinese proverb that "Prophesy is dangerous—especially when it concerns the future" and noted that it was "not so very long ago that those who claimed to be able to see into the future were given a show trial and then burned at the stake" (Rushby, 1990). These days it is only the expert's reputation that is burned.

I am even more hesitant to make prophesies when I read Philip Tetlock's award winning research on expert political judgement (Tetlock, 2005) which concluded that the "experts" were only slightly better than straight chance in their predictions about the future. For those of you who do not know this work, Tetlock asked 284 experts to make 28,000 predictions. The experts were drawn from many different fields. They ranged from university professors to journalists and had widely different beliefs from Marxists to free-marketeers. The predictions were followed up over a twenty year period and were—on average—dismally inaccurate. Interestingly, the most inaccurate were those experts who were certain in their predictions: those who spoke in terms of probabilities did rather better.

The lesson we should take from this, is that the rest of this paper and the companion papers from other editors, should be treated with great caution. You may do better by rolling dice!

I should also add that the thoughts which are set out in this paper are a work in process. I set out to write what, in an abbreviated form, is the first part of the paper. In conversations with myself and with colleagues, I began to realise that the traditional vision (now Vision 1) was flawed. As you read on, I hope you will understand why.

First however, let me deal with the question of why a journal such as the British Journal of Educational Technology (BJET) needs to be interested in what the future may hold for learning technology. It is more than idle curiosity! Journals have a complex relationship with the future: They are trying to predict the future so that, from the papers that are submitted for publication, they can select those that are likely to be of interest to readers in the future, and conversely, by their choice of papers they shape what people read and thus influence the future direction of research in their field.

The past forty years

It happens that 2011 marks my 40th Anniversary in the learning technology business. My postgraduate research in 1971 was on the use of artificial intelligence techniques in computer assisted instruction. Contrary to current popular belief, the use of computers for learning was already well established and we had no doubt that CAI was going to revolutionise education and training.

Over the following years, artificial intelligence grew and diminished in importance. It continues to support some learning systems, but the promise of intelligent tutoring systems has never quite been realised on any significant scale.

Around 1977 the first personal computers appeared and it was clear that these were going to revolutionise education. The UK Government set a target of equipping every school with at least one microcomputer so that every child could access to the latest technology.

This in what now seems very quick succession, came interactive videodiscs, CDi, compact disks, artificial intelligence (again!), the WorldWideWeb and mobile communications and ever more capable hand-held devices (I have omitted a number of other technologies in the interests of time and space). Each attracted its own enthusiasts, research projects in the classroom and initial trials, and some limited use—and then (with the exception of the WorldWideWeb) was superseded by a new technology with new enthusiasts. Thus we had a succession of sparkling innovations, but only a marginal impact on education and training.

In 2007 a colleague and I carried out a review of learning technology projects carried out in the UK during the period 1980-2000, and mapped their findings onto the research agenda of the British Educational Comunications and Technology Agency (Becta). We found that almost all of the research questions that were being asked at that time had been answered, at least in part, by research carried out years before, but that those findings had never been examined by the current generation of researchers (Rushby & Seabrook, 2008). In large part this was because the reports pre-dated the internet. Contemporary practice is to use the internet as the primary source of research data and so the early projects were invisible. It is as if they had never happened. The consequence was that large amounts of funding were being used to rediscover what was already known.

In part, as educational technologists we have ourselves to blame. We focus too much on the technology and not enough on the learning. The problem is that we work in a field that is now dominated by information and communication technologies ICT) that are very charismatic. The product lifecycle of the latest handheld devices for example, is very short and the functionality is ever increasing. We tend to start by looking at the functionality and wondering what we can do with it, rather than focussing on the problems of learning. So, as new technologies emerge, a new generation of researchers starts to explore what they can do, projects emerge and then, after a short while, interest fades as an even newer technology emerges.

Key issues 2011

Each year, The British Journal of Educational Technology carries out a survey of the key issues in educational technology as perceived by a sample of learning technologists. This takes the form of a simple questionnaire asking respondents to select their five top issues from a list of about 40 alternatives. Some of these are technologies, others are techniques. The survey goes to the members of the BJET board and the reviewer panel, to those who have submitted papers to the Journal, and to several educational technology online fora, such as ITForum. The simplified results are shown in figure 1 overleaf.
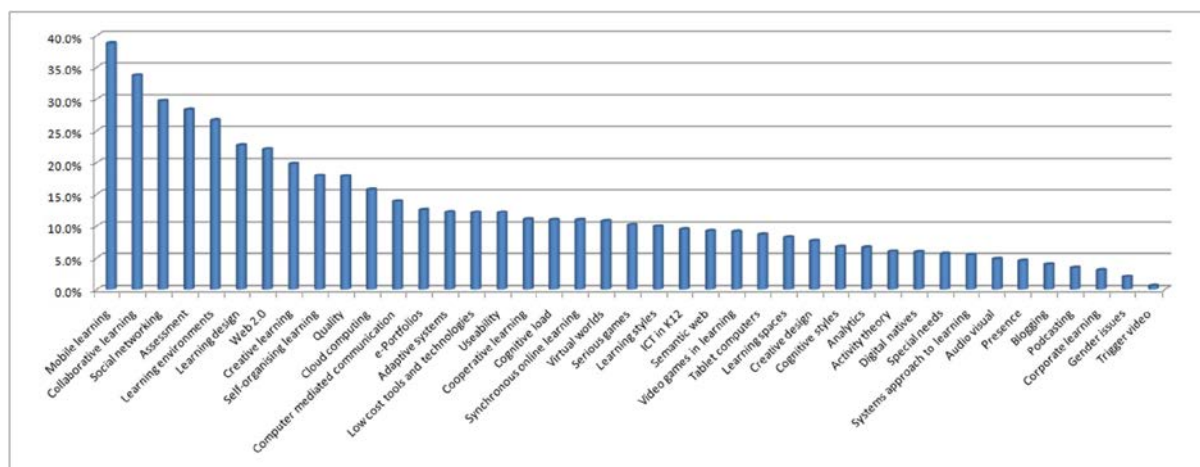
Figure 1. Key issues in educational technology – 2011 (n = 1139)

The top ten in the 2011 survey were (in descending order):
- Mobile learning
- Creative learning
- Social Networking.
- Assessment
- Learning environments
- Learning design
- Web 2.0
- Creative learning
- Self-organising learning and
- Quality

For comparison, the top six in 2010 (again in descending order) were (Rushby, 2010):
- Collaborative learning
- Web 2.0
- Learning design
- Mobile learning
- Social networking
- Assessment
- Learning environments
- Computer mediated communication
- Virtual worlds and
- Self-organising learning

We should take note that these are the topics which have been identified by this sample as the most important: They are not necessarily the topics that these same people are researching—or writing about!

So much effort - so little success

Do these key issues point the way to the future? Those who cannot remember the past are condemned to repeat it (Santayana, 1905). Given that I think we in learning the learning technology community are very bad at learning the lessons of history, one view of the future is that we shall be repeating the mistakes we have made in the past. History will repeat itself with new technologies. Even worse than an inability to learn the lessons, is the fact that we often do not even know the lessons. We have a strong tendency to ignore everything that has gone before in our excitement to get on with what we have now.

We now need to think very carefully about why it is that some much effort by so many enthusiastic people has led to such little real change. From within the educational technology community, reading the optimistic literature and talking to our friends at conferences, we seem to be on the brink of a breakthrough. The problems that prevent wide-spread adoption of ICT in education we have identified through our work will surely be overcome by the latest technology and we will move forward into a golden age in which education and training are transformed. The world will be a better place.

I suggest that we are deluding ourselves. It is easy to do so when we are gathered together in conferences such as this, where everyone is optimistically committed to new technologies in learning. We are among those who think like we do and this fosters our belief that everyone in education shares our view. But, with a few exceptions, technology has made little real impact on education. Our learners make extensive use of the new technologies—but less so for their formal education. The majority of exciting projects using handheld devices and mobile communications wither and die when their funding comes to an end. The greater part of formal learning continues to follow the traditional lecture-based model and is only slowly responding to the innovations of the past twenty years. Technology is neither the problem nor the answer.

We should look at the way in which innovations are taken up by the user community. Figure 2 illustrates the life cycle of a typical successful innovation. Initially the new idea or technology is used by a very few enthusiasts but, as

the news spreads, more early adopters come on board and the number of users grows. Then, more people get involved and finally the conservative late adopters take it up.
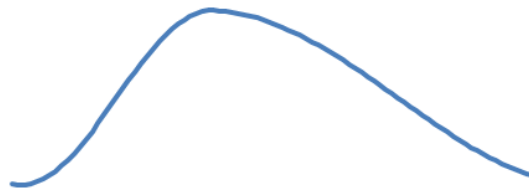
Figure 2. The innovation curve

As time passes the innovation is superseded by newer, perhaps better, ideas and its use gradually decreases. So we get a series of innovation curves as shown in figure 3.
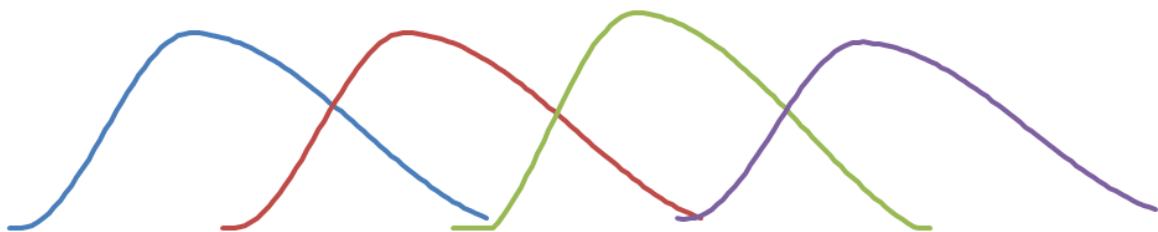
Figure 3. Successive innovations

However, this is an over-simplification of what happen in practice. Many innovations never make it past the involvement of the early adopters. Something prevents the majority of potential users from adopting the technology. In his book *Crossing the Chasm*, Geoffrey Moore (1991) suggests that there is a break point—the Chasm—dividing the early adopters from the cautious majority. The decision makers in that majority group are doing well in the existing system; they are, after all, senior figures who have prospered with the way things are, and there is little reasons for them to change.

This is particularly true in education which is, by its nature, conservative. One of the purposes of the education system is to guard society's culture and pass it on to the next generation.
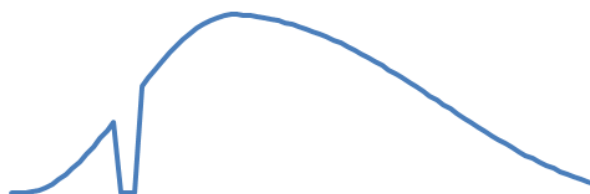
Figure 4. The Chasm

Before this cautious majority will adopt the innovation they look for other people like them to go first, to try it out, and report back on their success. But, given that they are all on the same side of the Chasm, it is difficult to get a critical mass of these decision makers who will endorse the innovation. Geoffrey Moore's book is concerned with the techniques that help innovators to cross the Chasm. Although it is written for the marketer and focussed mainly on commercial innovations, there is much of relevance to education and I commend it to you.

My first vision of the future is one that is technology led. As new technology becomes available, the researchers explore the new affordances, the early adopters trial it with their students and report the results of technology acceptance studies—but the overall impact on education and training is at the margins and the Chasm is not crossed. Most of the system continues as before with slow diffusion of the more cost-effective technologies. The exceptions may be in areas where there are pressing needs that cannot easily be met by conventional means. For example, the use of e-learning in the finance sector to deal with compliance legislation has resulted in companies in those sectors crossing the Chasm. In education, the political pressures to achieve higher student numbers and progression rates into higher education, coupled with a demand to reduced per capita resources are starting to result in ICT being used as a prosthetic to help teachers and administrators deal with an ever worsening situation. They are being forced to jump the Chasm.

The challenge and research direction for this first vision is focused on the technology: How rapidly will these technologies emerge and how can they be deployed in education and training. See for example, the New Media Consortium Horizon report (Johnson, Smith, Willis, Levine, and Haywood, 2011).

We need to be better at innovation

A recent paper by Xie, Sreenivasan, Korniss et al. (2011) uses computer modelling to show that a committed minority of around 10% is required to reverse the prevailing majority opinion. In terms of the context in which educational technologists work, that is a far larger minority than we currently have. It would mean that in given institution one in ten of the staff, randomly distributed through the institution, would be constantly advocating the use of ICT to their uncommitted colleagues and would be immune to any adverse influence that might cause them to lose their belief in the advantages of educational technology. Once that tipping point of 10% is reached, the model indicates that there is a dramatic decrease in the time taken for the entire population to become believers and to adopt the innovation. So we have to increase the size of the committed—evangelical—minority.

However, Selwyn argues for more pessimism in educational technology (Selwyn, 2011). He suggests that most people working in the field are "driven by an underlying belief that digital technologies are, in some way, capable of improving education" and that there is "a desire among most educational technologists to make education (and it follows, the world) a better place." I agree with his suggestion that this optimistic view of the potential of education and technology is not supported by reality. And that this "optimism and positivity has … served to limit the credibility and usefulness of educational technology within the wider social sciences." When those that we are trying to convince can see that there is only limited adoption of these technologies, it is difficult for us to maintain credibility. He quotes Dienstag (2006) that:

> "Pessimists do not deny the existence of 'progress' in certain areas – they do not deny that technologies have improved or that the powers of science have increased. Instead, they ask whether these improvements are inseparably related to a greater set of costs that often go unperceived. Or they ask whether these changes have really resulted in a fundamental melioration of the human condition."

I must confess that, in my earlier years, I have been guilty of unfounded optimism. My closest friends who have now gained the courage to tell me how they perceived me twenty or thirty years ago, report that I was quite insufferable in my unswerving belief that educational technology—or more specifically, ICT—would revolutionise education within a few year. All that was required was for everyone else to share my vision. Alas, they did not!

Perhaps it takes the perspective of a few decades to realise that educational technology is not a universal panacea and that uncritical euphoria is not the best way of converting the sceptics. Innovation is much more complicated, and takes much longer, than is immediately apparent.

In my second vision of the future, educational technologists have learned about innovation. They have amassed the evidence that will convince the cautious majority and have developed the social networking skills that enable them to pass the 10% tipping point. However, the education system as a whole is not transformed. With some exceptions, schools and universities look much as they have looked in the past although there is a growing emphasis on distance learning enabled by technology. The exceptions do not serve to prove the rule: rather they illustrate the distance that some institutions still have to travel. There is an emphasis on reducing the unit costs of learning so that education

budgets can cope with a larger number of students. Because ICT has become embedded in the mainstream as a means of doing the same things in a different way (in contrast to doing different things), there is a pronounced digital divide between learners in technology-rich and technology-impoverished environments.

The research focus is now on education and innovation. Research evidence is reported from a critical (pessimistic; realistic) perspective and this gives it the credibility that has been lacking in the past.

Transforming education

Personally, I find both of these visions unsatisfactory and depressing. More advanced technology and more of it. Is that all there is? It doesn't seem much of an ambition for the future!

In her book *Learning Futures*, Keri Facer (2011) supports the concern that the orthodox vision of the future is no longer robust and sustainable. It is no longer sufficient to have schools that are "future-proof"; we must look instead to 'future-building' schools. She argues that we need educational institutions that can:
- "help us to work out what intelligence and wisdom mean in an age of digital and cognitive augmentation;
- "teach us how to create, draw upon and steward collective knowledge resources;
- "build intergenerational solidarity in a time of unsettled relationships between generations;
- "help us to figure out how to deal with our new and dangerous knowledge;
- "act as midwives to sustainable economic practices that strengthen … local communities across the globe;
- "nurture the capacity for democracy and debate that will allow us to ensure that social and political justice are at the heart of the socio-technical futures we are building;

And can "act as pre-figurative spaces, as environments in which communities can model today how they might want to live with each other in the future" (Facer, 2011, pp. 102-103).

In Keri Facer's future the educational goal of qualifications and other traditional measures of academic success are inadequate if we are to discharge our duty of care towards our students. The role of educational technology as we currently envisage it, in helping learners towards those goals then becomes highly questionable.

Yet technology is both a driver and an enabler. It is the rapid advances in information and communication technologies that are driving these changes in society and making it imperative that we rethink the future of learning. And it is technology that will help us to realise the future-building school—in whatever form it evolves.

The reasonable man adapts himself to the world; the unreasonable one persists in trying to adapt the world to himself. Therefore all progress depends on the unreasonable man (George Bernard Shaw).

The third vision of the future of educational technology is one in where the technology and techniques that we have learned over the years are used to support a transformed education system (which may look like Keri Facer's future, or may take some other form). There is more capable technology, and there is more of it, but it is less obtrusive. Our focus will be on the evolving institution which will increasingly be an integral part of the community it serves. In this third vision, the grand challenge and research direction focuses on the sociology of education and of educational technology.

The approach of the reasonable educational technologist is to apply ICT to the educational system in an attempt to help colleagues make the best of the current, out-dated, system. What we need now are educational technologists who will work with those who are designing the schools of the future to make them fit for purpose.

Acknowledgements

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Bridging the Gap: Technology Trends and Use of Technology in Schools

Cher Ping Lim[1*], Yong Zhao[2], Jo Tondeur[3], Ching Sing Chai[4] and Chin-Chung Tsai[5]

[1]Curriculum and Instruction Department, The Hong Kong Institute of Education, Hong Kong S. A. R, China // [2]College of Education, University of Oregon, United States // [3]Department of Educational Studies, Ghent University, Belgium // [4]Instructional Science Academic Group, National Institute of Education, Singapore // [5] Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taiwan // clim@ied.edu.hk
*Corresponding Author

ABSTRACT

Considerable investment has been made to bring technology to schools and these investments have indeed resulted in many "success stories." However there are two significant gaps in educational uses of technology that must be addressed. The first is a usage gap. Compared to how and how much today's students use technology outside school, in-school technology usage is much less intensive and extensive. The second is an outcome gap. Compared with the outcomes achieved through investment in technology in sectors outside education, the gains in terms reduced costs and increased productivity achieved by schools is significantly smaller. This article discusses the causes of these two gaps and provides suggestions for bridging them by engaging in discussions about effective teaching and committing to technology planning.

Keywords

Educational uses of technology, Usage gap, Outcome gap, Effective teaching, Technology planning

Introduction

The technology investment in schools worldwide has increased more than a hundredfold in the last two decades. Much of this investment has been made based on the assumption that technology-mediated learning environments provide opportunities for students to search for and analyse information, solve problems, communicate and collaborate, hence equipping them with a set of competencies to be competitive in the 21st century marketplace. However, the history of the use of technology in schools has suggested that educators would abandon technology that does not fit the social organization of schooling (Cuban, 2005; Lim, 2007; Zhao & Frank, 2003). In 1922, Thomas Edison predicted that television would largely replace textbooks. In 1932, Benjamin Darrow suggested that radio would challenge the role of teachers and textbooks (Darrow, 1932). In 1984, Seymour Papert forecasted that computer would emerge as the key instructional tool (Papert, 1984). After a little less than a century, schools are still largely reliant on teachers and textbooks.

It is not the intention of this paper to argue that technology has no role in the existing school system or that technology investment in schools is a waste of money. There have been many "success stories" to show that when used properly, technology does lead to enhanced teaching and learning outcomes. In the Second Information Technology in Education Study (Law, Pelgrum, & Plomp, 2008) that involved 28 countries in Africa, Asia, Europe, North America and South America, researchers have shown that technology has been changing classroom practices and learning processes. These transformations include a shift in the role of the teacher from being the sole source of information to a more complex role of negotiating lesson objectives with students, providing a varying degree of support for different students, monitoring students' progress, and encouraging reflection on classroom activities. Students have also taken on a more active role in their own learning process by using technology to search for and collate information, and publish and share their findings. They are now more engaged and are able to make better connections between their previous learning experiences and the new concepts or principles being taught (see e.g., Kozma, 2003). A recent second-order meta-analysis has also revealed low to moderate effect size (around 0.3) of technology on students' achievement (Tamim, Bernard, Borokhovski, Abrami & Schmid, 2011). However, these "success stories" are not a widespread phenomenon in schools (Selwyn, 2008). Unlike hardware, connectivity, and software, the practices and their sociocultural contexts that have led to these positive teaching and learning outcomes have had a difficult time being sustained and spread across classrooms and schools to lead to the promised transformation in schools (OECD, 2010).

Although technologies have not transformed schools in a scale as some might have expected, they have led to irreversible changes in how we work, live, communicate and play. They have led to the development of new

industries, new laws, and new areas of research. Google, Microsoft, Apple, eBay, Amazon, World of Warcraft and Facebook are just a few examples of the magnitude of the importance of these technologies. This paper first aims to examine the gap between technology trends and the use of technology in schools, and then explore alternatives of how this gap may be addressed to transform the teaching and learning processes in schools. The emphasis of the discussion is not on the use of technology per se, but rather on how technology may serve as a foundation and mediator for the transformation of practices in schools. Such transformation is becoming especially urgent given that the activities our students engage in their everyday lives have become distinctly disassociated from the teaching and learning activities in their schools. When this happens, students may find classroom activities meaningless and become disengaged in school.

Modern technology and the way we work, live, and play

Modern technology is not only, as traditionally conceived, a new tool that we use to enhance our lives in the physical world, but has created a whole new digital world. In this new world, we use different technologies to seek and provide resources and information, express ourselves, communicate with others, create, consume, and play, often assuming new and multiple identities. The scope of the digital world is comparable to that of the physical world; from online gaming and online dating to e-learning and e-business. At the same time, the size of the involvement in the digital world is phenomenal and its growth dramatic. There were about 800 million Internet users around the world in 2004. This number had increased to about 1.97 billion as of June 2010 ("Internet," 2011), which is about 28.7% of the total world population.

Work and productivity

Studies have shown the ability of technology in improving productivity saving costs in sectors outside education. For example, a study conducted in 2002 found that the Internet "has already yielded current, cumulative cost savings of US$155.2 billion to U.S. organizations that have adopted Internet business solutions. In addition, these organizations indicate that their Internet business solutions have also helped to increase revenues cumulatively to approximately US$444 billion" (Varian, Litan, Elder, & Shutter, 2002, p. 5). The same study projected that these organizations would realize more than US$0.5 trillion in cost savings once all Internet business solutions are fully implemented by 2010 and "the Net Impact of these cumulative cost savings is expected to account for .43 percentage points of the future increase in the annual U.S. productivity growth rate" (Varian et al., 2002, p. 6). A more recent study of the impact of the Internet focused on the public sector. This 2004 study found that public sector organizations adopting the best identified practices in using the Internet could experience 45% improvement in efficiency, 40% in service volume, 25% in financials, and 55% in citizen satisfaction (Brown, Elder & Koenig, 2004).

Although modern technology may have contributed to business performance, economic growth and customer satisfaction, complementary innovations such as changes in work practices (increased lateral communication and teamwork, empowerment of employees, and revision of processes and workflow) and changes in aspects of products (convenience, quality and variety) have also contributed significantly to these improvements. Most investments in modern technology are usually complemented by organizational investments and the product and service innovation associated with it. When there is no or a lack of organizational changes being made in conjunction with technology investment, there may be significant productivity losses as the benefits from the technology investment may be outweighed by the negative interactions with existing organizational practices (Brynjolfsson & Hitt, 2000). Therefore, the effectiveness and use of these technologies depend on the people, processes, culture and structure of the context in which they are situated.

Live and play

Many people are spending their physical world time living a second or third life in the digital world. A recent study on massively multiplayer online games (MMPOG) found that the current global player populations of three popular game titles (Lineage I, Lineage II, and World of Warcraft) totaled over 9.5 million, which is about the combined total population of New Zealand and Singapore. These games are so compelling because they critique contemporary culture by allowing players to bend or temporarily dismiss social rules in order to try out new ideas and identities

(Steinkuehler, 2006). At the same time, an increasing number of people are merging their physical world life with their virtual one through mobile technology and dynamic websites such as blogs, discussion forums, personal websites, and social networking websites such as MySpace and Facebook.

The digital world is also beginning to penetrate the physical world, as more and more activities are consigned to and performed by means of digital resources. We learn, work, entertain, and stay connected with family, colleagues and friends in a world mediated by technology that has become an essential part of our daily lives. People are seeking real world information from the digital world, as they move away from traditional media such as TV and daily newspapers towards emerging media such as niche news channels and podcasts (Haller, 2005). In fact, traditional media has become increasingly intertwined with emerging media with one complementing the other. For example, in most of the Idols' series around the world (American Idol being the pioneer), they are being screened live on TV but supplemented by the official websites with video and audio links, the "wanna-be" websites, personal blogs of idols and fans, and also by mobile phones from which the short message system (SMS) originated. There is no doubt that in the future our world will be further digitized.

Modern technology and schools

In stark contrast to the great cost savings and improved business performances in other industries, schools may not have reaped as much benefit from the use of modern technology. The practices in many schools around the world have remained very much constant as classroom activities continue to be focused on standards, grades, and outcome measures. Not many schools have become more efficient, that is, operating with less cost, or more effective, that is, enhancing learning outcomes. On the contrary, modern technology may have increased the costs and pressure of running schools in a number of ways. First, in addition to the initial investment in putting technology into schools and wiring them to the Internet, schools have to constantly spend on maintenance and updating the hardware and software. Thanks to the rapidly evolving nature of technology, schools have to not only upgrade software, but also buy new hardware almost every three to five years just in order to keep the same level of access, just as the Red Queen tells Alice in Lewis Carroll's *Through the Looking Glass*: "it takes all the running you can do, to keep in the same place".

Second, schools are under pressure from the media, the public at large and from policymakers to ensure that technology is used for teaching and learning, and that students' learning outcomes are enhanced from the considerable magnitude of investment in technology. Given that a great part of these costs is financed by taxpayers' money, policymakers have the responsibility of ensuring significant returns of investments on technology in schools, hence demonstrating evidence-based policymaking. Some recent studies indicate notable positive outcomes. For example, Harrison and colleagues (2004) in England have statistically significant findings that positively associate higher levels of technology use and school achievement at different key stages in schools. A more recent study by the British Educational and Communications Technology agency, Personalising Learning with Technology, supported these findings but highlighted the challenges of isolating technology among many other factors that might affect school achievement (Becta, 2007).

There are indeed methodological constraints of demanding a high degree of validity and emphasising statistically significant correlations between use of technology and school achievement. Tamim and colleagues' (2011) meta-analyses also supported that learning aided by technology can have positive effects. However, many researchers have pointed out that the use of technology is peripheral to classroom instruction (see Arbelaiz & Gorospe, 2009; Selwyn, 2008; Greenhow, Robelia, & Hughes, 2009). This leaves one questioning the return of investment of technology (or rather, the lack of) after billions of dollars have been spent equipping schools with infrastructure, hardware and software, and training teachers and school leaders in the use of technology. At the same time, with increasing globalization, policymakers are under the pressure to measure these returns based on international benchmarks of school achievement. However, the huge differences between education systems make international comparisons and benchmarking almost impossible.

Lastly, schools are also under pressure to deal with the undesirable uses of modern technology by students. Technology enhances access and processes, and mediates the storage of information and communication with others without differentiating their quality. Thus schools have been drawn into numerous legal, ethical, and ideological battles over the uses and misuses of modern technology. More importantly, they must address the potentially harmful

or distractive effects of technology such as hacking, computer viruses, and cyber bullying. The concern over misuses of the Internet and the potential harm it may bring to students is so grave that many schools have taken an overly cautious approach by limiting access to websites and completely blocking other forms of online activities, especially synchronous communication (e.g., chat) and publishing on the Web (e.g., blogging and access to social networking websites).

These increasing costs and pressure of running schools may take a toll on the way technology is (not) being used for teaching and learning in schools. Like any ecosystem, a school as an organization has the tendency or ability to maintain internal equilibrium. The introduction of new innovations, intentional or unintentional, affects this equilibrium to varying degrees. Using the metaphor of schools as ecological systems, the next section examines why schools have not fully taken up the opportunities of technological innovations for teaching and learning (Zhao & Frank, 2003).

Nature of technological innovations and schools as ecological systems

Almost all technology policies and decisions are about change and often require specific changes in schools, such as reengineering the system and revising learning standards. In addition, technology is universally viewed as a change agent that can catalyze various changes in learning, teaching, and the learning environment. These changes have significant impacts on the organization. For example, a new technology project often requires the installation of new facilities, modification of existing policies or establishment of new policies and regulations, relocation of resources, changes in the informal and formal activities, and may also affect the social relationships of different groups of people (Nardi & O'Day, 1999). In this way, technology innovations introduced to schools are essentially invaders from outside. Whether they can be successfully adopted and become permanently established depends on their compatibility with the teaching and learning environment and the co-adaptation between the technology and the school as an ecological system (Zhao & Frank, 2003).

The school system as an ecosystem consists of diverse components and various relationships that promote or hinder the growth of young organisms within the ecosystem. In the complex sociocultural environment of the school, various groups and processes are closely connected with each other both within and outside the school, and form a network of changes. Similarly, these groups, processes and networks promote or hinder the learning of students within the school. The school is dependent on the other larger ecological systems (for example, the education system and society) within which it is embedded; a change of culture in the broader context, a switch of institutional setting, or an introduction of an innovation is likely to change the learning outcomes of the students. The contexts at different levels may change over time, but they are always interdependent of one another (Lim, Tay & Hedberg, 2011).

Technology as an innovation introduced into schools is not independent and isolated; it is situated in the ecological system of the school and connected to its broader systems. A newly introduced innovation often requires simultaneous innovations in pedagogy, curriculum, assessment, and school organization (Dede, 1998). It also affects the relationships within and outside the school, and the ongoing interaction catalyzes changes in social relationships. Similarly, changes caused by the interactions between an innovation and the school system not only determine how the innovation is adopted, but also affect the operation of the school system. Therefore, the dynamic co-adaptation and co-evolution of students, teachers and school leaders with technology and the system determines whether the opportunities of technology for teaching and learning can be realized in schools (Zhao & Frank, 2003).

The gap between the technology trends and use of technology in schools

The healthy co-adaptation of technology and the school system is influenced and constrained by many conditions. These conditions may be related to school technology resources, school culture, readiness and experiences of teachers and students regarding using technology, and the dynamics of the social interactions in the school system (Byrom & Bingham, 2001; Zhao, Kevin, Stephen, & Byers, 2002).These conditions are interdependent of one another, and their impact on technology implementation is beyond a simple and linear one. On the contrary, they are entangled with each other, their influence varies from case to case, their interactions and relationships change as the school environment evolves with the technology implementation, and the changes are situated in local contexts (Zhao & Frank, 2003). The school context gradually evolves, changing the characteristics of teachers, students, and

their technology uses, which further changes the challenges the school faces at different stages. Since technology use in schools constantly changes along with all of the other elements of the ecosystem - the users, the school system, and the relationships between these subsystems - there is no "once and for all" solution to technology implementation in schools. A technology implementation plan that works at one time may not work at another, so a dynamic plan that reflects changes will work better than a static plan (Tondeur, Van Keer, van Braak, & Valcke, 2008).

Even if a technology project has been successful, to continue its successful implementation, new policies need to be made, more money needs to be spent on upgrading software and updating hardware, more appropriate help needs to be provided to both teachers and students, and more investment needs to be put into sustaining and improving sufficient technical support—while all these changes depend on strong leadership. So it is important to provide ongoing technology planning and evaluation, to continuously revise and refine current practices, and provide timely support (Tondeur, Van Keer, Van Braak, & Valcke, 2008).

However, even if all the necessary conditions are in place, it is still difficult to judge the success of technology implementation because there is still a lack of specific goals or models to emulate. Although researchers have repeatedly suggested that successful policy implementation requires clearly defined goals directly connected to student learning (e.g., Fullan, 2001), no specific educational goals are defined in educational technology policy documents except for tangible intermediary goals such as amount of hardware, student- computer ratios, and connectivity rates. In a paper that reviews educational technology policy over the last 20 years, Culp, Honey and Mandinach (2005) identify six major goals/recommendations that have remained highly consistent over time, but none of them are about the educational outcomes of technology investment.

Although specific quantitative data (such as numbers, percentiles, and test scores) are commonly used in policy documents to demonstrate the current "crisis" in education and to justify the need for technology, no quantitative goals or outcomes are specified. Even if student outcomes are mentioned, it is done using vague and unmeasured terms. A convenient criterion for measuring student outcomes is student academic achievement. However, it is very difficult to establish causal relationships between technology use and student academic achievement, because student achievement is influenced by many factors. The impact of technology use on student outcomes is not determined merely by the particular technology uses, but rather is mediated by environmental factors, the users, and the constantly changing interactions and mutual influences. In addition, the use of technology in schools is part of a complex network, and changes in classroom technologies correlate to changes in other educational factors (OECD, 2010). Thus it is unrealistic to assume simple cause-effect relationships or to expect dramatic changes in student performance through one or two specific technology projects. Consequently, schools can only guess what is expected from their technology investment.

Most school leaders do not have a clear sense of how to evaluate effective use of technology (Russell, Bebell, O'Dwyer & O'Connor, 2003), and teachers do not know much about their schools' vision for the use of technology in their classrooms (Russell & Higgins, 2003; Tondeur et al., 2008). Due to the lack of sound understanding of the specific goals of technology integration, the use of technology per se may have become the goal in many cases. Schools, as well as educational technology research, often turn to how much time students spend using technology and what technology is available as indicators of successful technology integration, but do not measure whether or not, or how, technology is being used in meaningful ways in teaching and learning (Lei & Zhao 2007).

Bridging the gap

Defining effective teaching

There is no clear indication or widely used measurement of effective teaching. Although some research studies have attempted to use students' academic performance outcomes as a significant indicator of the effectiveness of teaching, these studies have been controversial and open to debate. It is controversial because it is seen as a vehicle to promote an education system that has been creating inequalities of social and intellectual capital. It is open to debate because effective teaching is one of the many variables that may affect students' academic performance, and there is no agreed-upon definition of effective teaching (Campbell, Kyriakides, Muijs, & Robinson, 2004). This is especially pertinent in the discussion of the use of technology and how it may enhance the effectiveness of teaching.

This may be further complicated by other terms such as school effectiveness, school improvement and teaching quality. Campbell and colleagues (2003) review the research on teacher effectiveness and identify three problems associated with the current concepts of teacher effectiveness. The first problem is the conceptualization of teacher effectiveness itself. The second problem is the relationship between school effectiveness and teaching effectiveness. There could be effective teachers in ineffective schools and ineffective teachers in effective schools, and therefore the relationship between school and teacher effectiveness is becoming problematic. We need to consider that the effectiveness of the school may help teachers to do a better job and thus teaching becomes more effective. For example if the school provides a conducive learning environment and a good technology infrastructure, is there a likelihood that teachers can try out new approaches that would engage students in the subjects they are teaching.

The third problem with the teaching effectiveness research is that while the research is analytical and lists the characteristics of effective teaching, it fails to inform teachers how to move from ineffective to effective practice. According to these studies, the narrowness of the operational definition is also causing problems; the definition should not be limited to the cognitive aspect only, but should include other aspects such as affective and moral values. Campbell and colleagues (2003) also pointed out that current teacher effectiveness studies tend to provide a set of characteristics that measure the teacher behavior, knowledge and beliefs, without considering the context and the levels at which they are teaching.

Shao, Anderson and Newsome (2007) reported the views of faculty members in their study regarding teaching effectiveness indicators. The respondents were asked to rate the importance of twenty general items that are commonly used to evaluate teaching effectiveness. They found that student evaluation scores, student written comments and teaching awards ranked highest, and that use of technology was not ranked at the top. From the literature review, it is noted that many instruments developed to measure the teaching effectiveness dimensions are diverse and inconclusive. Burdsal and Harrison (2008) propose that a multidimensional profile should be used to provide evidence for the overall evaluation of teaching effectiveness.

While the debate is still going on regarding the operational definition of teaching effectiveness, another set of questions is asked about the relationship between the use of technology and educational quality. Johannessen (2009) observes that we are increasingly using technology in all facets of our lives and we need to look at the question of whether the use of technology improves students' performance. He urges carefully selecting the indicators related to the use of technology that reflect the integration of new applications. School systems have been putting financial resources into technological infrastructure, and he suggests developing a knowledge base in search of evidence of the effective use of technology. It is becoming clear that providing technology to schools or teachers will not necessarily make a difference. But the way technology is used by teachers and students may make a difference.

ICT planning

Another cause of the mismatch between technology trends and the use of technology in schools is the lack of technology planning. In a technology policy plan, a school describes its expectations, goals, content and actions concerning the integration of ICT in education (Vanderline, van Braak & Tondeur, 2010). This includes elements such as vision building, professional development, and evaluation. While schools have been procuring hi-tech equipment with the aim of introducing the latest technologies in teaching and learning, the results are not clearly visible either in terms of acceptance by the teachers or in students' learning outcomes. Gulbahar (2007) notes that technology integration is a complex process and a demanding task for teachers and school administrators. In her study, she found that even teachers and administrators who felt themselves competent in using ICT reported that there was a lack of guidelines that would lead them to successful integration. Tondeur and colleagues (2008) confirm the importance of technology planning in schools. They found in the survey that ICT planned together with ICT support and ICT training has a significant effect on classroom use of ICT. They have also pointed out that school policies (in relation to ICT) are underdeveloped and underutilized. The results lead us to believe that a shared and school-wide vision of ICT is needed to succeed in technology integration.

Anderson (1999) noted that technology planning is a process of developing, revising and implementing technology plans in order to guide organizations to achieve their goals. A technology plan also describes the learning objectives, how the technology will be used and how it will be evaluated. According to Fishman and Zhang (2003), technology plans are the interface between research and development in learning technologies and their actual use in schools.

They present four characteristics of successful planning for technology. The first to be considered is using the technology plan as a policy document. A technology plan is usually devised at different levels of administration. At the highest level, such a plan can be considered as a blueprint for all stakeholders including educational planners, mid-level supervisors, and school level administrators. Secondly, this policy document would trickle down to teachers at the classroom level. A technology plan then exists at multiple levels and has multiple purposes.

Thirdly, a technology plan is never static. As technology changes rapidly, the plan to use technology also needs to be flexible and adapt to the circumstances. Fishman and Zhang (2003) note that a common error made by schools that have developed a technology plan is the assumption that the planning document is the end of the process. The evolving nature of technology requires constant adjustment to and revisiting of the plan. Such adjustment and revisiting not only allow teachers to make a better alignment with new technologies, but also help to adjust the changing learning environment and social context. The fourth characteristic is that any successful technology plan requires commitment, support and collaboration at different levels. It is important to establish a relationship with schools and outside organizations such as teacher training institutions and the corporate sector. Much needed help can be gained by having close connections with these organizations.

Implications and conclusion

The speed with which the revolution of technology has taken place is phenomenal. As stated before, teachers in many countries of the world are working with 'digital natives' who are growing up with technology as a non-remarkable feature of their world, in the same way as an earlier generation took radio or television for granted. Within these developments, technology brings a new set of challenges and pressures for educational institutions. Many teachers, schools, educational authorities and researchers are considering a range of questions about how to use technology within classroom practices: What educational goals and learning objectives will be accomplished by using technology in schools? Is there a need for a specific course in digital literacy? How can technology be integrated effectively in existing subjects? Many of these questions are still unanswered, and attempts to address them have generated widespread debates.

Clearly, effectively integrating technology into learning systems is much more complicated than for example providing computers and securing a connection to the Internet. Computers are only a tool; no technology can fix an undeveloped educational philosophy or compensate for inadequate practices (Ertmer, 2005). Therefore, choices have to be made in terms of educational objectives (Sugar, Crawley, & Fine 2004). In this respect, the process of technology integration is a dynamic one involving interacting factors over time (Tondeur et al., 2008). Moreover, no single solution exists to address the immense challenges of technology integration because different perspectives of integrating technology can be chosen.

Several studies have pointed at the critical importance of national policies in promoting the potential of technology in learning processes (e.g., Tawalbeh 2001; Tondeur, van Braak, & Valcke, 2007; Lim, 2007). However, the definition of a national curriculum on its own does not guarantee any instructional use of technology (Goodison, 2002). An interesting issue in the context of this discussion is the balance between the extrinsic and intrinsic forces that drive the integrated use of ICT by teachers. Imposing policy decisions is often less responsive to teacher perspectives and often neglects workplace constraints. A way forward is stressing the responsibilities of local schools to develop a school-based technology plan.

In a best-case scenario, such a plan will stimulate a dialogue among school managers, teachers and parents about technology use in the curriculum. Moreover, engaging teachers in the development of policy planning gives them the opportunity to reflect on their particular educational use of technology. It fosters the subjective meaning-making process of individual teachers as to how and why they will respond to technology use in class. In the context of this dialogue, the following questions can be explored: How can technology be integrated and tested in classroom practice? What feedback can be derived from classroom practice? What type of feedback is considered critical from a classroom perspective? As technology continues to drive changes in society and in education, we contend that such policies need to define their organisational vision and actions more clearly in view of planned change.

It is clear that technology integration is not yet achieved in a systemic or systematic way in most schools. Very few schools can be labeled as "learning organizations" with a shared commitment to technology in education. In this

respect, the literature about school improvement stresses the importance of leadership in developing a commitment to change. Their capacity to develop and articulate, in close collaboration with other actors from the school community, a shared vision about technology use is considered a critical building block in this process. An important implication, therefore, is that the training of principals should become a priority in developing technology-related professional development. The studies by Dawson and Rakes (2003) and Lawless and Pellegrino (2007) underpin the former: the more professional development principals receive and the more engaged they are in the professional development of their teachers, the more technology integration at school level is observed. Their findings suggest that without well-trained, technology-capable principals, the integration of modern technology into school curricula will remain deficient. This perspective adds to the holistic approach when exploring the gap between technology trends and use of technology in schools because teachers are not considered as completely independent, but share their context.

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Educational Games and Virtual Reality as Disruptive Technologies

Joseph Psotka

U.S. Army Research Institute for the Behavioral and Social Sciences, 1436 Fallsmead Way, Rockville, MD 20854 // Psotka@msn.com

ABSTRACT

New technologies often have the potential for disrupting existing established practices, but nowhere is this so pertinent as in education and training today. And yet, education has been glacially slow to adopt these changes in a large scale way, and innovations seem to be imposed mainly by students' and their changing social lifestyles than by policy. Will this change? Leadership is sorely needed. Education needs to become more modular and move out of the classroom into informal settings, homes, and especially the internet. Nationwide certifications based on these modules would permit technology to enter education more rapidly. Smaller nations may be more flexible in making these very disruptive changes.

Keywords

Disruptive technology, Educational games, Virtual reality, Modules, Assessment, Leadership

Introduction

We are at the cusp in time when the use of Virtual Reality (VR) environments and games and edutainment are resulting in a creative output that foreshadows a new Renaissance in learning—affording entirely new options for human creativity and global social interaction in science, business, and government. These technologies, as well as those emerging within the new cyber-enabled landscape of social networking and advancing neural computer technology in an emerging global technological workforce, are disrupting traditional education practice; producing new learning processes, environments, and tools; and expanding scientific discovery beyond anything this world has ever seen. In the context of these disruptive innovations, why are learning technologies, specifically game-based learning and VR environments, so glacially slow to be adopted in schools, universities, or across informal science education institutions, at a time when our world is in dire need of a highly creative, innovative, and technologically sophisticated workforce to manage its complexities on a global scale? It is time that the political forces in this world begin to understand this potential and own up to their responsibilities for transforming education. Education needs to become more modular and move out of the classroom into informal settings, homes, and especially the internet. Nationwide certifications based on these modules will permit technology to enter education more rapidly. Smaller nations may be more flexible in making these very disruptive changes.

Many computer visionaries have foretold the coming transformation of education by computing (e.g., Seidel & Rubin, 1977; Feurzeig & Papert, 2011), yet in retrospect, these prognostications sound alarmingly redundant year after year. It is unclear; however, whether there is negligible, slow, or incremental change, or is it building to a potentially massive disruptive revolution in school-based education? An early, respected pioneer, Seymour Papert, whose MIT Logo lab spawned many innovations, was known to believe that computer technology would not have much of an impact until education changed fundamentally. What sort of changes could facilitate the implementation of new technology. Collins and Halverson (2009) have suggested that the problem is not better simulations, games, and intelligent tutors; but a radical restructuring of the curriculum. We need smaller curriculum modules than entire schools of four or five year long course sequences. These modules need nationwide certification based on formally monitored assessments. With these smaller modules, technology could be focused on improving instruction or radically altering its form in a completely disruptive way.

What we are witnessing, however; is not that education is looking to change, but, conversely, technology is pushing fundamental change in education, and education is not willing to make any changes to adopt it. How education leadership and emerging education policies address this significant and emerging reorganization of where, when, and how children can now learn through technology will determine the extent to which education will experience a fundamental transformation and produce the creative knowledge workers of the future.

Disruptive technology

When mainframe computer manufacturers ignored the encroachment of personal computers they held back the development and innovation surrounding their use; and by doing so they ensured their own demise. Instead of seeing the enormous popular advances that PCs held, they adamantly refused to use their skill and expertise to promote and accelerate this marvelous new technology development: this cost them their pre-eminence. We worry that similar strategies may be delaying adoption of technology in education and thwarting, ultimately, every nation's opportunity to augment their intelligence.

In reality, mor than 2 Billion people are using the Internet globally as of 2010. This includes three quarters of the American population more than a doubling increase since 2000. Online learning increased from 45,000 enrollments in 2000 to roughly one million in 2007, and shows signs of continuing to grow at more rapid pace, a power function expansion.

Simulations and games, especially those that invoke the hyperrealism of Virtual Reality are burgeoning in many commercial and military enterprises but have made less impact on education then the very first rudimentary games, such as Rocky's Boots (Robinett & Grimm, 1982). About 30 years ago, it was both easy to incorporate computers in education and easy to ignore the technology. Today the touch-sensitive, easy to use direct manipulation interfaces on cell phones, with voice commands for many common tasks, were unthinkable for those early machines. With 64K (not megabytes, not gigabytes, just kilobytes) of memory, the early computers did little more than turn pages of text; provide simple drill and practice mathematical problems; or provide text-based quizzes. At the time, these affordances fit well with teachers' competences and were relatively easy to integrate into classroom activities and remediation. These simple educational activities were not sufficiently important then to justify the purchase of expensive machines, so often one or two machines sat frequently unused in the corner of classrooms or in special computer rooms with locked access. Yet, commercial successes that spread widely such as word processing, accounting, and producing business spreadsheets forced schools to recognize them. New processes demanded new workforce skills; therefore, a market developed around teaching these targeted skills, but educators safely ignored the main issues by relegating computers to teaching tasks like keyboarding.

In 1978, the National Science Foundation (NSF) and the Department of Education (DoED) funded a groundbreaking effort to build computer technology for education. Out of this enterprise came some very successful research and development, including the highly successful and dominant games: *Rocky's Boots*, *Carmen Sandiego*, and *Oregon Trail*. The use of these games became popular in mathematics, English, and history classes, and their use was undergirded, theoretically and practically, by new insights into motivation and emotion in learning. It was obvious that computer games were serious fun; subsequently launching the beginning of a new media industry and culture.
From these early efforts, theoretical frameworks emerged that focused on learning with levels of challenge, or social interaction, or intrinsic motivation (Malone, 1981b), and toward a theory of intrinsically motivating instruction (Malone, 1981a). Early games of the 1940s were based upon missile defense systems and then adapted in the 1950s into low-level games. During the 50s and 60s, mainframe computers were used to increase the complexity of games and gaming platforms. The first viable commercial game, sold in coin-operated settings that laid the foundation for the entertainment industry was the 1971 game *Computer Space*. The gaming industry experienced commercial ups and downs until ultimately console gaming crashed in 1977. Rising again in the 80s with low publishing costs, game development expanded with different genres, such as adventure, beat 'em up, fighting, and interactive movie games; maze, platform, platform-adventure, racing, and role-playing games; rhythm, scrolling, stealth, survival and horror games; and vehicle simulations. Video games became widespread and deeply established in the 1990s when they became mainstream entertainment and consolidated with publishers. Increasing computer power and lower costs afforded the integrated use of 3D graphics, multimedia capabilities, and the production of newer genres, such as MUDs (Multi-User Dungeons), multiplayer, real-time virtual worlds; first-person shooter games; and the massively multiplayer online role-playing games (MMORPGs) or Persistent Worlds (PWs).

Although the gaming industry spawned dozens of multibillion-dollar companies, most current commercial games and their predecessors have had little explicit education content, such as chemistry, mathematics, or physics, nor have they been designed with embedded pedagogical strategies that would make them appealing to teachers or parents (Kafai et al., 2007). Commercial games; however, have been shown to develop physical and cognitive skills in learners (Lin, Linn, Varma, & Liu, 2010). Many teachers and administrators are waiting for definitive proof that games and VR environments are more effective than traditional text-based ways of instruction, although we already

know from innumerable studies that students are not learning well using traditional and text-based instructional methods.

Virtual reality environments, games, and learning

Most games and VR environments emphasize intrinsic motivation strategies, focusing on participants' internal motivation to perform a task, which is derived from the participation itself (Malone, 1981a; Malone & Lepper, 1987). Research on intrinsic motivation has found greater success when students engage in creative or complex tasks (Utman (1997); however, this is not to state that extrinsic motivation has no role in effective game design; intrinsic and extrinsic objectives are often entwined. Immersive experiences in a VR environment can be pleasurable as well as disturbing or frightening so acute is the experience (de Strulle, 2009). Immersion or presence, is a state of consciousness where awareness of one's physical self and surroundings is diminished or nonexistent, and one's experience in the virtual world becomes acutely heightened and seemingly physiologically embodied (Psotka, 1995). Being immersed in a virtual environment provides a very specific set of affordances both internal and external to the environment itself. In *Why Virtual Worlds Can Matter* (2007), John Seely Brown discusses that some of the things that occur in and around virtual worlds "may in fact point us in the direction of new forms of knowing and acting in virtual spaces and give us insight into what new, technologically mediated worlds may look like in the coming decades." It is to this future world that this chapter is devoted; to the evolving interplay of humans and machines, and the emergent learning processes found in subtle and self-evident corners of invented realities and environments.

Can education cope with the new technologies?

The slow adoption in education of games and VR environments for learning may remain as is for reasons that have little to do with their effectiveness (Meltzoff et al., 2009). The problem at the core is that technology cannot be effective until the curriculum is fundamentally changed to allow for specific technologies to be integrated in meaningful ways. If however, the curriculum will not be changed until each technology is proven effective, this is a standoff and counter-productive to progress. Scaffolding is a widely used educational practice in which directed instruction gradually decreases as a student's competence increases, and this graduated weaning from assistance results in increased independence in the learning process (Quales et al., 2009) Through merging real and virtual objects, the authors address the issue of the augmented emergence of abstract from concrete knowledge. Results of the study with a large sample of students suggest that the merging of real and virtual spaces can offer "a unique level of educational scaffolding," as well as "an improved learning-transfer from abstract to concrete domains." Embedded, or augmented reality may not be just effective; it may in fact place a new premium on informal learning outside of school. This may do to the education environment what the Internet has done to bricks and mortar stores.

Distinguishing the good from the bad has not been easy, especially when past evaluation studies have generally found mixed effectiveness results. Although it is more difficult to demonstrate learning gains from higher-level tasks than from tutorials that focus on drill and practice, the benefits to be derived from real-world tasks that require the student to explore, analyze, interpret, solve, and communicate are acknowledged widely (Bangert-Drowns & Pyke, 2001; Kearsley & Schneiderman, 1998; Kozma, 2003; Yang, 2003). While technology can be made subservient to traditional teaching practices of drill and practice and page turning, and numbingly passive delivery of knowledge, it is evident that this robs not only the student, but the effectiveness of the technology. VR simulations and games bring motivation and challenge back to students with a powerful force.

Funded with generous support from the Carnegie Corporation, the National Research Council of the National Academies of is drafting a "Conceptual Framework for New Science Education Standards" articulating a vision of the scope and nature of the education in science and engineering that is needed in the 21st century (Strulle & Psotka, 2012). The NRC's framework is committed to the notion of learning as an ongoing developmental progression and seeks to illustrate how knowledge and practice must be intertwined in designing learning experiences in K-12 science education. It recognizes "the increasing importance of engineering and technology in developing understanding and using scientific knowledge and practices."

Research summarized in *Taking Science to School* (National Research Council, 2007) reveals that children entering kindergarten have surprisingly sophisticated ways of thinking about the natural world based on direct experiences

with the physical environment, such as watching objects fall or collide, and observing animals and plants. Many of these early experiences can be simulated in VR environments.

Bringing motivation and challenge to learning

The most longstanding and direct benefit of VR and games for education has been their power to motivate learning. At first it was thought to be a novelty effect, but it has sustained its power over the years (O'Neil, Wainess, & Baker, 2005). VR and games continue to expand and transform themselves to also provide continuing novelty effects, but this is now clearly subsidiary to the main effects of challenge, social interaction, peer feedback, and the instantiation of local goals that are intrinsically motivating. In part, the motivational effects transpire from the power of immersion and the feeling of presence in creative and dramatic environmentsThis aspect of VR and educational games is the easiest to adapt to current pedagogical goals and environments, since motivation is an essential part of pedagogy under any system of instruction.

Virtual reality and games have the potential of embodying abstract concepts in concrete experiences. Perpetual motion machines can be built to demonstrate the force of gravity without the drag of air or any other friction. Complex interacting systems can be seen from the simplest perspective and complex abstractions, such as the meaning of words and the links between concepts shown tangibly in a complex three-dimensional space. Imagine a starfield of related concepts that can be explored by walking among the concepts, touching the invisible links that connect them, experiencing the distance among them, vibrating one to discover all the others that resonate to similar meanings, activating the concept to see it in movies and textual explanations: all this is possible to create concrete meaning out of ambiguous abstractions. For teachers, however, this is a monumental challenge. How to use the obvious insights in the real world and the semantic world of mental life remains unexplored to modern pedagogy, and the insights are as new and strange to teachers as they are to their students. Examples of success are River City, an NSF-funded virtual world for middle school science classrooms (Ketelhut, Nelson, Clarke, & Dede, 2010) containing content developed from *National Science Education Standards, National Educational Technology Standards,* and *21st Century Skills.* The River City world allows students to conduct scientific investigations around an illness spreading through a virtual city and based upon realistic historical, sociological, and geographical conditions. The authenticity of the world allows learners to engage in scientific practices, such as forming hypotheses, running controlled experiments, and interpreting data to inform courses of action. (http://muve.gse.harvard.edu/rivercityproject/curriculum_p21_standards.htm).

The most popular social networks, such as *Facebook™,* the virtual world *Second Life™,* and massively multiplayer online games (MMOGs), such as *World of Warcraft* and the SIMs have inspired the public's imagination and their motivation to learn. World of Warcraft and Second Life have reported participation of 8.5 and 6.5 million users, respectively (Bainbridge, 2012; Squire & Steinkuehler, 2006). With such expansive participation in social media, informal learning has been "virtually" transformed by these emergent settings.

The public's enthusiastic adoption of new technologies has evolved a resounding need for informal education institutions to design increasingly sophisticated exhibits that incorporate immersive VR, augmented reality, game-based technologies, visualizations, and other emerging media. Advances in simulations for training pilots and astronauts; ubiquitous robots and nanotechnology; satellite imagery; and emerging, sophisticated visualized data have provided new opportunities for engaging the public in modern science. Findings from a study of a virtual reality science exhibit (de Strulle, 2009) revealed that some learners were frightened by specific types of nonrealistic virtual environments and positively affected by realistic images. Nonrealistic images decreased feelings of immersion, while some visual images moved or changed too frequently to produce any sense of immersion. Avatars were intended to personalize the VR experience; however, data reveal that avatars did not personalize the experience. Conversely, avatars were found to detract from learning. Options for interaction were confusing within the virtual environments, leading to cognitive load issues and frustration in participants, and the mix of audio, text, colors, movement, and navigation tools were together found to distract from learning. As far back as 1996, Cazden and Beck (2003) argued that it was critical for exhibits to model effective learning strategies based upon research on learning and be assessed for their pedagogical value. This remains true. Synchronizing exhibits to the learning strengths of students, multiage learners can provide unique options for self-directed learning. Differences emerged in understanding of exhibit content learning styles of multicultural audiences; differences in gender-based learning; consideration of age

differences among learners; and a new way of understanding how people learn within immersive environments (de Strulle, 2009).

WolfQuest is a highly successful NSF-funded science game, downloadable and free of charge (www.wolfquest.org). Developed by Educational Web Adventures and the Minnesota Zoo, the game is coordinated with a national network of informal science education institutions, including wolf research and conservation organizations. It is important to note that *WolfQuest* was designed to bring the same compelling, game-playing quality of commercial video games to online informal science learning and had the goal of teaching wolf behavior and ecology in an authentically rendered VR environment developed for scientific accuracy by wolf conservation scientists and wolf habitat ecologists. In a summative analysis of the game by the Institute for learning Innovation, several issues were identified as being notable: about 4,000 users downloaded the game in the first few hours after launch and over 350,000 people have downloaded the game in the 21 months post launch. On average, players have engaged in over 100,000 multiplayer game sessions per month. The game's online community forum has over 80,000 registered members who have made over 850,000 posts to the forum, with a current average of 1,400 posts daily. The game also successfully reached its target audience of 9-15 year olds with nearly 70% of players in that age range. Findings from a web survey, indepth phone interviews of learners, and content analysis of the conversation forums, reveal that interest in, connection to, and knowledge of wolves, wolf behaviors, and wolf habitats increased significantly. This is significant because the game's science content was woven throughout the game and rarely made explicit. In self-reported knowledge, a definite cognitive gain is found with respondents naming either general or specific facts related to habitats, hunting behaviors, territories and threats to wolf survival, social behaviors, and other facts related to the anatomy and species of wolves. Over three quarters of the survey participants either have, or intended to expand their interest in furthering their learning about wolves. Over half of the individuals correlate playing *WolfQuest* with their desire to visit zoos, nature centers and state parks and to participate in outdoor activities. This demonstrates that science rich games can be a significant factor in encouraging interest in grade-appropriate subject matter and advance visits to zoos and wildlife centers and as form of enhancement to traditional subject matter instruction.

Tüzün et al. (2009) studied the effects of computer games on primary school students' achievement and motivation in geography learning. Researchers designed and developed a three-dimensional educational computer game for 24 fourth and fifth grade students in a private school in Ankara, Turkey to learn about world continents and countries for three weeks. The effects of the game environment on students' achievement and motivation and related implementation issues were examined through quantitative and qualitative methods. An analysis of pre- and post-achievement tests showed that students made significant learning gains. In comparing student motivations while learning in the game-based environment and in the traditional school environment, it was found that students demonstrated statistically significant higher intrinsic motivations and statistically significant lower extrinsic motivations from learning in the game-based environment. In addition, students had decreased their focus on getting grades and were more independent while participating in the game-based activities. These positive effects on learning and motivation, and the positive attitudes of students and teachers suggest that computer games can be used as a tool in formal learning environments to support effective geography learning.

The military's leadership in game-based learning

In America's military there has been little opposition to innovation in education and training. None surpasses the military's leadership in education and technology; therefore, it is imperative that we understand the difference between the military's approach to leadership in education and training, and the American school system's rather lethargic approach to modernization. Why is one massive enterprise nimble enough to react to the changing dynamics of national interest, and one system entrenched in antiquated ideas, outdated textbooks, poor teacher preparation, and a serious lack of attention to the rise of technology?

Military officers often have an engineering background. Computers and technology are not unfamiliar but this is not the basis of the military's success. The military is driven by pragmatic urgency to improve their odds against very clever foes in very high-stakes environments. As a result, computer games and simulations were explored thoroughly at the beginning of the digital revolution and found to merit vast investment in research and development because these environments provided a unique learning edge. The military already used simulations of simultaneous linear equations to model weapons effects, called constructive simulations, and so there was an incremental change to qualitative digital simulations. Initially, the machinery of war, tanks and planes and ships were simulated with

mockups, and then embedded in computers to create virtual environments where Soldiers could learn their profession as realistically as possible. The Army created a vast desert stronghold to verify the success of these simulators in live training that is unparalleled in the world. Not only did they confirm the success of simulators and games, which was attested to by commanders in actual combat in Desert Storm and Operation Freedom, they also created an extensive modeling and simulation bureaucracy to guide the research and development of more formidable systems.

The U.S. Army has successfully emphasized "training as you fight" to instill the best possible fighting effectiveness in its Soldiers. Over the last two decades, this philosophy has heavily emphasized simulators and simulations that range from virtual environments of networked armor simulators with veridical motion and scenery to live training ranges with laser detectors pioneered at the National Training Center. In 2002, the U.S. Army created America's Army (http://www.americasarmy.com/), a game to provide entertainment while creating implicit skills and tacit knowledge about the variety of occupations in the military. The game was based on a commercially successful gaming platform and engine and was a huge success with millions of downloads and online players. Its effectiveness at creating Army skills and an improved understanding of the Army environment had been widely acknowledged as self-evident. America's Army has been going strong for more than 8 years with millions of downloads and players throughout the world. The success of this training has propelled the widespread development of less detailed simulators, such as DARWARS Ambush! (Foltz et al., 2008) for training convoy skills; videos in communities of practice (COPs) environments, (Cianciolo et al., 2007) (companycommand.com); and even professional discussion in text-based environments (Dixon et al, 2005). The range of training domains has been fairly broad, including interpersonal interactions (Hill et al., 2006; Barba et al., 2006); convoy operations (Roberts, Diller, & Schmitt, 2006); squad/platoon leadership (Beal, 2005); tactical operations (Beal, 2005); language and culture (Johnson & Beal, 2005), among others.

To avoid the high monetary costs and time requirements for developing scenarios in these high-fidelity environments, assessment of individuals was conducted in a low-fidelity environment. The use of a low-fidelity environment also provides a near-transfer demonstration of the skills/abilities developed through training with high-fidelity environments. With a low-fidelity environment, the training domain knowledge and decisions can be parsed from the skill in using the training tool, so the assessment can target the intended cognitive components of the training material.

ELECT BiLAT is a prototype game-based simulation for Soldiers to practice conducting bilateral engagements in a notional Operation Iraqi Freedom environment (Hill et al., 2006). The prototype provides students with the experience of preparing for a meeting, including familiarization with the cultural context, gathering intelligence, conducting a meeting, negotiating a successful resolution, and following up the meeting agreements, as appropriate. The ELECT BiLAT architecture is based on a commercial game engine that is integrated with research technologies to enable the use of virtual human characters, scenario customization, as well as coaching, feedback, and tutoring.

Military's assessment methods

To assess the effectiveness of military games for learning, simple facts are not enough. Improved decision-making based on experience is the goal; so multiple-choice tests and even essays are not appropriate. While essay answers may bring out the sought for skills, they are too time-intensive for everyday group use, so a new technology for testing has been developed: Situation Judgment Tests (SJT).

For ELECT BiLAT, an SJT was developed and used to assess how well learners made appropriate decisions. The SJT included nine scenario descriptions with multiple alternative actions presented as possible answers for each scenario. The learners rated each possible action (a total of 31 actions per scenario) on a Likert scale (0 = very poor and 10 = very good). The learner responses were standardized (i.e., a Z-score based on their own mean rating and the standard deviation of their own ratings). Learners' standardized ratings were then compared to a subject matter expert (SME) based rating key, using a correlation. The higher the correlation between the learner and the SME ratings the better the agreement on the relative goodness/badness of various actions in the highly complex situation of bilateral negotiations.

One of the benefits of using the SJT to evaluate progress was that there were no clear right/wrong answers for the ratings, and the scoring was based on a correlation to SME ratings. By taking the SJT without any feedback, a learner

would not be able to improvise a personal scoring key leading to improve scores based solely on repeatedly taking the test. Therefore, a pre-training assessment could be given prior to the training session, followed by the training, and then the post-training assessment could be conducted. Then by comparing the pre- and post-training correlation scores, it was possible to see how much a person learned from the training.

To our knowledge, no one at any level of the education system has yet adopted this new SJT technology, just as there is little use of educational games across the education enterprise.

Not all military training via games and game technology is combat-oriented. When deployed outside the U.S., for example, soldiers often are in different cultures and unable to speak the language. Various companies and university research programs are working to solve these problems. In 2004, researchers at the Information Sciences Institute at the University of Southern California were working on *Tactical Iraqi*, a game-based effort to teach Arabic to U.S. soldiers. These types of games involve work with speech recognition technology, since speaking a language is vitally important to learning it. A human facilitator monitors and corrects trainees, since the technology is still relatively new.

Most military personnel are not involved in frontline combat. The actual warfighters are supported by a host of analysts, drivers, cooks, and so on, who are doing traditional jobs under extremely adverse conditions. The military is aware that they need training for non-combat personnel. During the fighting in Iraq, non-combat troops suffered more casualties than combat troops. Games have been used to train these personnel as well.

In 1999, the U.S. Army in conjunction with the University of Southern California created the Institute for Creative Technologies (ICT), bringing together educators, video game developers, and other entertainment companies to create the next generation of military training tools and simulations. The Army's Joint Fires and Effects Trainer System, or JFETS, is one of the projects to come out of the ICT. In JFETS, the location of the mission, with simulated personnel and defenses, is presented to the player-trainee. Since most missions are team missions, the training becomes a multiplayer game experience. Superiors can monitor the performance of individuals, as well as the entire team, and can provide feedback, both positive and negative, in debriefings after the mission is completed. If the design of the simulation is engaging enough, it's not impossible to assume that soldiers would be willing to play the games in their off hours, combining unsupervised entertainment with training.

Live training operations, deploying hundreds or even thousands of military personnel into the field, have been a staple of military training for centuries. The cost of such operations, in terms of both men and equipment, makes them less than ideal. With massively multiplayer online games (MMOG) technology, bringing together troops from around the world, operations can be done less expensively and with much more secrecy. In addition, the military is contemplating Virtual Reality trainers.

Training for the military has advanced significantly in the past decades, and games for training have played a large part. Though there are still many in command and training positions that distrust games as teaching tools there is evidence of its success and the use of games will become even more important in the years to come. For the military's games, After Action Review (AAR) is particularly important. The process reviews what was supposed to happen, establishes what actually happened, and then determines what went right—essential to assessing both the game and a Soldier's performance. Past studies always have mixed effectiveness results.

Conclusions & recommendations

Outside of classrooms, students and adults are highly engaged in using a range of complex technologies and have generally surpassed the expertise of their teachers. Technologies of many kinds, from online universities to interactive learning environments and distance education are nibbling at the edge of school systems (Collins & Halverson, 2009). The failure to recognize technology and its affordances for improving teaching and learning is thwarting our ability to develop a technologically skilled workforce and thereby inhibiting our ability to compete in

the global marketplace. Students in less affluent public schools are unable obtain a modern and competitive education, and our system of education is not consonant with the goals of other high performing Western countries. Technological innovation is creating rampant discord in well-established industries that have been entrenched at all levels of the education enterprise. Textbook, magazine, and newspaper publishers are in a quandary about how to deal with current digitization of information and massive amounts of data, and the vast global networks now used for global information and communications (Jones, 2009). To what extent, we ask, do the industries tethered to the education system, such as textbook and publishing companies, student exam preparation companies, college boards, and an array of resource providers with contracts to schools constrain the use of technologies and software applications because their business is not yet technology-based? Although few groups adopt the Luddite strategy of destroying technological innovation, other strategies may be equally destructive, preventing the level of creativity, innovation, and progress our nation needs. Change demands radical new skills and practices.

Future learning progressions

The inferential processes of children in their genetic epistemology of knowledge remain largely a mystery to our understanding, although some generalizations about the progression from sensory experience to concrete manipulation and formal knowledge (Piaget, 1926) are superficially understood. What is clear, is that the implicit creation of concepts and knowledge structures during the first few years of life where every new experience seems to add measurably to a child's progress. The meanings of words grow in parallel with each other incrementally; so that within five years (1825 days) more than 5,000 unique conceptual meanings are learned while only one or two new words are encountered each day (Landauer & Dumais, 1998). With the exception of some parental assistance, *no teacher was involved in these learning achievements*.

Exposing children at early ages and grade levels to complex ideas could turn around children's natural learning progressions. For example, a game has the potential to provide young children with experiences that convey the impact of human behavior on an ecosystem, giving them immediate insight into the concept traditionally taught in high school. Although we do not know how the mind can extrapolate from VR experiences at such early ages, we do know that simulated environments, as previously mentioned, can create immersive states of consciousness that are "as if" the student is there. In addition to basic gains, VR could be tested as an intervention. As an example, exposure to novel learning experiences outside of school has been linked to higher academic performance in elementary school. Affluent children typically spend summers hours traveling or in learning activities, as opposed to economically challenged children who have little enrichment outside of school. Academic gains made by affluent students over the summer are compounded yearly resulting in a perpetually widening academic gap between affluent and economically challenged students during the formative school years. Because VR and games can provide simulations with experiences of real environments, including augmented reality, these environments can expose students to "realistic" and "authentic" enrichment activities potentially closing the learning gap in the early years. Our minds are attuned to implicit inferential learning from experiences provided by our perceptual systems; yet, education largely fails to stimulate and leverage these powerful learning systems. Imagine allowing children to experience and explore the conceptual universe of atomic and chemical structures; an unspoiled ecosystem; historical reenactments; the plays of Shakespeare, just as concretely as they now explore their playrooms and backyards. Imagine not just two-dimensional graphs of forces and relations, as in *SimCalc* but embodied forces moving and changing dynamically in complex relationships that students can be engaged with using all their perceptual and intellectual systems. Games, VR and other emerging technologies are strategies for learning that embrace complexity and rely upon the amazing capabilities of the neural networks of the brain to create organized knowledge and understanding. The formation and ingrained acceptance of many misconceptions is prevalent in K-12. Ideas such as the geocentric solar system; medieval theories of circular motion; or overly simplistic views of predator and prey relations, can easily be eliminated through VR and games in early elementary school, allowing for complex and accurate conceptions of the world to form at early ages, freeing up valuable academic time for more meaningful and detailed exploration. At this point of unprecedented opportunity for learning, we should be exploring a plethora of possibilities.

Scientific misconceptions

Misconceptions about the world abound in students from the obvious flat Earth and geocentric solar system; to the much less obvious impetus theories of motion for objects swung in circles and let go, or objects dropped from

moving vehicles. Misconceptions in science and mathematics have an important role in creating graduated and more complex understanding of the world; just as the Bohr atom is a crude approximation of more detailed atomic structure; however, some misconceptions are the direct byproduct of our perceptual system. Even after seeing the Earth rise from the moon's surface it is still difficult to conceive perceptually that the sun is not orbiting the earth in the sky. In spite of this perceptual conflict, VR can provide the direct experience to understand more directly and convincingly that a heliocentric view of the solar system is a more scientifically congruent conception. Similarly, it can provide a point of view of objects being dropped from moving vehicles that takes either the perspective of the moving vehicle or the stationary ground, and the accurate flight of objects can be made clearly visible. In this way, VR provides pedagogic agency of novel and unrivalled power. In order to use this power, teachers must understand these misconceptions; must understand the role of misconceptions in the cognitive growth of their students; and must be able to integrate these things into their curriculum, and nothing seems as imaginative and compelling as seeing and doing through immersive technologies.

Exploiting the power of disruptive technology

Reviewing these strengths of VR and educational games, the pattern of their disruptive powers becomes obvious. Instead of providing facts and abstractions, VR and educational games offer an embodiment of selected, refined experiences distilled from real life. An example of leading-edge work with experiential simulation is *ScienceSpace*, an evolving suite of virtual worlds designed to aid students in mastering difficult science concepts (Salzman, Dede, Loftin, & Chen, 1999). Whether to counter misconceptions; provide access to normally unperceivable phenomena of Earth's systems and processes and inaccessible environments; or immerse students in exciting, motivating adventures with incidental but important meaning, games and VR technologies offer unprecedented educational opportunities. These opportunities may never fit into the existing framework of education unless current approaches to the use of educational technologies change. VR and games can stretch and shape students' minds in ways that have not yet been explored by educators in large-scale implementations. This is disruptive technology at its core.

Students live in this world of immediate sharing, with cell phones, instant messages, online social networking sites, and games, in a continuing evolution of technology that dominates their lives. The education system used to be the access point for new information and knowledge, now the Internet and social networking technologies offer resources of unparalleled magnitude making information and knowledge gained in classrooms appear outdated. New technologies offer fresh and highly effective new approaches to creativity in the context of education, such as ways to adjust pedagogical structures in favor of a more individual approach to learning that creates opportunities for teachers to engage students individually and provide feedback. Technology provides opportunities for individualized, automatic feedback, and promotes collaboration and peer interaction in new powerful ways. Online games in particular demand teamwork and sharing expertise.

Humans are endowed with magnificent sensory systems to investigate and explore the world. Children use these systems to make powerful, far-reaching generalizations about complex everyday events and structures that are so amazingly accurate that they survive to reach school age and beyond. It does not take much imagination to see that the structures and function of the brain are intimately in harmony with these perceptual systems. Yet, once in school these powerful systems and exploratory urges are harnessed, reined in, and often constrained only to focus narrowly on text-based learning and images in books. The advanced new technologies of VR and games make these persistent restrictions unnecessary, but the education system must be radically changed to position itself to take advantage of these new teaching and learning opportunities.

The future workforce

Workplace employment demands increasingly more knowledge adeptness with online interaction and collaboration essential to job functions. Education has moved much too slowly in taking an active lead in promoting these skills and focusing on higher order thinking skills that leverage these technological breakthroughs. Many technologies are inherently educational in ways that could easily be exploited by schools; yet, it appears that the zeitgeist is predominantly one of shutting these technologies out of school-based learning, preventing cell phone use in classes because of their potential disruption of teachers' lectures and control. The true disruption, however; is not inside classrooms, it's outside the classroom, in out of school learning where information and communications technologies,

games, and virtual worlds are dominating the attention of youth and perpetuating and evolving with such sophistication that it will ultimately cause the educational system to change, but when, and at what cost to our nation's leadership?

It is up to leaders, principals, administrators, school boards, and local officials to begin to design the necessary educational technology framework for how schools might undergo a transformation and oversee it through to a successful end. A demand for new curricula with a culture of embracing technologies for learning must evolve. Schools of education must teach preservice teachers how to teach and collaborate through technology; foster student research using technology; and engage students in the use of current technologies in order to gain necessary competitive expertise in using technology for a range of interdisciplinary career opportunities; evolve essential abilities to solve problems through analysis of emerging data; and design new forms of innovation for a technological world.

VR can present science content through sophisticated simulations allowing users to interactively experiment, collect and interpret data, pose questions, explore new hypotheses, and analyze results of their own virtual experiments. Conducting scientific inquiry within a VR environment allows learners to progress to more difficult and sophisticated science investigation experiences at their own pace of inquiry. Such experiences promote improvement in learners' critical thinking and problem-solving skills through manipulation of scientific data, data analysis, and speculation of results.

For teachers with students who have varied academic backgrounds, propensities, and abilities, VR can integrate a range of personalized strategies. Students who may have difficulty performing in class could potentially have time away from teachers and peers to engage in virtual problem-solving strategies synchronized to a learner's individual pace.

Learning from experience

Researchers have created innumerable prototypes and disseminated them to educators, researchers, and schools only to continue to flounder alone. Such a piecemeal research agenda and implementation strategy will not effect any change in education in radical ways. The education enterprise must systematically draw from the body of evidence but also and most importantly, from the real-world exchange of ideas in the world marketplace in order to absorb visionary new ideas and recommendations. Leadership is needed in government and industry to forge a bold new plan to let America's children learn.

Change in the structure of schools

Collins & Halverson (2009) have offered a stimulating new program for integrating technology into schools. Just as education had to change dramatically in response to the industrial revolution, the knowledge and technology revolution are demanding a similar degree of change. The two changes they suggest are national certification and modular assessment systems. The main proposal they make is to create a national set of credentials that could be administered online on any learning center or school by trained professionals. By creating smaller certifications that are nationally recognized students could use their own motivation to decide which certification tests they take, when they take the tests, and the topics to research. These certifications would rely on assessment systems that are nationally standardized. Not only would this increase student motivation to pursue their own interests when and where they want, the modular architecture would allow the penetration of research innovations into school based, informal, and internet based curricula. This motivation factor has the potential to improve education in many ways. Education is somewhat modular already, with materials broken into years, or semesters. This should provide a start, but smaller modules would be more amenable to technological simulations, games, and VR. The changes it demands maybe too great for huge national systems, but smaller nations may be more agile and flexible in creating these new systems. Everywhere, however, dynamic leadership is needed to overcome stagnant lethargy and implement change that may well be disruptive in its short term consequences.

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Positioning Design Epistemology and its Applications in Education Technology

Chin-Chung Tsai[1*], Ching Sing Chai[2], Benjamin Koon Siak Wong[3], Huang-Yao Hong[4] and Seng Chee Tan[5]

[1]National Taiwan University of Science and Technology, Taiwan // [2,3,5]Nanyang Technological University, Singapore // [4]National Cheng-Chi University, Taiwan // cctsai@mail.ntust.edu.tw // chingsing.chai@nie.edu.sg // benjamin.wong@nie.edu.sg // hyhong@nccu.edu.tw // sengchee.tan@nie.edu.sg

[*]Corresponding author

ABSTRACT

This position paper proposes to broaden the conception of personal epistemology to include design epistemology that foregrounds the importance of creativity, collaboration, and design thinking. Knowledge creation process, we argue, can be explicated using Popper's ontology of three worlds of objects. In short, conceptual artifacts (World 3) like theories are products of human minds that result from personal thinking and experience (World 2) and are encrypted through language, signs and symbols on some physical media (World 1). Examined from this perspective, knowledge creation necessitates design thinking, and ICT facilitates this process by providing a historical record of the development of ideas and allows for juxtapositions of ideas to create new ideas. The implication for education is that educators and researchers should develop students' epistemic repertoires, or ways or knowing, so as to create cognitive artifacts to make sense of the problems and challenges that a student encounters.

Keywords

Design, Epistemology, Educational technology

Introduction

The challenges posed by the contemporary world on education can be succinctly summarized as the requirement to transform educational practices to prepare students of all ages for the knowledge society (Bereiter & Scardamalia, 2006; Chai, Wong, Gao, Wang, 2011; Macdonald & Hursh, 2006; Paavola & Hakkarainen, 2005). The knowledge society, sometimes known as the learning society or the knowledge economy (Valimaa & Hoffman, 2008), produces "high value-added goods and services driven by … strong innovation performance; intensive use of generic technologies…sound research and development investments; and, above all, high education standards, human resources in science and technology" (Dufour, 2010, p. 984). The foci of the education system in such a society are targeted at cultivating learners who are able to produce knowledge and associated products through transdisciplinary research. The key competency of the workers in the knowledge society is the ability to create usable knowledge, and not just knowledge that are governed by academic interests concerning the "truth" (Bereiter, 2002; Valimaa & Hoffman, 2008).

The preceding account of the educational needs of the knowledge society is now widely shared among educators and policy makers. Many national and international education policies that attempt to integrate information and communication technology (ICT) in education have the ultimate goal of empowering students' construction of knowledge with ICT (e.g., Anderson, 2010; Partnership for 21st century skills, 2011). Classroom realities, however, often fall short of realising these policy objectives. This is especially so in the Asia Pacific region when teacher's use of ICT for students' knowledge construction is not prominent (Bate, 2010; Hogan & Gopinathan, 2008; Hsu, 2011; Law, Lee & Yuen, 2009). While the advancement of networked technology, along with the development of myriad e-learning platforms and social networks, has broadened the scope for ideas, insights, experiences, and knowledge to be articulated, constructed, shared, and distributed (Chai & Lim, 2011), it is now generally recognized that true transformation of education has to happen at a deeper level (Bruner, 1996; Castell, 2005; Ertmer, 2005; Bereiter & Scardamalia , 2010; Yang & Tsai, 2010). Current education systems have been based primarily on traditional epistemological beliefs and the needs and infrastructures of the Industrial Age (Bereiter & Scardamalia, 2006; Macdonald & Hursh, 2006). To meet the challenges posed by the knowledge society and to harvest the pedagogical affordances of ever more powerful ICT, it is imperative to re-conceptualize what education is about; in particular, to collectively (i.e., involving all levels of educators) examine the epistemic foundations and purpose of schooling. Our purpose in this paper is to reflect on a lesser known area of research in personal epistemology, namely design epistemology, and to argue for its relevance in ongoing efforts to address the epistemological bases of

education reform. In the following sections, we argue for the need of fostering design epistemology among teachers and students and the roles of ICT in this process.

Design epistemology

Epistemology is an important field within philosophy that deals with the nature and the justification of knowledge. Regardless of which perspectives of learning an educator holds, whether learning as acquisition of knowledge or knowledge creation (Paavola & Hakkarainen, 2005), one cannot avoid engagement with issues about the nature of knowledge and ways of knowing. In terms of education reform in the context of knowledge society, it would be pertinent for teachers to be acquainted with epistemology supported by personal experiences in creating knowledge.

Since 1970s, there has been growing interest among educational psychologists in the study of students' and teachers' personal epistemology. The core dimensions of personal epistemology include the nature of knowledge (whether knowledge is certain or tentative, for example) and the source of knowledge (for example, whether knowledge is from an authorititative source or is personally constructed) (Hofer & Pintrich, 1997). Relationships between personal epistemology and various learning outcomes, such as learning approaches, reading comprehension, conceptual learning and learning strategies have been established (Schommer-Aikins, Bird, & Bakken, 2010).

Wong and Chai (2010) argued that prevailing conceptions of knowledge, based on traditional notions of epistemology and the popular views of the scientific method, are unduly limiting. Etymologically, the Greek term *episteme* translates into *scientia* in Latin to give us the modern word for *science*. Traditionally, *episteme* in Greek has often been used in contrast to *techne* (art or craft), *poiesis* (making or inventing) and *praxis* (doing). Due to this traditional bias, current conceptions of epistemology tend to privilege scientific knowledge or propositional forms of knowledge. With the emphasis on innovation, creativity and the use of technology in the knowledge economy, it opens the way for a more dynamic, comprehensive conception of knowledge construction that cuts across not only various disciplines but also across domains of skills, practices, and even dispositions (Schön, 1983; Caws, 1997; Simon, 1996, Rowland, 2004, Pink, 2006, Cross, 2006, Edwards, 2008; Fry, 2009; Martin, 2009; Brown, 2009).

We therefore argue for a broader conception of personal epistemology that foreground the importance of creativity, collaboration, and design thinking for future research. In other words, we propose a conception of design epistemology that is not divorced from traditional epistemology, but one that emphasizes the dynamic, social, and creative aspects of knowing and knowledge construction. Focusing on this area of personal epistemology is, in our opinion, crucial to the transformation of education, especially in the Asia Pacific region, which is culturally more oriented to collectivism and traditional teacher-centric pedagogy. Design epistemology could leverage the communitarian aspects of Asian culture to promote a more creative and dynamic approach to teaching and learning.

The design approach to knowledge

Nigel Cross (2006) suggested a useful way to characterize the design approach to knowledge. According to Cross, human knowledge can be broadly divided into three realms-- namely the sciences, the humanities, and design—each with its unique focus of study, methods and set of values and dispositions.

The main focus of study for the sciences is the natural world. The methods employed by the sciences include controlled experiments, classification, and analysis. The values corresponding to scientific inquiry are objectivity, rationality, neutrality, and a concern for truth. The arts and humanities focus on human experiences and employ tools such as analogies and metaphors to understand and to give expression to the world of human experiences. This realm of human knowledge values human subjectivity and imagination, and is often propelled by concerns for justice. *Design* realm of knowledge focuses on the artificial world, and employs methods such as modeling, pattern-formation, and synthesis. Practicality, ingenuity, empathy, and a concern for appropriateness are paramount for design realm of knowledge. The ability to synthesis disparate knowledge and information is widely held to be a central feature of design thinking (Cross, 2006; Pink, 2006; Simon, 1996). In addition to modeling, the use of simulation and prototyping are typical tools to experiment with new ideas. Not only do these tools enable the realization of abstract ideas, but they could also serve as vehicles for the discovery of new knowledge and facilitation of thinking (Simon, 1996; Brown, 2009).

The division of knowledge into these three realms is, of course, a human creation –a product of design thinking, so to speak. In actuality, all three realms of knowledge are intimately related in the act of thinking and doing in a creative fashion. While it is focused on the production of material and conceptual artifacts, design thinking cannot take place without the necessary supports of the arts and sciences. In addition, we would argue that design thinking is critical to all three forms of knowing. Artists design the stories they want to tell about human experiences. Scientists design the theoretical frameworks and the empirical experimentations about the phenomena they encounter. Technologists design products that interface between the users and the objects to be worked on. Regardless of the professional emphases, the viability of what is created has to be judged and assessed by potential users. The creation of a science fiction movie such as the Star Wars series illustrates how these three forms of knowledge are tightly woven together through design to produce an artifact that has been well received by movie lovers. The success of Apple's iphone with its growing number of apps is another case in point.

Design thinking is likely to be more fruitful in a collaborative environment. Project teams comprising members with different skills and expertise are crucial for design in the knowledge age. The creative potential of the team is based on its capacity to collaborate across disciplines and realms of practice. In educational terms, such collaborative efforts point to the desirability of fostering "T-shaped" individuals (Brown, 2009). The vertical axis of the letter refers to the depth of skill and knowledge that allows a person to make tangible contributions to the outcome of the project. The horizontal axis refers to the capacity to pursue a wide spectrum of interests outside of one's professional, technical, or academic specialty.

Ultimately, design is aimed at meeting human needs and purposes, and as such, design is guided by a normative goal. Since design thinking aims to produce artifacts or ideas useful and meaningful to life, the logic of their enterprise has ethical implications on their participants. Thus, in addition to "the arts of planning, inventing, making and doing" (Cross, 2006, p.17), the design approach fosters the development of empathy, tolerance for ambiguity, positive attitudes towards failure or error, and bias towards service and responsibility (Rowland, 2004). This is also quite different from scientific thinking, which often considers uncertainty as a threat for knowledge development (Duschl, 1990). Last but not least, design thinking understood in this context also promotes a high degree of reflexivity, in which the agent grows in self-awareness and social consciousness through interacting with others in the process of producing goods and services that transform the social and physical environment.

The preceding outline of the main features of the design approach to knowledge shows that design thinking is more than what has been considered in the traditional research of personal epistemology. To date, studies in personal epistemology is mainly based on classroom phenomena in general. This, in turn, is based on the belief mode of thinking that is focused on the truth value of knowledge claims (Bereiter & Scardamalia, 2006). Consequently, there is little we know about how teachers and students understand knowledge creation in the context of knowledge society. However, before we discuss possible ways of fostering knowledge creation in the classrooms, it would be beneficial to explicate a possible ontological foundation to engender knowledge creation in classrooms. To this end, we turn to Popper's postulation of three worlds.

Popper's three worlds and knowledge creation

Popper conceptualized a pluralistic view of the universe consisting of three worlds to explain how civilization progresses. World 1 consists of the world of physical things and events. World 2 refers to the subjective world of experiences, and Popper regarded this as especially important as it includes the world of moral experiences. World 3 is made up of the products of the human mind. As products of the human mind, World 3 objects can also be referred to as conceptual or cognitive artifacts (Bereiter, 1994). World 3 objects are primarily embodied or physically realized in world 1 physical objects. For example, Beethoven's Fifth Symphony is a World 3 artifact that is realized or embodied in various performances or recordings of those performances, which are events or things occurring in World 1. The experience and appreciation of a live or recorded performance takes place in World 2, and is experienced differently by different listeners who can then engage in informed or critical discussion of the merits of the performance. It may seem surprising that this interaction of the three worlds may well lead to changes in the elements of the symphony to improve or enhance its performance.

The contemporary significance of Popper's three worlds to research and development community lies in the potential of tentative theories or designs being articulated and/or improved over time as they are being subjected to criticism,

error elimination and/or refutation. An example of such a process is the Wright brothers' effort in building a plane that took place as a theory about flight control was concurrently being developed and articulated (Bereiter, 2009). To work on an epistemic object with the intention of producing a good or service and advancing its utility is, in essence, the kind of innovative work today's knowledge worker is engaged in. In other words, the interaction of the three worlds is part and parcel of what it means to be engaged in knowledge creation.

The main point of World 3 objects is that they are human creations and therefore they can be improved for the most part through the dynamic interaction the three worlds. Treated as such, the ideas, theories and designs created by knowledge workers such as scientists, engineers and architects are assessed less for their truth value but more for their utility or pragmatic value. Moreover, these theories and ideas, once created, have a life of their own in that they can and should be improved and transformed by people who interact with them. They are treated as tentative ideas that should be subjected to error elimination under Popper's schema or idea refinement from Bereiter's perspective. In other words, all created knowledge is open to further inquiry and improvement. Design thinking is more concerned with notions of utility and significance than with the question of truth (Pink, 2006). Even so the material or conceptual artifacts of the design process do not "ignore or violate the laws of nature" (Simon, 1996, p. 3); indeed, it could be said that the success in simulating, modeling or prototyping an artifact points to underlying truths about the ideas that inform its production. This would be in keeping with the realism informing Popper's conception of World 3 objects.

Popper's three worlds provide educators with alternative ways to re-conceptualize what education should be about. Bereiter (2002) has successfully employed this paradigm as a foundation for the pedagogical model of knowledge building community. Bereiter (2002) criticizes current education systems for focusing too much on changing the World 2 of students (i.e., the students' mind) and often neglecting the enculturation of students' competencies to work in World 3. Bereiter therefore advocates that school should shift the focus of classroom students' work to include as much emphasis on World 3 objects. Bereiter and Scardamalia (2006) described this shift as resulting in pedagogies reflecting the design mode of thinking. According to Bereiter and Scardamalia, in a knowledge building community that employs the design mode of thinking, it is essential to guide students to ask questions such as: (1) What is this idea good for? (2) What does it do/fail to do? And (3) how can it be improved? In other words, the guiding concerns are not necessary those associated with academic pursuit of truth, but with issues of practical constraints confronting proposed solutions to real world problems. In assessing the value or success of ideas, designers appeal to criteria such as feasibilty ("what is functionally possible within the foreseeable future"), viability ("what is likely to become part of a sustainable business [or social] model"); and desirability ("what makes sense to people and for people") (Brown, 2009, pp.18-19).

The last criterion points to a fundamental strength of the design approach: its emphasis on the human-centered nature of idea generation and knowledge construction. In so doing, the design approach highlights the normative and ethical aspects of the aim of producing and improving ideas that benefit individuals and society. As design approach seeks to find practical solutions to complex and at times wicked problems, it promotes and develops the capacity for judgment, and hence self-reflection. As Rowland (2004) observed, designers

> do not confront decisions that are clearly correct or incorrect, right or wrong. Instead they make judgments and learn how wise those judgments are through their consequences. Judgment is neither rational decision making nor intuition. It is the ability to gain insight, through experience and reflection, and project this insight onto situations that are complex, indeterminate, and paradoxical (p. 40).

In light of the complex nature of challenges and problems of the 21st century, the development of mature judgment complements efforts to educate for responsible local as well as global citizenship.

Building on the foregoing arguments, we would like to point out that Popper's model can be applied in wide contexts of other models of knowledge creation, which could include the knowledge spiral that is realized through the processes of socialization, externalization, combination and internalization (SECI) (Nonaka & Takeuchi, 1995); the expansive learning framework that is undergirded by cultural-historical activity theory (Engestrom, 1999); and "designerly" ways of knowing (Cross, 2006). These models of knowledge creation, together with the knowledge building community (Scardamalia & Bereiter, 2006), were constructed based on research in different social-cultural contexts and therefore emphasize different aspects of knowledge creation. For example, the knowledge spiral was based on studies of Japanese firms; the designerly ways of knowing were based on research in the context of western industrial design; expansive learning originated from studies of traditional craft and is concerned with innovating

practices; while the knowledge building community is practiced in classrooms focusing on students' creation of theories and knowledge (for review, see Paavola, Lipponen & Hakkarinen, 2004). Despite their differences, the common mode of knowledge creation is arguably design thinking in the broadest sense, that is, to pursue fruitful and generative ideas resulting in the production of goods, services, or solutions for authentic problems and challenges within their respective social cultural contexts. Design epistemology is thus the study of the dynamic, collaborative and holistic aspect of this process of knowledge creation that yields useful practice, products, and services. We suggest these models and Popper's view of three worlds as a generic knowledge creation model that could be applied to a wide range of disciplines and practices and therefore to a wide range of classroom contexts. Figure 1 depicts how various models of knowledge creations could be employed to mediate the relations between the three worlds.
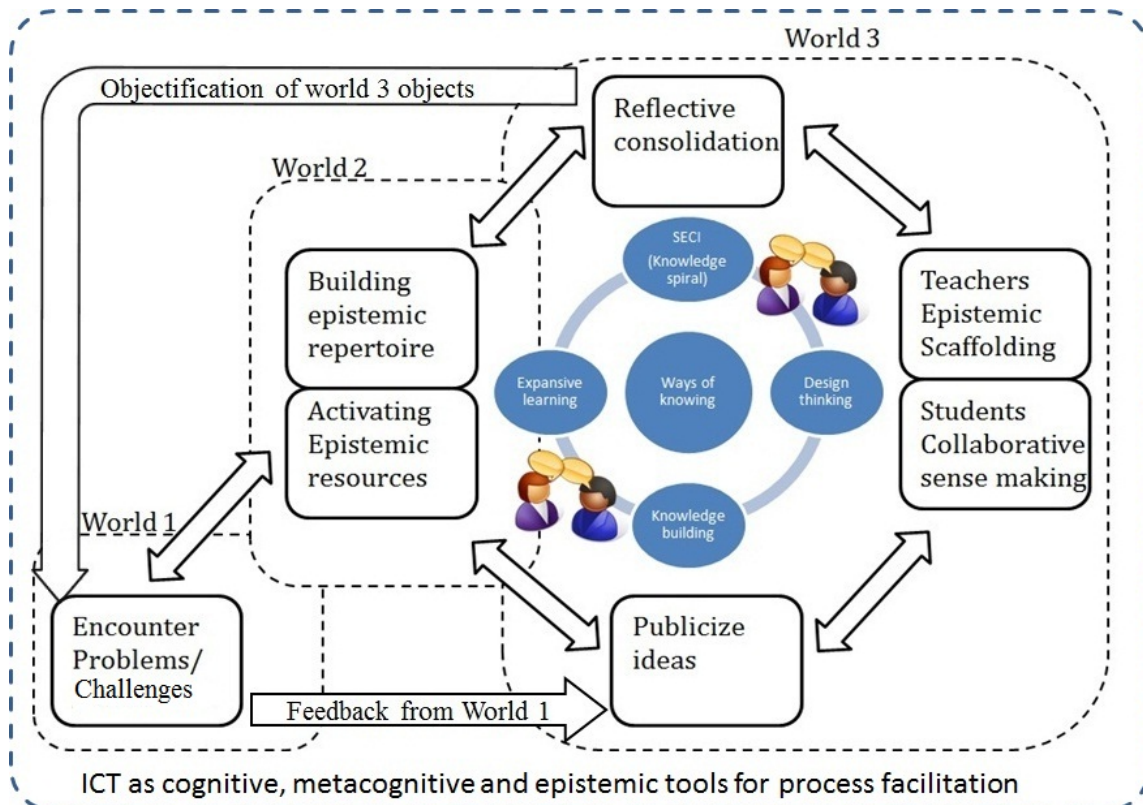
Figure 1. A knowledge creation model

Our model sees knowledge creation as a process that begins with the encountering of challenges or problem in their lived world (World 1). Encounter with challenges or problems that cause cognitive and affective dissonance are likely to drive individuals to seek resolutions. Resolution begins with the process of forming initial ideas (including problem representations and possible solutions). These initial ideas are likely to be formed through the activation of the initial epistemological resources, which refers to prior knowledge and everyday ways of knowing (see Hammer & Elby, 2002). Through articulation of the initial ideas (World 3) in a community (World 1 & 2) who share common interest and co-own the problem, various ways of knowing, acting, and making can be brought to bear and guide the knowledge creators to model and perform iterations of potential solutions. The initial articulation of ideas would also introduce diverse ways of understanding the problems and challenges, which would create multiple zones of proximal development to engage members in the community in interaction (Oshima, 1998). Through distributed and the collaborative sense making processes, the ideas are refined and some designed solutions are formed. This process in turns fosters the development of new epistemological resources for students. Through self-directed reflective activities, the epistemological resources that emerge during the process of idea improvement can be consolidated as epistemic repertoire or ways of knowing that can be drawn upon for future collaborative sense making. Elby and Hammer (2010) proposed similar approaches as they also see the possibilities of the development of coherent epistemological beliefs "as a progressive construction of patterns of resource activation" (p. 413).

In essence, as depicted in figure 1, we propose that the three worlds of Popper are interconnected through the conscious human mind (World 2) and they interact with one another reciprocally. Changes in one world invariably influence another ecologically. The key task of educators is to help learners appreciate the problems and challenges at hand and nudge the learners to adopt appropriate epistemic frames (Elby & Hammer, 2010) for collaborative knowledge construction. For example, when students are struggling to understand a natural phenomenon, the knowledge building approach is likely to be an appropriate approach in that it seeks to construct theories from students' prior knowledge and these theories are subjected to community refinement based on extensive range of epistemic activities which include both empirical research and literature review (see Zhang, Hong, Scardamalia, Teo & Morley, 2011). On the other hand, in dealing with problems pertaining to some social practices, it may be more fruitful to draw upon an expansive learning model as such a model was designed to innovate human activity system (Engestrom, 1999). In this proposed model, all legitimate ways of knowing developed to date can and should be drawn upon to improve enrich the social environment. . In addition, all World 3 objects are epistemic resources and they should be treated as improvable ideas (Bereiter, 2002; Elby & Hammer, 2010). We propose that when teaching and learning are framed from this ontological perspective, the epistemic nature of classroom would be dramatically transformed.

The role of ICT for design epistemology

ICT, in recent decade, has been used widely as a cognitive and metacognitive tool (Jonassen, 2000; Jonassen et al., 2008). In light of this perspective, the main objectives of ICT-assisted instruction are to help learners construct knowledge and develop relevant skills, learn how to re-organize knowledge and learn how to learn. Some educators (e.g., Tsai, 2004) also proposed that ICT can promote epistemic development by acting as an epistemic tool. When ICT is utilized as an epistemic tool for instruction, learners are encouraged to evaluate the merits of perspectives, information and knowledge acquired from ICT-supported environments, and to probe the nature of learning and knowledge construction.

Similarly, we believe that ICT can be an adequate tool for promoting learners' design epistemology. With rapid advances in ICT, more creative learning and knowledge construction become possible (Stahl, Koschmann, & Suthers, 2006). In fact, it is difficult to imagine any current professional involved in creating knowledge not using multiple affordances of ICT. Similarly, if teachers engage students in knowledge creation, ICT integration would become a norm in classrooms. A major affordance of ICT in fostering design epistemology lies in the fact that ICT encourages user to play with ideas. Computers can store many versions of the idea in the idea improvement processes and help track the historical development of ideas, for example, in an online forum. In addition, the ease of juxtaposing parts from different sources together and remixing these parts to form new ideas also encourages users to look at ideas from a new perspective. Researchers have articulated a range of technological affordances that support the cognitive, metacognitive, collaborative and epistemic aspects knowledge creation (Chai & Lim, 2011; Jonassen, Howland, Marra, & Crismond, 2008; Scardamalia & Bereiter, 2006; Tsai, 2004).

Possible research for design epistemology

Drawing upon the various knowledge creation models reviewed above, the common demand of these models can be summarized as nurturing learners' "*epistemic repertoire*." By epistemic repertoire, we refer to a range of ways of knowing that enable an individual to develop viable cognitive artifacts to make sense of the problems and challenges that he or she encounters. Emerging problems and challenges in the current world originate from all areas of our live, and they are necessarily addressed through multiple ways of knowing. These ways of knowing, which are often associated with discipline-based or inter-disciplinary approach to knowledge creation, offer different and competing perspectives and solutions to the problems. In essence, we see the key challenge of today's education as building an individual's epistemic repertoire that could facilitate in-depth understanding of the cognitively (and likely to be affectively) challenging encounters and formulation of innovative/creative responses to address these challenges.

Knowledge creation and design thinking are complex processes that defy simple reduction. To date, studies in personal epistemology have drawn upon various methodologies to address different level of analysis (see Bendixen & Feucht, 2010). However, many gaps in understanding still exists and the findings are at time contradictory (Hofer, 2010). To achieve comprehensive and coherent understanding of personal design epistemology, we would therefore

advocate that multiple methods be brought to bear on this area of research. A review by Deng, Chen, Tsai and Chai (2011) of research on scientific epistemology has illustrated how multiple methods illuminate different aspects of students' beliefs. It is therefore necessary to design questionnaire to survey general epistemic outlooks especially on the aspects of individual's view about design thinking and knowledge as human construction or viable improvable ideas. In addition, interviewing all levels of knowledge creators would help to piece the puzzle together. However, instead of beginning research of design epistemology with what people say or believe in, we would suggest that a better foundation to build understanding about personal epistemology is on what people do during the act of constructing knowledge through the design mode of thinking. In other words, we argue that researching individual epistemic repertoire should begin with how they are enacted.

Work by Hammer and Elby (2002) on epistemological resources could give us a more concrete handle in terms of what epistemological repertoire consists in and how it can be investigated. Epistemological resources are regarded as fine-grained knowledge elements possessed by a student, which can be activated by different contexts (see also p-prim theory by diSessa (1993), that is, they are by nature World 2 elements stored in the mind of the students. Hammer and Elby propose four categories of epistemological resources:

- The general nature of knowledge and how it originates (e.g., knowledge as propagated stuff; knowledge as constructed, knowledge as fabricated…)
- Resources for understanding epistemological activities and forms (e.g., brain-storming, building or making to think, and lists)
- Epistemic games and epistemic forms (we would also include modeling, or prototyping)
- Resources for understanding stances one may take towards knowledge (e.g., doubting and accepting)

In classroom situations, depending on how the pedagogical intentions are framed epistemologically by the teachers, students discursively activate various aspects of his or her epistemological resources to deal with the problems at hand. Elby and Hammer (2010) view the activation of as locally coherent (e.g., sometimes across contexts) rather than haphazard and incoherent. In addition, they proposed students' "development as a progressive construction of patterns of resource activation" (p. 413). However, the contextually activated resources may not be appropriate to the epistemic task at hand and this would hamper students' effort or distort the teachers' epistemic framing of the task (see for example, Rosenberg, Hammer, & Phelan, 2006). In other words, students may activate inappropriate World 2 or World 1 objects to work on a World 3 object, or vice versa. A teacher's job would then be to reframe students' effort through epistemic scaffold. Beyond such one-to-one epistemic scaffolding, it is clear that teachers need to shape and reshape the epistemic climate of the class, represent subject matter as World 3 objects to be improved upon; steer the metacognition of the class towards coordinating multiple perspectives for idea improvement and engage students in using appropriate ICT tools to support the complex problem solving processes.

Assuming that the teacher could successfully achieve the above, what, how and why students' epistemic repertoire are formed and changed would be of great interest to researchers. However, as portrayed in Figure 1, to study students' epistemic repertoire in isolation is to confine it to World 2 exclusively. This is likely to distort understanding rather than unpack the emergence of epistemic repertoire. We therefore suggest that regardless of the researcher's approach to the study of design epistemology, sufficient characterization of the World 1 and the World 3 is also necessary.

Conclusion

In this paper, we argue for design epistemology, an extension of personal epistemology, as the epistemological basis for educational reform to prepare our students for the Knowledge society. We elaborate the construct of design thinking and its roles in knowledge creation from two key perspectives: Nigel Cross's design realm of knowledge and its relation to science and humanities realm of knowledge, and Popper's three ontological worlds of objects. Educational technologies, we suggest, play an important role in supporting knowledge creation by reifying conceptual artifacts, tracking historical development of conceptual artifacts, and juxtaposing these artifacts for creation of new artifacts. Most importantly, we argue that in this Knowledge Age, developing students' epistemic repertoires, or ways of knowing, should be the key educational reform effort and research agenda.

Moving forward, we propose a few key research agenda and directions anchored on design epistemology. Our arguments, we hope, serve as World 3 objects that could trigger further discussion and research effort for the benefit

of our students, who are the future pillars of the knowledge society. Researchers can further explore how educational technologies can play an essential role in this respect.

Note

All of the authors contribute to the paper equally.

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Sustainable e-Learning: Toward a Coherent Body of Knowledge

Karen Stepanyan[1*], Allison Littlejohn[2] and Anoush Margaryan[2]

[1]University of Warwick, Department of Computer Science, Coventry, CV47AL, UK //
[2]Caledonian Academy, Glasgow Caledonian University, 70 Cowcaddens Road, Glasgow, G40BA, UK //
K.Stepanyan@warwick.ac.uk // Allison.Littlejohn@gcu.ac.uk // Anoush.Margaryan@gcu.ac.uk
*Corresponding author

ABSTRACT

This paper explores the concept of sustainable e-learning. It outlines a scoping review of the sustainability of e-learning practice in higher education. Prior to reporting the outcomes of the review, this paper outlines the rationale for conducting the study. The origins and the meaning of the term "sustainability" are explored, and prevalent approaches to ensure sustainable e-learning are discussed. The paper maps the domains of the research area and concludes by suggesting directions for future research that would improve current understanding of key factors affecting the sustainability of e-learning practice to develop a more coherent body of knowledge.

Introduction

Many e-learning initiatives fail. Transient as they are, these projects often exhaust the resources and degrade in their impact—and, therefore, are destined to be unsustainable. The lasting success of e-learning initiatives is a growing concern for educational institutions that rely on governmental funding or commercial benefits. Austerity measures have led to a renewed interest in the concepts of sustainability and sustainable practice in e-learning. There is also renewed interest by educational researchers in finding practical solutions to improve the sustainability of e-learning. These studies investigate the viability of integrated e-learning services and their cost-effectiveness, aiming to inform policy and strategic decision making. While many studies in the field of e-learning deal with issues of sustainability, such as cost-effectiveness and quality management, without explicitly using the term, we propose that "sustainability" is a useful umbrella concept because it helps bring together diverse terminology and various strategies addressing a range of interrelated issues in the area of e-learning. This paper provides an overview of predominant approaches to research on sustainable e-learning and outlines findings of a scoping study (Stepanyan, Littlejohn, & Margaryan, 2010) funded by the UK Higher Education Academy (HEA) through the "Supporting Sustainable e-Learning Forum" special interest group (SSeLF SIG). The paper also addresses a gap in the literature by providing synthesis of the empirical research on sustainable e-learning, outlining prevalent perspectives on the concept of sustainability, presenting and discussing the outcomes of the scoping study, and suggesting directions for future research.

Rationale for researching sustainable e-learning

Educational institutions face challenges in ensuring effective teaching and learning in a rapidly changing society. The education sector is constantly adapting to external drivers, including societal and technological changes, quality standards, and financial constraints. Information technologies are extending opportunities for learners to learn outside institutions, transforming conventional views on education (Collins & Halverson, 2010). These transformations require educational systems to adapt, to meet the needs and expectations of learners and other stakeholders. Hence, institutions have to anticipate, withstand and, where possible, capitalise on the present and future waves of change. Consequently, e-learning attracts the attention of educational administrators and policy makers. However, many e-learning initiatives are not sustained. There is a pressing need to seek explanation to this phenomenon in the context of the recent funding cuts.

One consequence of the global economic crisis of 2008 is the widespread cuts in government funding (Bates, 2010). The higher education (HE) sector across Europe is negatively affected, with most European countries reducing HE funding (EUA, 2010). For example, the UK Government plans to cut HE funding by 40% by 2014–15 (Morgan,

2010). Similar patterns can be observed beyond Europe, with comparable reductions in HE sector funding announced in Australia (Nicol, 2010), the US (Chea, 2009; Toope & Gross, 2010), and Canada (Cunnane, 2010). To deal with financial austerity, some universities have decided to invest in improving their international reputation, hoping to attract students and maximise their return on investment (Brown, 2010). International and domestic students alike, faced with the prospect of paying fees rather than receiving scholarships, are evaluating the value they receive for their money. Student opinion affects institutional ranking, stimulating universities to improve the quality of their provision and to enhance their reputation (Baty, 2010). To address some of these challenges universities are exploring ways to capitalise on emerging technological affordances.

Many institutions have introduced e-learning to improve cost-effectiveness. However, it is unclear whether return on investment is actually realized. Where return on investment is achieved, does this result in a sustained reduction in costs or an increase in benefits? Funding agencies increasingly demand guarantees for long-term maintenance of e-learning projects. Furthermore, sustainability and longevity remain a pressing concern for the users of e-learning resources and systems (Weibel et al., 2009). Therefore, a sound evidence base on the sustainability of e-learning practices and their long-term benefits is essential to the future development of universities. Critical reviews of the evidence around the sustainability of e-learning are vital for strategic decision and policy making. Yet, there is no literature synthesising the multiple perspectives related to the sustainability of e-learning. Given the gap in the literature, the need for conducting a review such as a scoping study becomes evident. The methodology of a scoping study enables synthesising a broad range of existing perspectives and outlining the existing knowledge. This study aims to provide a baseline in the current understanding of sustainability of e-learning by carrying out a review of research in this area. It synthesises existing literature that reports key factors affecting the sustainability of e-learning. The paper outlines a review of a broad range of literature in areas broadly associated with sustainable e-learning.

Methodology and data sources

This study uses a methodology known as a "scoping review" (Davis, Drey, & Gould, 2009). A scoping review is a broad, comprehensive study of the literature, which is augmented through consultation with key experts with knowledge of the area (Arksey & O'Malley, 2005). This method allows identification of themes and trends emerging from diverse bodies of scientific knowledge (Davis et al., 2009; Rumrill, Fitzgerald, & Merchant, 2010). The methodological foundations of a scoping review allow the synthesis and mapping of a broad empirical knowledge base into a single realm. The concept of mapping can be described as a process of interpreting and synthesising qualitative data by sifting and sorting material according to key issues and themes. The purpose of the mapping is to summarise the evidence uncovered by the review and to identify gaps in knowledge (Levac, Colquhoun, & O'Brien, 2010).

Scoping reviews provide a systematic method for critically appraising disconnected resources, creating an overview of current knowledge. Scoping reviews are conceptually different from systematic reviews or meta-analyses; Meta-analyses or systematic reviews are usually restricted to papers that employ specific methodologies. Scoping reviews are a useful method in situations where systematic reviews are problematic, for example within relatively new areas such as e-learning, where ideas and evidence are still emerging (op. cit.). A scoping review is particularly useful in providing an overview of the current knowledge around sustainable e-learning because it brings together the multitude of perspectives that contribute to this area. However, scoping reviews have some limitations in that they provide only narrative or descriptive accounts of broad research areas, rather than in-depth analysis. Therefore, the usefulness of a scoping study is linked to decisions on defining the breadth and depth of the review (Arksey & O'Malley, 2005). Despite this limitation, scoping reviews provide insight into complex areas, and the output from the review can be used to focus and refine future studies (Levac et al., 2010). This scoping review identifies and maps concepts relevant to sustainable e-learning, to provide a baseline for future research studies.

This scoping review is purposefully broad in nature to allow key concepts associated with sustainability to be mapped against primary sources of evidence. This is not an attempt to systematically review or perform a meta-analysis of sustainable e-learning. Future studies could adopt alternative methods to provide a more in-depth understanding of sustainable e-learning. This study aims instead to provide a baseline to inform future developments in the education sector.

To ensure a broad, yet systematic approach, this scoping review adopted a five-phase methodological framework proposed by Arksey and O'Malley (2005). This framework is a useful tool for the analysis, synthesis, and review of a range of broad, diverse research studies (Davis et al., 2009).

The first phase of the scoping study explored the concept of sustainability and operationalised it within the context of e-learning. This phase was divided into the following sub-phases:

1. conducting an initial review to gain an overview of the variety of approaches adopted in sustainable e-learning research
2. adopting a working definition of the term sustainable e-learning, based on the initial review
3. compiling a set of key themes common to sustainable e-learning research
4. compiling a set of search keywords associated with these themes
5. identifying electronic databases, web services and journals to carry out a literature search

The second phase involved an in-depth literature search to identify relevant studies around each of the operational domains. In the third phase, we defined inclusion and exclusion criteria applied to all the articles sourced through the literature review. The fourth phase involved data extraction, synthesis, and interpretation of the material. A spreadsheet summarising all articles that were reviewed was compiled for further analysis. Finally, in the fifth phase, articles were collated and analysed to abstract key issues and identify gaps in the literature.

The literature search made use of the library services provided via electronic databases available at Brunel University (which were accessible to the lead author at the time of the review) using the DialogDatastar service. British Education Index (BEI), Australian Education Index (AUEI), and the Education Resources Information Center (ERIC) databases were used for literature search. BEI covers over 500 English and European journals and includes over 150 thousand records to journal and conference papers, research reports, and electronic texts (Sheffield, 2005). Finally, the ERIC database index was used to search key articles (published by Elsevier, Sage, Routledge, and other key publishers). ERIC is a key database for education literature (Hertzberg & Rudner, 1999). The search was limited to publications between 2000 and 2010, covering a recent broad body of literature.

The inclusion criteria limited the reviewed papers to a) discussions of issues of sustainable e-learning practice in HE; b) studies of sustainable strategies and approaches applied and implemented in universities, and finally, c) case studies and empirical research reporting on issues of (un)sustainable e-learning practice. Papers focusing on education sectors other then HE, such as primary or secondary education or adult workplace learning, were not considered. The review includes both peer-reviewed and non-peer-reviewed grey literature. As part of the assessment, papers published in peer-reviewed journals were prioritized. However, articles from non-peer-reviewed sources were included when they pointed to new ideas or gaps in the literature. Literature that was not available as full text was not considered. Key studies referenced within texts were sourced where necessary.

The literature search was conducted in two stages. First, a set of generic keywords—"sustainable e-learning," "sustainable online learning," "sustainable technology enhanced learning," and "sustainable distance learning"— were used to explore the literature. The compound results of the queries around 500 papers, which were further filtered down. The process of initial filtering was based on assessing the title, keywords, and the abstract of the papers. The resultant papers were assessed against the inclusion criteria. The vast majority of papers did not satisfy the inclusion criteria reducing the number of papers selected in this initial stage to 15. The review of the selected papers pointed to a range of variations of research foci. The observed variations suggested extending literature search by using additional keywords identified from the reviewed literature. The use of additional keywords allowed consideration of studies that addressed issues of sustainability, without directly referring to the term. Among the identified keywords were, for example, "cost-effectiveness," "economies of scale/scope," "effective/innovative practice," "communities of practice," and "networks," used along with keywords such as "longitudinal" and "long-term," to identify studies focused on continuity over time. These keywords were used to extend the first stage of the literature search.

The second stage of the literature search focused on empirical works (as defined above by the inclusion criteria [b] and [c]) that matched the selected set of keywords. In addition to using educational databases, Google Scholar was used at this stage to enable scoping a greater pool of literature. A Google search purposefully broadened the domain of literature included in the review. A comprehensive review that covers all research areas associated with each of the chosen keywords is beyond the scope of this study. Nevertheless, the review was broad and around a thousand papers were retrieved and assessed.

To complement the literature search, feedback on the initial drafts of the review and references to other relevant sources were requested from eleven experts in the field, acknowledged at the end of the paper. As a result, a total of 46 articles that focus either on sustainable e-learning as a main topic or examine individual factors that contribute to improved sustainability were selected, reviewed, and discussed.

Results and findings

The concept of sustainability

The concept of sustainability spans a number of academic disciplines and is closely associated with environmental science. Sustainability has been considered from philosophical, historical, economic, political, social, and cultural perspectives (Becker, Jahn, & Stiess, 1999). Given the large number of perspectives and contexts in which the term *sustainability* is used, its meaning varies widely across the literature. Therefore, a clear definition is useful (Brown, Hanson, Liverman, & Merideth, 1987). Shearman (1990) outlines key factors, framed as key questions, required to bring about sustainability: Why is sustainability desirable? What form of sustainability is best? How should sustainability be pursued? An inquiry into the etymological as well as the lexical origins of the term *sustainability* provides a clearer understanding of the term.

The term "sustainable" is defined by dictionary references as: "able to be maintained at a certain rate or level" (*Oxford Dictionary of English* [Soanes & Stevenson, 2005]). The verb "sustain" is defined (ibid.) as: "cause to continue for an extended period" or "uphold, affirm, or confirm the justice or validity." Regardless of the variations in the definitions of the term, there appears to be a common foundation: a property of continuity over time.

The concept of sustainability is frequently associated with the mandate adopted by the International Union for Conservation of Nature (IUCN) in 1969 and the United Nations Conference on the Human Environment in Stockholm in 1972 (Adams, 2006). Since then, sustainability has been discussed and debated across a range of contexts and from a range of perspectives. The notion of sustainability has penetrated political, economic, and social agendas and plays a major part in shaping the discourse on sustainable society, economy, energy, agriculture, and resource use (Brown et al., 1987). Sustainability is often described as the "goals or endpoints of a process called 'sustainable development'" (Diesendorf, 2000, p. 22). The *Brundtland Report* (1987, p. 43) defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This definition captures the complexity of the term by integrating a set of dimensions into a single concept. It appears, therefore, that the concept of sustainability brings together ideas from multiple disciplines to describe progress in different domains.

Sustainability in the environmental literature

The environmental literature provides insight into the origin, meaning, and development of the term *sustainability*. Analogies between educational and ecological systems and the growing interest toward studies of educational phenomena in their complexity of interrelated factors further justify this line of inquiry (Davis & Sumara, 2006; Mason, 2008). Lélé (1991) views ecological sustainability as a developmental process with three interlocking dimensions: economic, environmental and social. Mainstream thinking in the area of sustainability employs these dimensions as the so-called "three pillars" of sustainability (Adams, 2006). Ideas around sustainability are frequently based around the integration of these pillars into a unified system. As such the instantiation of sustainability is viewed as a long-term, perpetual process (Kemp, Parto, & Gibson, 2005).

Sustainability in an educational context

Discourse around sustainability in education has developed in two broad directions, focusing on either: a) education *for* sustainability or b) sustainability *of* education. Education for sustainability focuses on environmental sustainability through educational solutions (Bourn & Shiel, 2009; Dawe, Jucker, & Martin, 2005; Sterling, 2001). Sustainability *of* education focuses on the implementation of sustainable forms of "successful" practice through educational development, leadership, and innovation (Davies & West-Burnham, 2003). Despite these two differing

foci, the traces of environmental perspectives are evident in both views: sustainability *of* education and education *for* sustainability. Furthermore, sustainable education is commonly used throughout the literature regardless of the focus. In this paper, sustainability *of* education is the main focus.

Environmental perspectives on sustainability have diffused into the field of e-learning. A commonly used definition of sustainability, first outlined in Brundtland's report, has been adopted within the e-learning context. One example of this adoption of the term is Robertson's study, which defines sustainable e-learning as "e-learning that has become normative in meeting the needs of the present and future" (2008, p. 819). Articles on sustainable e-learning discuss a number of key factors that offer potential long-term improvements to e-learning practice (Arneberg et al., 2007; Bates, 2005; Littlejohn, 2003b). Variations of scale are also apparent in the literature, as studies discuss the issues and implications of sustainability on macro/global (Downes, 2007), meso/institutional (Hope & Guiton, 2005), and micro/project levels (Grossmanna, Weibela, & Fislerb, 2008).

One definition, by the National Committee of Inquiry into Higher Education emphasises the balance between the costs and added value of employing technology, defining sustainable e-learning as "the adoption of technology to maintain teaching quality at reduced unit costs" (2003b, p. 91). Other definitions include the continuity of the advantageous positions defining sustainability as "the continuation of benefits after project funding has ceased" (Joyes & Banks, 2009); or similarly as "programmes being offered on a continuous basis and not phased out after a defined project period or after specific subsidies are terminated" (Arneberg et al., 2007, p. 6). Some definitions place emphasis on policy. For example, Meyer (2006, p. 1) defines sustainability as "policies and practices that improve the likelihood that an online educational program will be financially viable."

Some studies highlight impact and educational quality as an important element of sustainability. For example, the study by Bates (2005) identifies organisational factors that lead to sustained benefits of e-learning. Bates argues that an institutional culture geared toward continuous improvement and adopting a positive attitude toward personal development increases the sustainability of e-learning. Similar views are held by Hope and her colleagues (2005). However, despite the significance of sustainable e-learning in the literature, no generic framework or model for sustainable e-learning was identified. This gap in the literature may be explained by the fact that there are few studies that synthesise the knowledge in the area. This scoping study, and the research that may spawn from it, may contribute to addressing this gap.

Since this scoping review was exploratory, the study had to take a wide view of the concept of sustainable e-learning. Despite the diversity of perspectives on sustainable e-learning, "sustainability" is a useful umbrella term that brings together diverse terminology and various strategies addressing a range of inter-related issues such as effectiveness, efficiency, or progress in the area of e-learning. Therefore, synthesising reviewed definitions, a broad working definition of sustainable e-learning was adopted as follows: Sustainability is the property of e-learning practice that evidently addresses current educational needs and accommodates continuous adaptation to change, without outrunning its resource base or receding in effectiveness.

Domains and themes of sustainable e-learning

As part of the review, we collected information about the methods, keywords, and descriptions of the included papers (Stepanyan et al., 2010, Appendix 5, pp. 46–55). A number of themes regularly resurfaced from the articles reviewed. These themes were identified, coded, and abstracted, through an iterative process. All themes associated with sustainable e-learning were then inductively categorised and synthesised into a set of broad domains that capture all these themes. These three domains are: Resource Management, Educational Attainment and, Professional Development and Innovation. Each of the papers reviewed during this study were mapped against at least one of these domains, depending on their keywords, main contributions, approach, and primary focus.

Although each domain is distinct, there is overlap across the domains as illustrated in Figure 1. The numbers in each section of the diagram correspond to the number of papers reviewed and categorised.
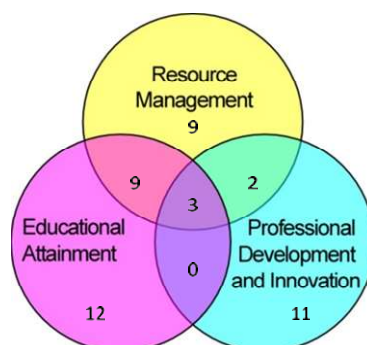
Figure 1. Domains of sustainable e-learning research and numbers of associated papers

These domains illustrate the foci of research in sustainable e-learning as abstracted from the literature. They are akin to the "three pillars" of sustainable development (Adams, 2006; Robertson, 2008, p. 819). Each domain allows integration of a range of competing factors influencing sustainable e-learning. The factors were analysed in line with each of the three domains to abstract common research themes within each domain and to discuss their contribution to the wider discourse on sustainable e-learning. In the next section we outline and discuss the results and highlight the potential impact of the studies in relation to sustainable e-learning.

Resource management

The domain of Resource Management focuses on the cost of e-learning. Articles that mapped against this domain include studies of the strategies and approaches adopted by institutions to improve the effectiveness of human and other resources. Resource Management studies examined cost-effectiveness, efficiency gains, and economies of scale and scope. The emerging themes included models and frameworks for resource management, cost-effectiveness of distance and blended learning, Open Educational Resources (OERs), and reusable learning materials.

Costs were considered in relation to strategic targets, for example, the quality of teaching/learning, the numbers of students, or technological and pedagogical innovation. Amongst the models proposed for improving the productivity and cost-effectiveness of HEIs is Molenda's (2009) systems theory approach that rationally divides teaching and learning tasks. Nicol and Coen (2003) and Laurillard (2007) suggest more complex models to evaluate the benefits and costs of e-learning.

Some studies focussing on fully online e-learning practice (for example, Perraton & Naidu, 2006; Ramage, 2005) focused on problems with distance learning business models. Ramage (2005) focused on return on investment, identifying that 83% of the considered institutions were not cost-efficient. The more successful institutions recorded a return-on-investment of only 15%. Other studies examined reducing staff workload as a strategy to improve resource management. For example D. Nicol and Draper (2009) examined the redesign of course assessments to improve learning outcomes and reduce staff workload. Similarly, Loewenberger and Bull (2003) examined reusable question banks as a means of reducing staff time on assessment.

Another approach to reducing staff workload is reusing, rather than recreating, educational resources, to produce a so-called economy of scale of reusable resources (Littlejohn, 2003a). There are many studies and initiatives on Open Educational Resources (OERs) in the literature. Although OERs offer potential for cost-effectiveness, there is little empirical evidence on actual cost savings, due to systemic difficulties in calculating return on investment in universities (Friesen, 2009; Geser, 2007). An active "movement" has formed around developing and managing OERs, the Open Educational Resources Movement (D'Antoni, 2009). Business models are being developed to capitalise on the collaborative creation of content by large numbers of users (Bruns, 2006). However, tensions and contradictions exist between the release of resources within communities of practice and "open release," which releases content to anyone who wishes to use it. This has been identified as a major barrier to the future development, release, and reuse of OERs (McGill, Beetham, Falconer, & Littlejohn, 2011). The potential of OERs to improve the sustainability of e-learning is significant, however reviewing this growing domain in depth is beyond the scope of this paper.

Educational attainment

Educational Attainment is another domain abstracted from the literature on sustainable e-learning. Discussions around Educational Attainment focus on measures of student achievement, retention rates, skill acquisition, and personal development. Emerging themes include evidence of benefits, perceptions of quality, usability of new technologies, and student performance.

Benefits rather than costs of e-learning are often considered. For example, Dyson and colleagues (2009) claim that mobile technologies offer affordable and effective solutions for mainstream teaching and learning. They identify the benefits of mobile learning as mobile-supported fieldwork, stimulation of interactivity in large lectures with mobile technology, use of mobile devices for learning about mobile technology, and use of podcasting. They claim that mobile technologies offer affordable and effective solutions that can be adopted for teaching and learning on a wider scale. Comprehensive assessment of the sustainability of mobile technologies, however, requires longitudinal studies, of which few exist.

Another group of studies focused on the benefits of using information technologies for teaching and learning (Clark, 2001; Means, Toyama, Murphy, Bakia, & Jones, 2009). Bernard et al. (2004) argued that the quality of course design is more important than the medium of learning. Two further studies, based on questionnaire data, focused on individual factors of successful educational practice, such as student retention (Levy, 2007) and student satisfaction (Lee, Yoon, & Lee, 2009). A key message emerging from this domain is that studies that prioritise sustained benefits rarely or only indirectly consider the associated costs of maintaining or improving effectiveness of e-learning practices.

Professional development and innovation

Some studies view sustainability as a commitment to continuous improvement and adaptation to a constantly changing environment. This perspective is evident in the third broad domain described as Professional Development and Innovation. Articles mapped within in this domain focused on strategies for adapting to change. Emerging themes within the domain include teacher training and development, institutional transformation, and educational leadership.

Restructuring educational institutions to adapt to the external constraints is viewed as important for sustainability. For example, a study by Gunn (2010) emphasised the importance of institutional restructuring, not just physically, but culturally as well through introduction of supportive organisational structures and adoption of a shared vision (ibid.). Similarly, e-learning policies (De Freitas & Oliver, 2005) and educational leadership (Garrison & Akyol, 2009) are considered important for institutional change, with key stakeholders (e.g., teachers and learning technologists) central to driving forward improvements in e-learning practice (ibid).

Despite limitations of formal training programmes, faculty development is seen as important to successful and sustainable applications of e-learning (Rovai & Downey, 2009). Lefoe et al. (2009) report the need for comprehensive faculty development and support programmes and offer a set of strategies that include developing shared understanding of philosophies and technological affordances; encouraging active practice; continuous reflection; and development of shared vocabularies. However, teacher training is not the only way of improving faculty expertise. Another approach is through communities of practice or professional networks.

There is a growing body of literature on strategies for developing and sustaining communities of practice (Russell, 2009). Professional networks have a less cohesive structure and different power dynamic compared to communities of practice. These networks can induce a qualitatively different form of professional development. The ubiquity of social platforms and readily available networking tools allowed Brouns and colleagues (2009) to explore perceptions of academic staff of their use of social network platforms for professional development. In summary, the literature on Professional Development and Innovation highlights the role of educational leadership and teaching staff in implementing sustainable e-learning.

Discussion and conclusions

This scoping study enabled initial mapping of the area of sustainable e-learning, highlighting the differences and limitations of the reviewed literature. By categorising and synthesising a selection of the current literature, the paper enables commenting on the state-of-the-art of sustainable e-learning research. This section outlines a number of broad observations arising from the scoping study.

First, the literature contains a number of studies that discuss Resource Management as part of sustainable e-learning. If educational research is to contribute to societal wellbeing, it should be grounded within current social, political and philosophical changes (Biesta, 2009). Reeves et al. (2005) call for "socially responsible" research, through which researchers position their work in relation to society as a whole. Yet, most research into the sustainability of e-learning practice is not framed within fundamental societal issues related to education. When sustainability is considered in a constricted way, for example by examining financial viability and return on investment without consideration of wider issues, contributions to the wider debate of public good may be limited or even distorted. This imbalance constrains the evaluation and questioning of educational practices.

Second, cultural and societal changes are challenging traditional educational practices. Institutions are being forced to adapt to ongoing change; harnessing the power of technology is an important step (Collins & Halverson, 2010). Thus, sustainable e-learning cannot be explored without consideration of the rapid and continual development of digital technologies. Technological affordances open up new, ubiquitous opportunities for people to learn in a number of ways using a variety of approaches. We identified a gap in the literature in relating educational attainment to technological change (within the Professional Development and Innovation domain). In other words, the knowledge base to support effective implementation is dispersed across a number of domains. The integration of key relevant research elements into a coherent body may lead to more effective adaptation within institutions.

Third, the inquiry into origins of the term sustainability and its use within educational literature reveals two independently developing streams of research, sustainability of education and education for sustainability. While there are arguments in support of the potential for bridging the gap between sustainable e-learning and wider concept of sustainability (Hall, 2010; Hopkins, 2009), the research into sustainable e-learning practice develops independently from that of environmental sustainability.

Fourth, through categorising and recording the methodological foundations of the studies we reviewed, we can conclude that *few studies combine and synthesise empirical work.* Meta-analyses or systematic reviews could give greater insight into Educational Attainment. However, we sourced only two meta-analysis studies within the domain of Educational Attainment. Consequently, it is difficult to translate and diffuse findings beyond the narrow contexts in which studies were carried out. Despite this limitation, many studies do try to transfer findings through "best practice" examples or case studies, when in fact the consequences of a particular e-learning approach is likely to be different in diverse settings. We found a shortage of long-term studies that explore key factors for sustainability and to distinguish these from short-term benefits. Furthermore, studies in Educational Attainment that rely on questionnaire data when analysing technology adoption tend to overlook the critical changes in mindset or culture that underpin successful adoption of e-learning (Collis & Moonen, 2008). A recommendation is to conduct long-term research studies.

Fifth, the distribution of the papers identified during the literature search across the domains (see Figure 1) suggests that few studies examine the tensions between the concepts of cost-efficiency, effective pedagogy, and continuous innovative practice. There are a limited number of studies on strategic approaches that reduce costs and improve the effectiveness of teaching. Future research must investigate the trade-offs. There are noticeable differences in the priorities within empirical studies, such as example costs versus benefits, or preferences such as teacher training versus opportunities to network. Improved understanding of these tensions, aligned with better insight into multiple stakeholder perspectives, could provide better pointers toward future e-learning sustainability.

Sixth, taking into account the balance of the studies sourced through this review, there is scope for developing sustainable business models for higher education, based on e-learning approaches. Few projects or initiatives have explored new business models (Nicol & Coen, 2003; Nicol & Draper, 2009). Interest in finding new ways of generating revenue and attaining return on investment has increased in the current period of austerity (Crossick, 2010). These business models range from reducing the time period of the degree, changing the costs/benefits of

conventional teaching approaches, to introducing radically new business models, such as Massive Open Online Courses (MOOCS), or drawing upon networks and collectives (Dron & Anderson, 2007). Research on the creation and release of OER is examining actual, rather than perceived, benefits around the release of resources, providing a more realistic view of return on investment (McGill et al., 2011). Investigation of these business models is important in ensuring return on investment is achieved, either through reduced costs or increased benefits to learners or institutions.

In summary, this scoping review identified significant gaps in the literature. The gaps were identified by assessing the limitations of reviewed papers and discussing future work. Within the Resource Management domain, gaps include the following:
➢ meta-analysis of e-learning costs (these have been restricted due to lack of available data)
➢ empirical research on economies of scope
➢ long-term longitudinal analysis on the effects of reducing costs
➢ empirical research on cost-effectiveness of OER

The Educational Attainment domain would benefit from further research in the following:
➢ student/teacher mindset toward e-learning and its change
➢ improvement of learning outcomes and retention rates without substantial increases in costs
➢ benefits of employing new technologies such as mobile devices or podcasting. Professional Development and Innovation would benefit from
➢ long-term analysis of leadership impact on change
➢ long-term analysis of faculty development on change

Overall, research on new business models for higher education, costs, and benefits, focusing on return on investment, are vital for future sustainable e-learning.

The major limitation of this study is the limited number of articles reviewed in comparison with the wide range of literature related to sustainable e-learning. However, this study provides a starting point and this future studies can build on these findings, adopting other methods (systematic reviews or meta-analyses) to allow in-depth analyses.

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A Wiki-based Teaching Material Development Environment with Enhanced Particle Swarm Optimization

Yen-Ting Lin[1], Yi-Chun Lin[1], Yueh-Min Huang[1*] and Shu-Chen Cheng[2]

[1]Department of Engineering Science, National Cheng Kung University, Taiwan, R.O.C. // [2]Department of Computer Science and Information Engineering, Southern Taiwan University, Taiwan, R.O.C. // ricky014@gmail.com // jellyplum@gmail.com // huang@mail.ncku.edu.tw // kittyc@mail.stut.edu.tw
[*]Corresponding Author

ABSTRACT

One goal of e-learning is to enhance the interoperability and reusability of learning resources. However, current e-learning systems do little to adequately support this. In order to achieve this aim, the first step is to consider how to assist instructors in re-organizing the existing learning objects. However, when instructors are dealing with a large number of existing learning objects, manually re-organizing them into appropriate teaching materials is very laborious. Furthermore, in order to organize well-structured teaching materials, the instructors also have to take more than one factor or criterion into account simultaneously. To cope with this problem, this study develops a wiki-based teaching material development environment by employing enhanced particle swarm optimization and wiki techniques to enable instructors to create and revise teaching materials. The results demonstrated that the proposed approach is efficient and effective in forming custom-made teaching materials by organizing existing and relevant learning objects that satisfy specific requirements. Finally, a questionnaire and interviews were used to investigate teachers' perceptions of the effectiveness of the environment. The results revealed that most of the teachers accepted the quality of the teaching material development results and appreciated the proposed environment.

Keywords
Particle swarm optimization, Wiki-based revision, Material design

Introduction

Over the last decade, e-learning has become widely applied in the educational domain. A major aim of e-learning is to increase interoperability and reusability of learning objects. Thanks to the establishment of various standards such as IEEE Learning Object Metadata (LOM) and Sharable Content Object Reference Model (SCORM), several authoring tools have been developed to assist instructors in producing and packaging learning objects with metadata that are compliant with the standards to enhance the interoperability. For example, in 2005, García and García complied with LOM to propose an authoring tool, namely HyCo, to facilitate the composition of hypertext, which are stored as semantic learning objects in a backend database (García & García, 2005). Furthermore, Wang et al. (2007) designed a rich-client authoring environment for creating learning contents that are compatible with various e-learning standards without redundant efforts. Additionally, Kuo and Huang (2009) presented an authoring tool that can produce adaptable learning content to support both e-learning and m-learning, complying with SCORM standard. Although the above approaches significantly enhanced the interoperability of the learning objects, the support of the reusability for such learning objects is not enough.

In fact, teachers often have to design and produce individual teaching materials for specific subject matter by themselves. Moreover, a typical approach to content design consists of five stages, known as ADDIE (ADDIE, 2004), short for analysis, design, develop, implement, and evaluate, and this process requires that teachers spend a considerable amount of time and effort. Furthermore, such costs obviously increase unnecessarily when different individuals are working to develop similar teaching materials for the same course units simultaneously. Therefore, e-learning materials could be very useful resources for further education, because instructors can reuse existing learning objects to re-produce specific teaching materials more efficiently and effectively for different contexts.

As mentioned above, in order to solve this we first have to consider how to assist instructors in assembling such materials, and one problem with this is the huge amount of learning objects that may need to be considered. Furthermore, in order to form well-structured teaching materials, instructors also have to take more than one factor or criterion into account simultaneously, adding to their already challenging workload. Although previous studies have

applied query expansion techniques to address the first problem, they do not take multi-criteria into account to fit the real-world situation (Jou & Liu, 2011; Shih, Tseng, & Yang, 2008).

Bearing this in mind, this study aims to develop a rapid prototyping approach by employing particle swarm optimization (PSO) with multi-criteria to accelerate the development of drafts of teaching materials, as well as utilizing wiki-based techniques to enhance the revision quality of the materials thus produced. The ultimate aim of the study is to reduce the time, effort, and cost associated with the development of high-quality teaching materials.

Background and related work

Particle swarm optimization

PSO is a population-based optimization algorithm. Kennedy and Eberhart proposed the algorithm in 1995, inspired by the social behaviors of fish schooling and bird flocking, because they thought swarm intelligence could increase both the speed and the success rate for certain processes (Kennedy & Eberhart, 1995).

To carry out the PSO, each investigator has to formulate a fitness function according to the requirements of different optimization problems. Following this, a swarm of particles is generated and then distributed over a problem space, where each particle represents a potential solution to the optimization problem and is able to "remember" its own past status. During the optimization process, the PSO algorithm quantifies the location of each particle through the fitness function, and then utilizes the velocity function to produce the next generation until the process is terminated. Simultaneously, each particle can keep track of its own coordinates in the *N*-dimensional problem space that are related to the optimal solution it has achieved so far.

The velocity function consists of two models, cognition-only and social-only, which are both composed of two main parameters, called personal best location (PBest) and global best location (GBest). The formulas of the velocity function are described in the following paragraphs.
Cognition-only model

$$V_{id} = V_{id} + C_1 \times rand() \times \left(P_{id} - X_{id} \right) \tag{1}$$

Social-only model

$$V_{id} = V_{id} + C_2 \times rand() \times \left(P_{gd} - X_{id} \right) \tag{2}$$

Where V_{id} is the velocity vector of the *i*th particle in d dimension of the problem space, P_{id} is the personal best position vector of the particle in d dimension, P_{gd} is the global best position vector of the particle in d dimension, X_{id} is the current position vector of the *i*th particle in d dimension, C_1 is the personal cognitive learning rate, C_2 is the social learning rate, and rand() is a random real number in [0,1].

As the velocity function relies on the social-only and cognition-only models, the following formula specifies the complete velocity function, which combines Equation (1) with Equation (2).

$$V_{id}(t+1) = V_{id}(t) + C_1 \times rand() \times \left(P_{id} - X_{id}(t) \right) + C_2 \times rand() \times \left(P_{gd} - X_{id}(t) \right) \tag{3}$$

Each particle's velocity and direction are evaluated by Equation (3), and its current position is updated through Equation (4).

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t+1) \tag{4}$$

In addition, Kennedy and Eberhart further presented a discrete binary version for the PSO algorithm in 1997 (Kennedy & Eberhart, 1997), and this is used for combinational optimization, where each particle is structured by a binary vector of length d. Moreover, the velocity of a particle is represented by the probability that a decision

variable will take the value 1 to update each particle's current position. In short, the bit of a particle will be restricted to zero or one, where each V_{id} represents the probability of bit X_{id} taking the value 1.

Wiki technology

The concept of wiki was first proposed by Ward Cunningham in 1995, who used the word to name an environment he developed for co-workers to share specifications and documents for software design.

The specific functionality of a wiki is called open editing, and the inherent characteristics of this mean that such systems can be excellent tools to support group processes and to create knowledge repositories in an online environment (Leuf & Cunningham, 2001). Moreover, some investigators have suggested that wiki systems can be useful tools for building communities of practice (Lo, 2009; Shih, Tseng, & Yang, 2008). In recent years, many wiki sites have been built on the Internet, with the most famous being Wikipedia, an online open-source encyclopedia (Wikipedia, 2004). In the educational domain, many studies have been inspired by Wikipedia to investigate the effectiveness of such systems with regard to teaching and learning, as well as to develop practical approaches for online collaboration (Ebersbach, Glaser, & Heigl, 2006; Wheeler, Yeomans, & Wheeler, 2008).

Problem description

In this study, we propose an enhanced particle swarm optimization (EPSO) method to model a teaching material generation problem under different assessment criteria, and the EPSO aims at minimizing the differences between execution results and instructors' actual requirements. Three indicators are usually considered in the literature with regard to instructors developing teaching materials (Hofmann, 2004; Shih, Tseng, & Yang, 2008), and thus this study adopts these as the assessment criteria, namely: the difficulty of the material, the expected lecture time, and the relevant topics.

In this study, a learning object, in compliance with the IEEE LOM standard, is a digital entity containing a lecture about a particular topic. With regard to the difficulty and lecture time, IEEE LOM has defined two elements, namely difficulty and typical learning time, to describe these (IEEE, 2002). A five-rating scheme is used to describe the difficulty of learning objects from very easy to very difficult, while the typical time required to learn an object is obtained using an open text field that developers can enter their own responses in. According to these two elements, educators can obtain both the desired difficulty and lecture time of the learning objects, and thus better plan their courses. Generally, the difficulty and time required to learn a learning object can be determined by domain experts, but this is a time-consuming task. To cope with this problem, several studies have proposed automatic metadata generation approaches (Meire, Ochoa, & Duval, 2007; Motolet, & Baloian, 2007). Furthermore, with regard to topic relevance, several researchers have proposed various approaches that can help teachers to relate learning objects and topics (Hwang, 2003; Jong, Lin, Wu, & Chan, 2004), and educators can obtain this information in different ways, based on their specific requirements. Therefore, this study assumes that such information is already available when it works on the teaching material generation problem.

More specifically, assume there is a learning object repository (LOR) consisting of n learning objects, O_1, O_2,..., O_i,..., O_n. An instructor requires a teaching material which aims at k topics, T_1, T_2,..., T_x,..., T_k, and the lecture time is expected to range from l seconds to u seconds. Moreover, suppose the instructor requires the teaching material with a specific difficulty degree, D. Therefore, to organize the teaching material, c learning objects will be selected from the LOR. Furthermore, each learning object selected cannot be repeated in the final combinational result and is relevant to one or more of the specified topics. Naturally, the c learning objects are a subset of the n learning objects, $c \in n$. The variables used in this model are given as follows:

- n, the number of learning objects in the learning object repository
- k, the number of topics to be provided by the teaching material
- c, the number of learning objects to be selected to organize a draft of the teaching material
- O_i, $1 \le i \le n$, the ith learning object in the learning object repository which consists of n learning objects
- T_x, $1 \le x \le k$, the xth topic to be provided by the teaching material which aims at k topics
- s_i, $1 \le i \le n$, s_i is 1 if the O_i is organized in the draft of the teaching material, 0, otherwise
- D, $0 < D \le 1$, the target degree of difficulty for the draft generated

- d_i, $1 \leq i \leq n$, $0 < d_i \leq 1$, the degree of difficulty of O_i
- r_{ix}, $1 \leq i \leq n$, $1 \leq x \leq k$, the degree of association between the learning object O_i and topic T_x. r_{ix} is 1 if the O_i is relevant to T_x, 0, otherwise
- e_i, $1 \leq i \leq n$, the expected lecture time needed for O_i
- l, the lower bound of the expected lecture time needed for the teaching material
- u, the upper bound of the expected lecture time needed for the teaching material

The formal definition of EPSO is as follows:

Minimize $Z(\mathbf{P}y) = f + C_1 + C_2 + C_3$ (5)

The *Equation* (5) is a fitness function designed for addressing this problem. The aim of this function is to minimize the difference between the learning objects selected by EPSO and the target assigned by instructors on each assessment criterion.

$$f = \left| \frac{\sum_{i=1}^{n} s_i d_i}{\sum_{i=1}^{n} s_i} - D \right| \tag{6}$$

f indicates the difference in difficulty between the selected learning objects and the target. This formula first computes the average difficulty of the selected learning objects and then further measures the difference between the average and target difficulties.

$$C_1 = \frac{\sum_{x=1}^{k} \left(1 - \frac{\sum_{i=1}^{n} s_i r_{ix}}{\sum_{i=1}^{n} s_i} \right)}{k} \tag{7}$$

C_1 represents the degree of relevance between the selected learning objects and assigned topics. The function is used to compute the average relevance degree of the selected learning objects with regard to the k-assigned topics. Moreover, in order to satisfy the fitness function, a reverse computation is designed to obtain the minimized value in this function.

$$C_2 = \max\left(\min\left(l - \sum_{i=1}^{n} s_i e_i, 1 \right), 0 \right) \tag{8}$$

$$C_3 = \max\left(\min\left(\sum_{i=1}^{n} s_i e_i - u, 1 \right), 0 \right) \tag{9}$$

C_2 and C_3 indicate that the expected lecture time needed for the selected learning objects is outside the specified lower or upper bounds. The two functions can sum up the expected lecture time of the selected learning objects and then compute the difference with the lower and upper bounds. If the expected lecture time of the selected learning objects is satisfied the lower and upper bounds respectively, the results of the two functions would be minimized.

As mentioned previously, $Z(\mathbf{P}_y)$ is the fitness function which consists of four assessment criteria to solve the teaching material generation problem. Since the discrete binary version of PSO is adopted in this study for combination optimization, all decision variables of the teaching material generation problem take binary values (either 0 or 1). To satisfy this, a particle can be represented by $\mathbf{P}_{y,i} = [s_1 s_2 ... s_i ... s_n]$, which is a vector of n binary bits, where $\mathbf{P}_{y,i}$ indicates the ith bit of the yth particle, s_i is equivalent 1 if the learning object O_i is organized in the draft of the teaching material, and 0 otherwise.

In addition, the velocity function is also a vital part of EPSO. According to the discrete version of PSO, a logistic transformation $S(v_{y,i})$ is used to update the velocity and position of each particle, and it is used as the probability

scale in [0.0, 1.0] to determine which particle bit will have the value of 1. In this study, we apply the sigmoid function to transform velocities into probability, as follows:

$$S(v_{y,i}) = \frac{1}{1 + e^{-v_{y,i}}}$$

$$(10)$$

Wiki-based teaching material development environment

The wiki-based teaching material development environment is a web-based system that is integrated with a LMS named ANTS (Agent-based Navigational Training System) to facilitate the teaching material generation process (Jeng, Huang, Kuo, Chen, & Chu, 2005; Lin, Lin, Huang, 2011). In order to describe the system in detail, this section will be organized into two sub-sections to depict the architecture of the system and the procedures of content development.

Architecture

Figure 1 shows the architecture of the wiki-based teaching material development environment that consists of four components, which are described below.

- ➢ *Learning object repository*. The contents of learning object repository are organized based on information about the learning objects. This consists of several pieces of information, such as the title, description, keywords, difficulty, lecture time, and so on. Each learning object can be defined or associated with different topics according to these.
- ➢ *Teaching material generation module*. The module is used to organize a tailor-made draft of teaching materials for each instructor based on specific requirements by measuring the fitness and velocity functions.
- ➢ *Wiki-based revision site*. The site was developed to allow instructors to revise drafts collaboratively. Inappropriate teaching materials would thus be revised until they are reliable.
- ➢ *Instructor interface*. The wiki-based teaching material development environment provides user-friendly interfaces for instructors who can administer the entire process through them.
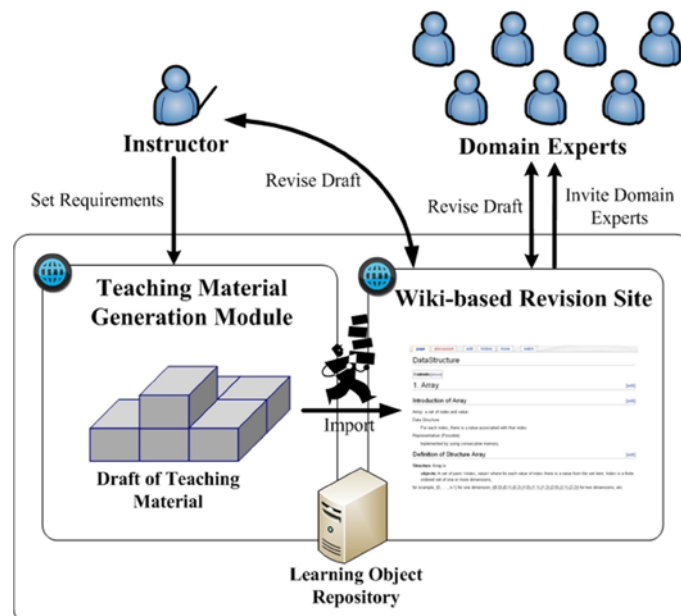
Figure 1. Architecture of Wiki-based teaching material development environment.

Procedure

Figure 2 schematically depicts the flow path of the complete system. The proposed approach is composed of three main phases, which will be described in detail in the following paragraphs.
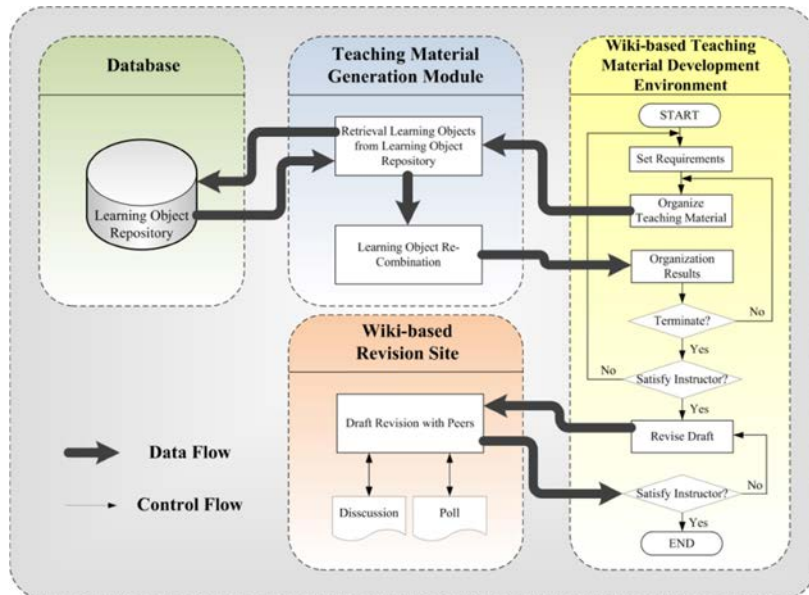
Figure 2. Logical system flow of wiki-based teaching material development environment

Phase 1. Requirement verification

This phase requires instructors to specify the relevant requirements for a teaching material, which include k topics T_1, $T_2,..., T_x,..., T_k$, the target difficulty level D, the lower bound lecture time, l, and the upper-bound lecture time, u, as shown in Figure 3.
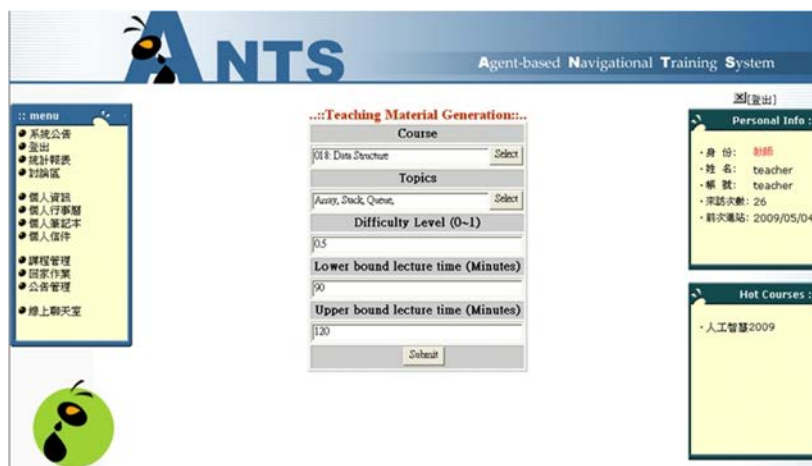
Figure 3. Screenshot of the parameter-setting interface

Phase 2. Learning object re-combination

To retrieve and re-combine relevant learning objects from LOR, an initial swarm is generated by the teaching material generation module. Because the module can obtain the expected lecture time for each learning object from

the LOR, the number of selected learning objects in any particle can be bounded in an integrity rule, $[l/\max_{i=1\sim n}\{e_i\},\ u/\min_{i=1\sim n}\{e_i\}]$, during the generation of the initial swarm. Moreover, to obtain a quality initial swarm, a selection rule is developed that can give higher selection probability to the learning objects that have difficulty levels closer to the target. Formally, the selection rule is defined as $(S-|d_i-D|)/S$, where d_i is the degree of difficulty of learning object O_i and S is a constant.

After initiating the particle swarm, the module applies Equation 5 to measure the quality of each particle and then conducts particle iterations. In order to make sure that the best particle in each iteration survives, the elitist concept of the genetic algorithm (GA) has been incorporated into EPSO (Lin, Huang, & Cheng, 2010). If the best particle of the present iteration is worse than that of the previous iteration, the latter would replace the worst particle of the present iteration. By using Equation 10, each particle can update its velocity and position. Until the iteration terminates, the draft is displayed in a web-based interface and the instructor can check the results based on her or his own expertise, as shown in Figure 4. If the instructor is unsatisfied with the results, then she or he can require the module to produce another draft of the teaching material or revise the draft in the wiki-based revision site, as shown in Figure 5.
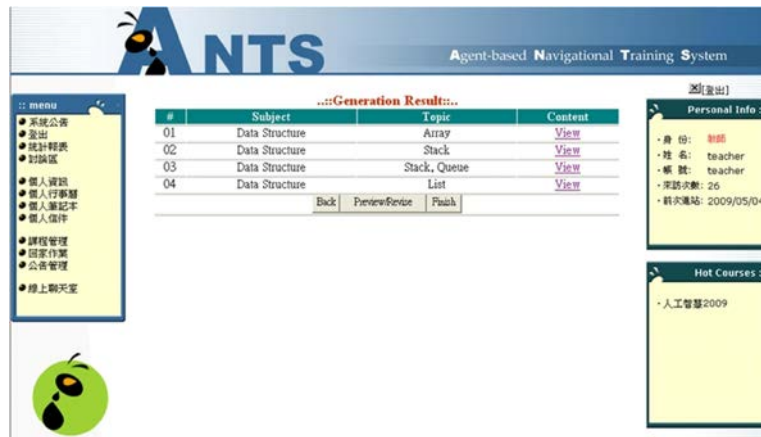
Figure 4. Screenshot of the draft generation interface
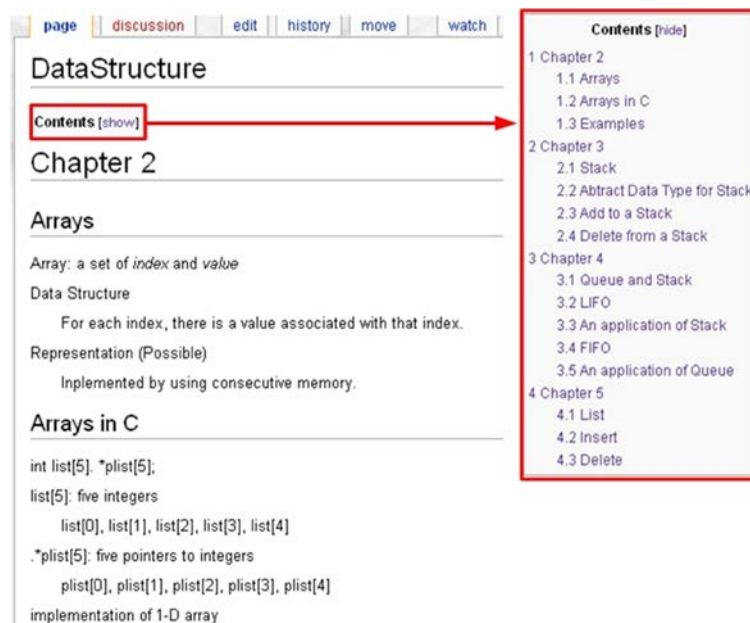
Figure 5. The draft of the teaching material

Phase 3. Wiki-based revision

Through the wiki-based revision site, the instructor can collaboratively improve the draft with peers or domain experts. Finally, the revised draft can be a formal version for use by instructors and learners, as shown in Figure 6.
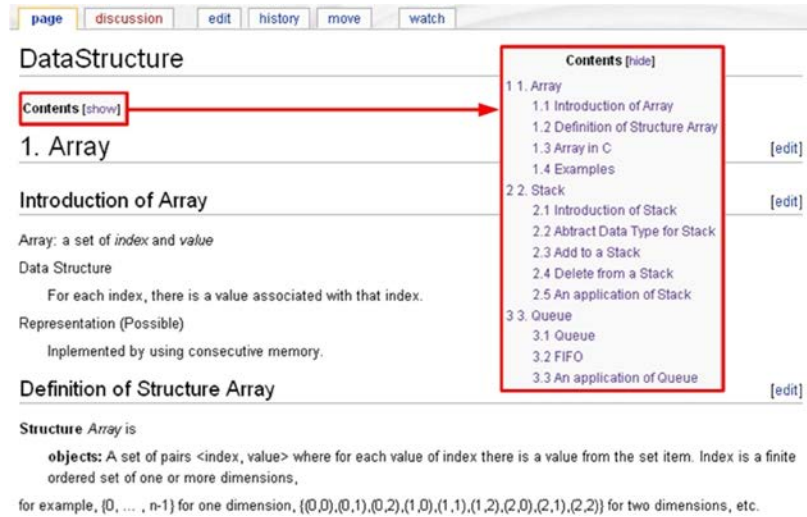
Figure 6. The final version of the teaching material

Experiments

The performance of the proposed approach is analyzed according to a series of experiments. First, we demonstrate that EPSO can adequately deal with the teaching material generation problem. Second, we analyze the robustness of EPSO against the variance between repeated runs and different problem scenarios. Third, we evaluate whether the wiki-based revision site can really help teachers to revise draft teaching materials. Finally, we investigate teachers' perceptions with regard to using the system.

Experiment settings

To analyze the comparative performance with other competing algorithms, nine simulation datasets were generated by varying the parameters. Table 1 shows the features of each dataset.

Table 1. Description of the experimental datasets

Dataset	Number of learning objects	Average Difficulty (ranging from 0 to 1)	Average expected lecture time for each learning object (seconds)
1	15	4.933	1078.333
2	20	4.050	953.500
3	50	5.100	1079.300
4	100	4.310	1095.970
5	300	4.963	1061.410
6	500	4.758	1090.926
7	1000	4.971	1072.026
8	1500	5.047	1123.973
9	2000	5.012	1101.681

Before conducting the experiments, we repeatedly ran EPSO with various values for the number of particles (P) and the maximal number of generations (G), as shown in Table 2, in order to obtain the best performance of EPSO. The results are tabulated in Table 3. Considering the computational time and optimal fitness value, the results indicate that the best performance of EPSO is when administering up to 10 generations with 20 particles, where the

computational time (6.671 seconds) required is only longer than that needed for 10 generations with 10 particles, and the fitness value (0.045) obtained is the second best among all trials. Therefore, in the following experiments, EPSO is set with 20 particles and 10 generations.

Table 2. Combination of various values of P and G

P	G
10	10, 50, 100, 200, 300, 400, 500
20	10, 50, 100, 200, 300, 400, 500
30	10, 50, 100, 200, 300, 400, 500

Table 3. Computational times and the fitness values derived from EPSO with various values of P and G

	P = 10		P = 20		P = 30	
G	t (sec)	f	t (sec)	f	t (sec)	f
10	4.922	0.139	6.671	0.045	9.687	0.108
50	21.969	0.092	33.234	0.089	43.890	0.105
100	38.250	0.059	65.796	0.043	82.906	0.068
200	73.781	0.085	131.734	0.084	156.625	0.073
300	107.172	0.093	182.437	0.077	234.690	0.082
400	139.094	0.086	249.233	0.081	301.509.	0.052
500	198.641	0.103	321.057	0.094	392.052	0.065

Evaluation of EPSO performance

In this experiment, we evaluated EPSO by comparing its performance with those of three competing algorithms: non-enhanced particle swarm optimization (NEPSO), random method (RM), and exhaustive method (EM), using the nine simulation datasets tabulated above. The characteristics of the four competing algorithms are explained below.

➢ EPSO: The characteristics of EPSO are described in detail in earlier sections. In particular, all of EPSO trials are conducted with 20 particles and 10 generations according to the preliminary analytical results.

➢ NEPSO: NEPSO generates teaching materials by selecting learning objects randomly to meet all of the requirements, and discards the elitist mechanism of the genetic algorithm during the process determining PBest and GBest. As with EPSO, to obtain the best performance, we repeatedly run NEPSO with various values for the number of particles and the maximal number of generations, as shown in Table 2. The results indicate that the best performance of NEPSO is when administering up to 10 generations with 20 particles, where the computational time (5.582 seconds) required is only longer than that needed for 10 generations with 10 particles, and the fitness value (0.103) obtained is the second best among all trials. Therefore, NEPSO also uses 20 particles and 10 generations in all runs.

➢ EM: The characteristic of EM is that it guarantees to find out the optimal fitness value in each run because it exhaustively explores all possible solutions to the teaching material generation problem.

➢ RM: RM merely generates candidate solutions to the teaching material generation problem, rather than compute all possible solutions. Therefore, the optimality of the final solution is not guaranteed.

Since EPSO, NEPSO, and RM are stochastic-based methods, the performances of the three approaches were assessed according to the average of 10 runs on the nine datasets. In addition, the exhaustive method was run once so that it could enumerate all possible solutions. In order to conduct the performance experiment, we used the four programs to organize teaching material from the nine simulation datasets. The teaching material aimed at three topics, the target degree of difficulty was set at 0.6, and the expected lecture time ranged from 90 to 120 minutes.

Since EM is guaranteed to obtain the true optimal fitness value, we can evaluate the quality of solutions derived from EPSO, NEPSO, and RM by examining the differences between the four methods. As shown in Table 4, the fitness values derived from EPSO are very close to those produced by EM for the four smallest problems. However, the results also show that EM can only tackle the four smallest problems within a reasonable time. For the other large-scale cases, the computational time needed by EM would grow exponentially with the problem size. Although the computational time required by EPSO also increases with problem size, the rate of increase is relatively low.

Table 4. Comparison of the performances of EPSO, NEPSO, RM, and EM (with five particles and different numbers of iterations)

n	EPSO		NEPSO		RM		EM	
	t (sec)	f	t (sec)	f	t (sec)	f	t (sec)	f
15	0.702	0.043	0.609	0.113	0.067	0.586	1.343	0.000
20	1.017	0.086	0.913	0.127	0.083	0.755	3.281	0.000
50	4.531	0.092	3.953	0.117	0.217	0.814	85.828	0.000
100	7.684	0.062	6.503	0.120	0.397	0.827	700.547	0.000
300	19.864	0.046	17.103	0.133	1.167	0.789	N/A	
500	33.880	0.058	29.265	0.152	1.935	0.830	N/A	
1000	68.316	0.085	61.540	0.127	3.873	0.795	N/A	
1500	108.041	0.068	96.027	0.168	5.854	0.823	N/A	
2000	143.231	0.064	128.068	0.150	8.634	0.816	N/A	

We then compared the performance of EPSO with that of RM. With regard to the computational time, the amount needed by RM is rarely affected by the factors used and always remains acceptable in practice. In contrast, the computational time required by EPSO is affected with the number of learning objects. Nevertheless, even though EPSO needs a little more time than RM in all cases, the quality of the final solutions it finds is significantly better. As for EPSO and NEPSO, the results of their comparison provide evidence as to the effects of the integrity rule, selection rule, and elitist mechanism on the solutions. As shown in Table 4, approximate solutions to all of the datasets can be obtained in a reasonable time, from 0.609 seconds to 143.231 seconds. However, the solution quality derived from EPSO is better than that with NEPSO, especially as the size of the datasets increases.

Figure 7 shows the variations with regard to the fitness values obtained by EPSO, NEPSO, and RM as the number of learning objects increases. The result shows that the fitness value increases as the problem size becomes larger for NEPSO and RM. Nevertheless, the rate of increase for the fitness value obtained by NEPSO is less than that for RM. In addition, the fitness values are of a relatively smaller magnitude for EPSO in all cases.
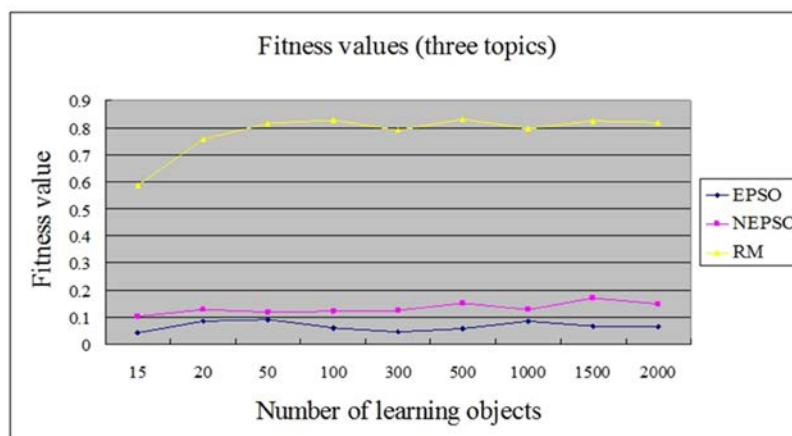
Figure 7. Variations in the optimal fitness value derived by EPSO, NEPSO, and RM as the number of learning objects increases

To summarize the performance experiment, EPSO can meet the requirements of most real-world applications for rapidly organizing teaching materials efficiently and effectively. Moreover, the initial rules (integrity and selection rules) and elitist mechanism are useful in aiding EPSO to deliver better solution quality.

Evaluation of EPSO robustness

The robustness is evaluated from two aspects. First, we evaluate the three methods with different numbers of learning objects. Second, we evaluate the standard deviation of the optimal fitness values obtained by the three

algorithms for different numbers of topics. In order to conduct the two evaluations, the three stochastic methods were run 10 times each and the standard deviation of the fitness value was computed over the 10 runs.

Figure 8 and Figure 9 show the variations of standard deviation of the optimal fitness values derived from EPSO, NEPSO, and RM, with different numbers of learning objects and topics. In the two evaluations, the standard deviations of EPSO are smaller than those of NEPSO and RM. The results demonstrate that EPSO is the most suitable and reliable method.
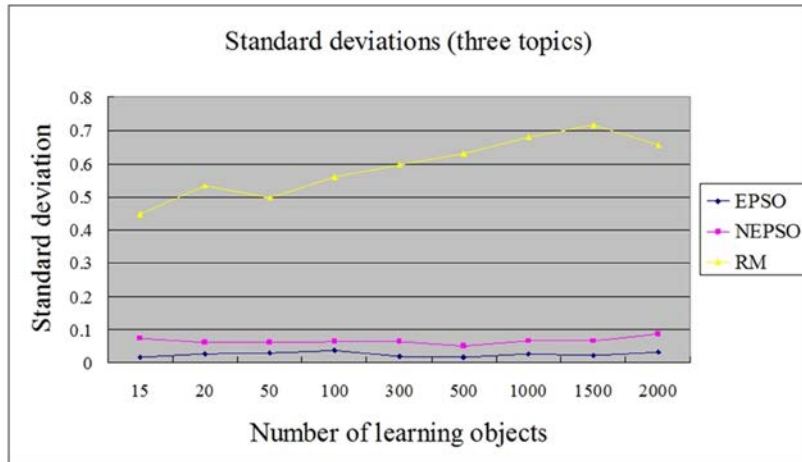
Figure 8. Variations in standard deviation of the optimal fitness values derived by EPSO, NEPSO, and RM
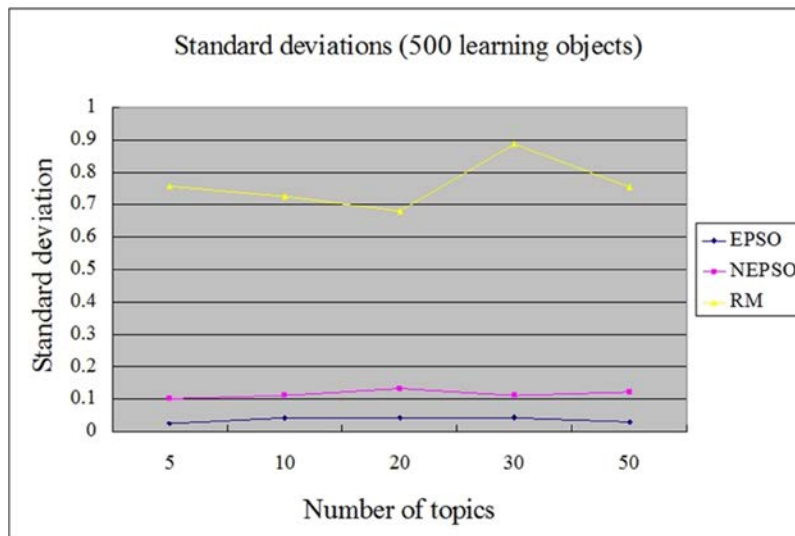
Figure 9. Variations in the standard deviation of the optimal fitness values derived by EPSO, NEPSO, and RM

Evaluation of the wiki-based revision approach

This experiment is to evaluate whether the revision time required for the teaching materials using the wiki-based revision site is shorter than without the proposed approach. Therefore, in this experiment a treatment group (using the wiki-based revision site) and a control group (not using the wiki-based revision site) were organized to investigate the effectiveness of the proposed function. The participants were 24 data structure course teachers, including 16 lecturers and eight professors. The average age of the teachers was 34. In the experiment, the 24 teachers were randomly divided into two groups of 12, each with eight lecturers and four professors. One group served as the experimental group, which had the wiki-based revision site to use throughout the revision process. The other served as the control group, working without the aid of the site, and thus they could only revise the teaching

materials manually by working alone. In contrast, teachers in the experimental group were able to form a wiki community to revise the materials with their peers or domain experts. All the participants were assigned the same teaching material formed by EPSO. The teaching material consisted of four learning objects that were selected from 20 learning objects. The parameters of each learning object were determined by a panel of experts. In addition, all the participants were provided with an Internet-enabled environment that meant they could search for information online while engaging in the revision process. At the end of the revision process, two data sources were used to evaluate the effectiveness of the proposed approach, including data logs and interviews with the experimental group. First of all, we analyzed the revision time required by the two groups. As shown in Table 5, an independent t-test was used to examine whether the experimental treatment could really help the teachers to revise the materials more than the control group at a selected probability level (alpha 0.05 was selected in the analysis). The results reveal that there was a significant difference in the amount of time required between the two groups.

Table 5. Means, standard deviations, and independent t-test of the two groups in the evaluation study

Variable	Mean	Std. dev.	t-test(22)
Experimental group	46.799	9.739	2.022[*]
Control group	55.677	11.678	

Note: $n = 24$ for all measures. [*]$P < 0.05$

We next analyzed the behaviors of the teachers in the experimental group. A total of 42 comments were posted, and 25 comments were sent as replies to coordinate the process in the 10 teachers' wiki communities. To clearly present the data logs, this study synthesized the comments into three main topics with regard to opinion expression, opinion decision, and information sharing, as illustrated in Table 6.

Table 6. Example comments for the three topics

Inductive topics	Sample comments
Opinion expression	I thought that before teaching the queue unit, we should teach them the stack concept.
	I disagree with this arrangement, because the stack concept has been taught in the previous chapter.
	I would have preferred more interactions with students in this course.
	I felt the concept is difficult to grasp for students, therefore, we should add more examples to explain the concept.
Information sharing	I found a resource from this hyperlink. I thought that it could help you to complete this work.
	If you need more examples with regard to this concept, you can refer to this book.
	The students in the experiment group often gave feedback and asked questions.
Opinion decision	Do you agree to teach stack unit before teaching queue unit?
	Do you prefer which instruction strategy to teach this unit?

With regard to opinion expression, most of comments posted and replied to express personal opinions about revising the teaching materials. Working in this way, the teachers could not only get feedback from their peers, but also be stimulated to consider and help solve the problems that others were experiencing. By sharing what they know, the group of teachers using the wiki were able to access more information than would have had been possible had they been working alone. This assistance enabled them to produce the teaching materials more efficiently and effectively. However, despite the sharing of opinions and knowledge, sometimes a consensus could not be reached. In such circumstances, the teachers can use the poll function of the wiki to focus more clearly on an issue. In addition, by using a poll, some otherwise silent participants can be stimulated to offer their opinions. As mentioned above, we observed that the wiki-based revision site did indeed act as an effective medium to help the teachers revise the teaching materials collaboratively.

Finally, we interviewed the teachers in the experimental group to capture their perceptions of using the wiki-based revision site in more detail. As noted earlier, we found that the comments that were collected came from only 10 teachers' wiki communities. Therefore, in the interviews we first surveyed the two teachers who did not post any

comments during the revision process. The two teachers indicated that they could revise the teaching materials by themselves. Hence, they used the wiki-based revision site alone. We also interviewed the other 10 teachers in the experimental group who felt that they could revise the teaching materials more efficiently because they could discuss issues with their peers or experts by posting messages on discussion pages, as shown in Figure 10. Furthermore, we asked the three teachers about their attitudes with regard to the polls that they used, and they all indicated this function helped to speed up decisions that needed to be made on a debatable revision, as shown in Figure 11. In addition, four teachers suggested that the site should integrate a tool to help novice teachers find collaborators and domain experts, as they felt that this would not be easy for them to do, since they tend to lack the necessary professional connections.
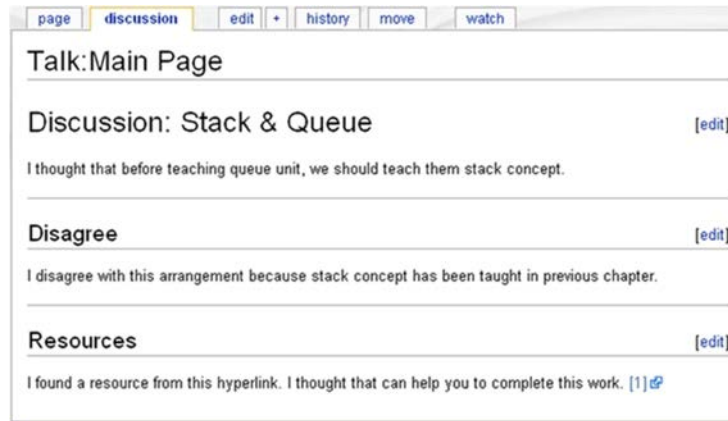
Figure 10. Screenshot of discussion page
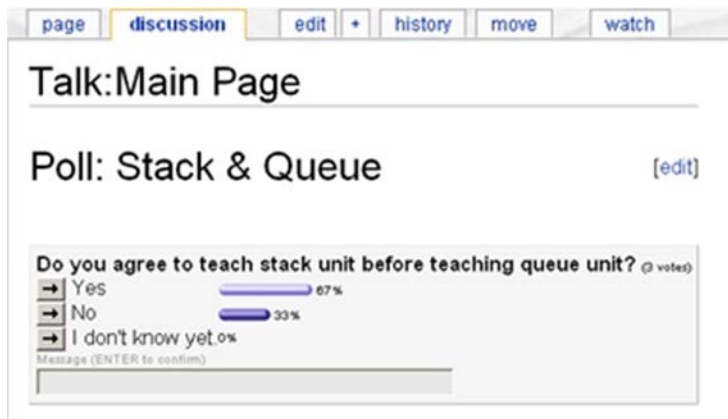
Figure 11. Screenshot of poll function

Perceived usefulness of the wiki-based teaching material development environment

In this experiment, the 24 teachers in the above experiment were asked to use the system. The perceived usefulness scale of the technology acceptance model (TAM) consists of five questionnaire items with a seven-point Likert scale (Davis, Bagozzi, & Warshaw, 1989), and it was applied to measure the users' perceptions with regard to the usefulness of the environment. The Cronbach's alpha value of the questionnaire items was .8040.

The results shown in Table 7, show that 78.3% of the users were in favor of using the wiki-based teaching material development environment.

Table 7. Users' perceptions of using the wiki-based teaching material development environment

#	Question	EU (%)	QU (%)	SU (%)	Neither (%)	SL (%)	QL (%)	EL (%)	Mean
1	Using the environment in teaching material development would enable me to organize appropriate learning objects more effectively	0%	8.3%	4.1%	4.1%	41.6%	20.8%	20.8%	5.25
2	Using the environment would improve my performance in developing teaching materials	0%	0%	4.1%	25%	37.5%	25.0%	16.6%	5.08
3	Using the environment in teaching material development would increase my productivity	0%	0%	4.1%	16.6%	54.1%	12.5%	12.5%	5.13
4	Using the environment would make it easier to carry out teaching material development	0%	4.1%	37.5%	29.1%	12.5%	12.5%	4.1%	4.96
5	I would find the environment useful in teaching material development	0%	0%	0%	16.6%	45.8%	41.6%	0%	5.21

Note. EU: Extremely unlikely; QU: Quite unlikely; SU: Slightly unlikely; SL: Slightly likely; QL: Quite likely; EL: Extremely likely

Next, the 24 teachers were interviewed to capture their perceptions of using the proposed approach in more detail. According to the interview results, the majority of teachers indicated that they felt the user interface of the proposed environment was clear and straightforward. Moreover, they felt that the teaching material development process could be carried out more easily and efficiently with the proposed approach, and that they had much more time to prepare the incoming instructions. Additionally, during the development process, the teachers could first think over the teaching materials. This added period of consideration helped them to prepare a better final product. However, one fourth of the teachers felt that if the teaching material generation module could provide extra information to explain the development results, then this could further reduce the development time.

With regard to the use of EPSO, a statistical result revealed that each teacher averagely use EPSO 2.333 times to obtain suitable results. Two teachers indicated that they could purposely and curiously run EPSO several times to see what the next result produced by EPSO. By excluding the phenomenon, the average times of using EPSO can be reduced to 1.916 times per teacher. Therefore, each teacher can spend only several seconds to obtain the suitable results. In addition, most of the teachers also stated that although the teaching materials developed by EPSO needed some manual modifications or even re-organization, the results were acceptable because the system had already saved a lot of time, and the computational time of EPOS is short. Moreover, 17 teachers indicated that the proposed environment allowed them to manually rearrange the teaching materials, thus enabling the materials to better meet their requirements. Finally, five teachers hoped that future versions of EPSO could consider the learning sequence of each learning object in order to further enhance the quality of the output.

As mentioned above, the results of this investigation show that EPSO can assist teachers in organizing teaching materials and further reduce the development time. Nevertheless, the wiki-based revision site will not always save time, because it may also need additional revision time, as well as discussions with their community members. However, this additional time can enable the teachers to produce higher quality teaching materials.

Conclusions

This paper describes a wiki-based teaching material development environment. By conducting a series of experiments, we show that the proposed approach can help instructors to develop and revise teaching materials in a collaborative manner. Although the users felt that the proposed environment could help them to form teaching materials, there are still some limitations to the proposed approach. First, more information should be provided to explain the development results, since EPSO cannot help users to automatically refine the developed teaching materials, in terms of the course sequence, content selection, and so on. Second, multimedia learning objects were ignored by the proposed approach, as they cannot easily be embedded and edited on the currently available wiki platforms.

Therefore, the future direction of this study is to continuously refine the proposed approach to support course sequence function. To address this problem, another element of LOM, namely semantic density, can be adopted to be a selection criterion of learning objects. Also, more participants with different background knowledge and teaching experiences will be invited to evaluate the proposed approach. We expect that the proposed approach can assist novice as well as experienced teachers to develop useful teaching materials rapidly and easily. Additionally, according to the zone of proximal development, the degree of difficulty of learning objects can be used as an attribute to develop an intelligent tutoring system based on the knowledge level of learners.

Acknowledgements

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A Fuzzy-based Prior Knowledge Diagnostic Model with Multiple Attribute Evaluation

Yi-Chun Lin[1] and Yueh-Min Huang[1,2*]

[1]Department of Engineering Science, National Cheng Kung University, No. 1, Ta-Hsueh Road, Tainan 701, Taiwan, R.O.C. // [2]Department of Applied Geoinformatics, Chia Nan University of Pharmacy and Science, 60, Erh-Jen RD., Sec. 1, Jen-Te, Tainan 710, Taiwan, R.O.C. // jellyplum@gmail.com // huang@mail.ncku.edu.tw
[*]Corresponding author

ABSTRACT

Prior knowledge is a very important part of teaching and learning, as it affects how instructors and students interact with the learning materials. In general, tests are used to assess students' prior knowledge. Nevertheless, conventional testing approaches usually assign only an overall score to each student, and this may mean that students are unable to understand their own specific weaknesses. To address this problem, previous work has presented a prior knowledge diagnosis model with a single attribute to assist instructors and students in diagnosing and strengthening prior knowledge. However, this model neglects the fact that a diagnostic decision might involve multiple attributes. In order to provide more a precise diagnosis to instructors and students, this study thus proposes a fuzzy prior knowledge diagnosis model with a multiple attribute decision making technique for diagnosing and strengthening students' prior knowledge. The experimental results from an interdisciplinary bioinformatics course have demonstrated the utility and effectiveness of this innovative approach.

Keywords

Fuzzy multiple attribute decision making, Prior knowledge diagnosis, Interdisciplinary course, Computer-assisted testing

Background and objectives

Evaluating and strengthening the prior knowledge of individual students is an important task before teaching and learning new knowledge or skills, since prior knowledge affects how instructors and students interact with the learning materials they encounter (Chieu, 2007; Moos & Azevedo, 2008; Ozuru, Dempsey, & McNamara, 2009). From the perspective of instructors, gaps in the students' prior knowledge often confound their best efforts to deliver effective instructions (Roschelle, 1995). Moreover, they can also affect how instructors plan their teaching strategies for new material in order to enhance students' learning motivation and performance (Biswas, 2007; Tseng, Chu, Hwang, & Tsai, 2008).

If the students do not have the necessary prior knowledge, then there is a strong risk that they may build new knowledge on faulty foundations (Dochy, Moerkerke, & Marten, 1996). It can thus be seen that inadequate or fragmented prior knowledge is an important issue, and if the instructors' expectations of the students' knowledge are very different from their actual knowledge, then both teaching and learning are likely to adversely affected (Hailikari, Katajavouri, & Lindblom-Ylanne, 2008).

To avoid this risk, tests are usually adopted to assess how well students understand a concept or piece of knowledge (Panjaburee, Hwang, Triampo, & Shih, 2010; Tao, Wu, & Chang, 2008; Treagust, 1988). Nevertheless, conventional testing systems usually assign only an overall score or grade to students, and thus instructors and students may be unable to identify which specific concepts or pieces of knowledge are misunderstood, making it difficult to improve the learning performance of students (Gerber, Grund, & Grote, 2008; Gogoulou, Gouli, Grigoriadou, Samarakou, & Chinou, 2007; Hwang, Tseng, & Hwang, 2008). To work around this issue, instructors can further analyze the testing results to determine the students' learning deficiencies. However, this is a time-consuming task that presents a heavy workload for instructors, since there are often many students on a course, especially in higher education or e-learning contexts. Hence, previous work has led to the development of a prior knowledge diagnosis (PKD) model to assist instructors and students in diagnosing and strengthening prior knowledge before new instruction is undertaken (Lin, Lin, Huang, 2011).

Nevertheless, one of the major problems when applying the PKD model is that it only uses correctness rates answered by students to determine their level of understanding with regard to particular concepts, and diagnoses based on a single attribute lead to inaccurate results (Hwang, Tseng, & Hwang, 2008). Therefore, it is necessary to develop a more effective approach to assist instructors in identifying the specific learning problems of individual students in the context of multiple attributes, and this issue actually matches a traditional computer science problem, called Multiple Attribute Decision Making (MADM) (Chen & Hwang, 1992). The MAMD problem is to select the best choice among the previously specified finite number of alternatives (Seel, & Dinter, 1995), with the alternatives evaluated based on their attributes.

Therefore, this study proposes a Fuzzy Prior Knowledge Diagnostic (FPKD) model by applying the Efficient Fuzzy Weighted Average (EFWA) technique (Lee & Park, 1997) to assist instructors in diagnosing the level of students' understanding of prior knowledge, and to provide appropriate feedback to individual students. Based on this model, a testing and diagnostic system has been implemented, and an experiment on an interdisciplinary bioinformatics course was conducted to demonstrate the efficacy of the proposed approach.

Fuzzy Prior Knowledge Diagnostic Model

The aim of the FPKD model is to assist instructors in diagnosing students' prior knowledge with multiple attributes. Figure 1 shows the hierarchical structure of the decision making problem and its criteria. To realize and diagnose the knowledge strength of students, instructors usually apply tests and consider the difficulty of the test items, the relevance of the concept, and the students' answers (Saleh & Kim, 2009).

As shown in Figure1, each criterion has its rating, r_i, which is associated with the measured value of the attribute. Furthermore, each criterion has been assigned a relative weight, w_i, which is used to adjust the weight of each criterion in relation to the decision goal.

In this study, the relative weight values of the three criteria are adjusted by the instructors according to different education contexts. Therefore, in order to develop the FPKD model, the ratings of each criterion first have to be retrieved and measured.
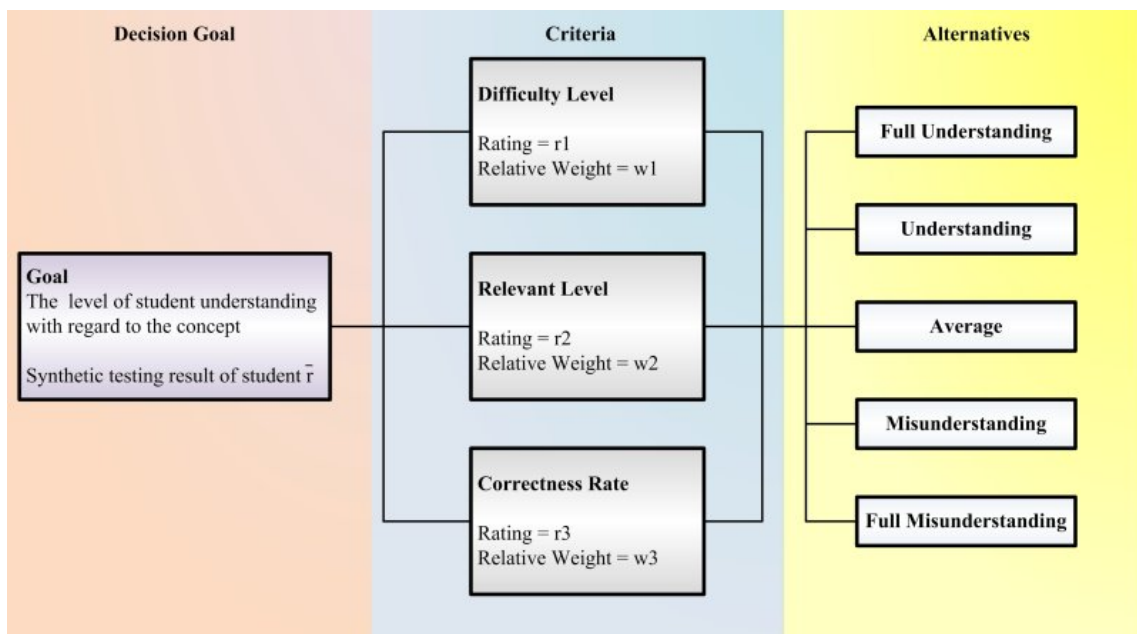
Figure 1. The hierarchical structure of the decision problem.

Analysis of decision attributes

The ratings of each criterion are retrieved from two data sources, the first is the testing information assigned by teachers, representing an association between each concept and test item, and the relationships among the concepts. The second is derived from students, which represents an association between their answers and the test items.

Assume that an instructor aims to teach a subject of a course, and the instructor specifies n concepts, $C_1, C_2, C_3, \ldots, C_i, \ldots, C_n$ that are the requisite prior knowledge of the objective subject for r participating students, $S_1, S_2, S_3, \ldots, S_l, \ldots, S_r$. Before teaching the subject, the instructor selects k test items, $I_1, I_2, I_3, \ldots, I_j, \ldots, I_k$ from a test item bank to form a pre-test, with k test items that possibly have different degree of difficulty , $D_1, D_2, D_3, \ldots, D_j, \ldots, D_k$.

In addition, each test item is relevant to n concepts, and each concept is possibly related to the others. The k test items and n concepts in the pre-test can be associated with each other, and the relationships among each concept can also be associated. After the initial setting of the test items, the instructor then conducts the pre-test to assess the r students' levels of understanding with regard to the n concepts using the proposed approach to measure their prior knowledge.

The test items are coded with a number ranging from one to k and each test item is relevant to from one to n concepts in the pre-test. To represent the degree of relevance between each concept and test item, an X-value is used. X_{ij} indicates the relevance between the ith concept and the jth test item. If the jth test item is relevant to the ith concept, X_{ij} is 1; otherwise X_{ij} is 0.

The concepts are coded with numbers ranging from one to n and each concept is relevant to from one to n concepts. To represent the relationships among the concepts, a Z-value is adopted that also ranges from 0 to 1. Z_{im} indicates the relationship between the ith and the mth concepts, $i, m \in n$.

After the r students have taken the test, their results for each item can be recorded. To represent the relationship between the students' answers and test items, an R-value is adopted using a binary coding scheme. R_{lj} indicates the answer of the lth student for the jth test item. If the student answers the test item correctly, then R_{lj} is 1; otherwise R_{lj} is 0.

Therefore, three assessment functions can be developed to measure the three decision attributes by using the above testing information. Firstly, based on the D, R, and X values, the highest difficulty level of concept C_i answered by student S_l correctly can be measured as:

$$HDL(S_{l,} C_i) = \max_{1 \le j \le k} \left\{ R_{lj} D_j X_{ij} \right\} \tag{1}$$

where $HDL(S_{l,} C_i)$ represents the highest difficulty level of ith concept answered by l^{th} student correctly, $0 \le HDL(C_i) \le 1$; R_{lj} indicates the answer of the lth student for the jth test item, $R_{lj} \in \{0,1\}$; D_j represents the difficulty degree of jth test item, $0 \le D_j \le 1$; and X_{ij} indicates the relevance between the ith concept and the jth test item, $X_{ij} \in \{0,1\}$.

Furthermore, based on the R, X and Z values, the relevant level of concept C_i answered by student S_l correctly can be measured as:

$$RL(S_{l,} C_i) = \sum_{j=1}^{k} \left\{ R_{lj} \left[\frac{\sum_{w=1}^{n} x_{wj} z_{iw}}{\sum_{w=1}^{n} x_{wj} \left(\sum_{v=1}^{n} z_{wv} \right)} \right] \right\} / \sum_{j=1}^{k} R_{lj} \tag{2}$$

where $RL(S_{l,} C_i)$ represents the relevance level of ith concept answered by l^{th} student correctly, $0 \le RL(S_{l,} C_i) \le 1$;

R_{lj} indicates the answer of the lth student on the jth test item, $R_{lj} \in \{0,1\}$; X_{ij} indicates the relevance between the ith concept and the jth test item, $X_{lj} \in \{0,1\}$; and Z_{iw} indicates the relationship between the ith and the wth concepts.

In addition, based on the R and X values, the correctness rate of student S_l with regard to concept C_i can be inferred as:

$$CR(S_{l,}C_i) = \frac{\sum_{j=1}^{k} R_{lj}X_{ij}}{\sum_{j=1}^{k} X_{ij}}$$

(3)

where $CR(S_{l,}C_i)$ represents the correctness rate of the lth student with regard to i^{th} concept, $0 \le CR(C_i) \le 1$; X_{ij} indicates the relevance between the ith concept and the jth test item, $X_{ij} \in \{0,1\}$; and R_{lj} indicates the answer of the lth student for the jth test item, $R_{lj} \in \{0,1\}$.

Multiple attribute decision making algorithm of the FPKD model

After the rating measurements of the three criteria, the Efficient Fuzzy Weighted Average (EFWA) technique is used to produce the FPKD model. The criteria can be synthesized by *Equation* (4), and the fuzzy average $\bar{r}$ is produced based on the input criteria.

$$\bar{r} = \frac{\sum_{i=1}^{n} w_i r_i}{\sum_{i=1}^{n} w_i}$$

(4)

In the FPKD model, the $\bar{r}$ presents the synthetic testing result of the students with regard to a concept, and it is used to judge which alternative is appropriate to represent the students' level of understanding of the concept. Furthermore, to present the rating and relative weight of each criterion, two fuzzy membership functions are shown in Figure 2 and Figure 3, respectively. Note that a fuzzy membership function can be used to represent the extent to which a value from a domain is included in a fuzzy concept, such as "low relevance", "high performance", and so on. In addition, each fuzzy concept can be represented in a formula form. For instance, the fuzzy concept "Average" of Rating in Figure 2 (a triangular curve) can be mapped to the membership function of "Average" of Rating in Table 1. In this study, the transformation between the triangular curve and the formula can be by solving the linear equations (Huang, Kuo, Lin, & Cheng, 2008).
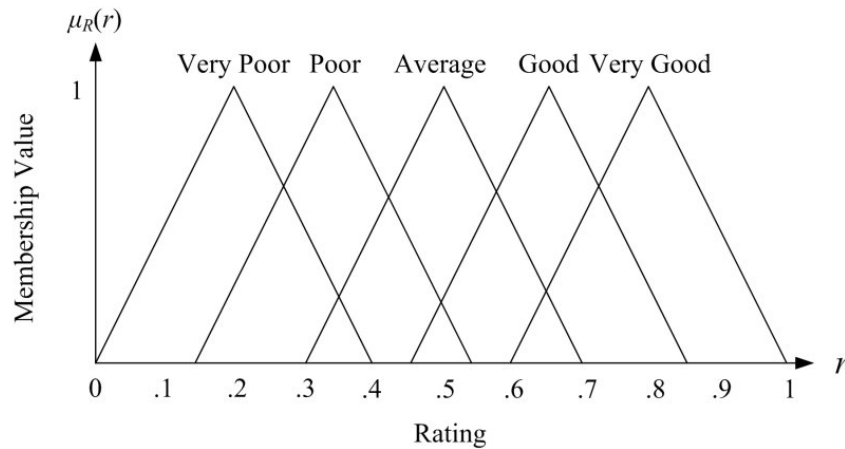
Figure 2. The membership functions of rating level.

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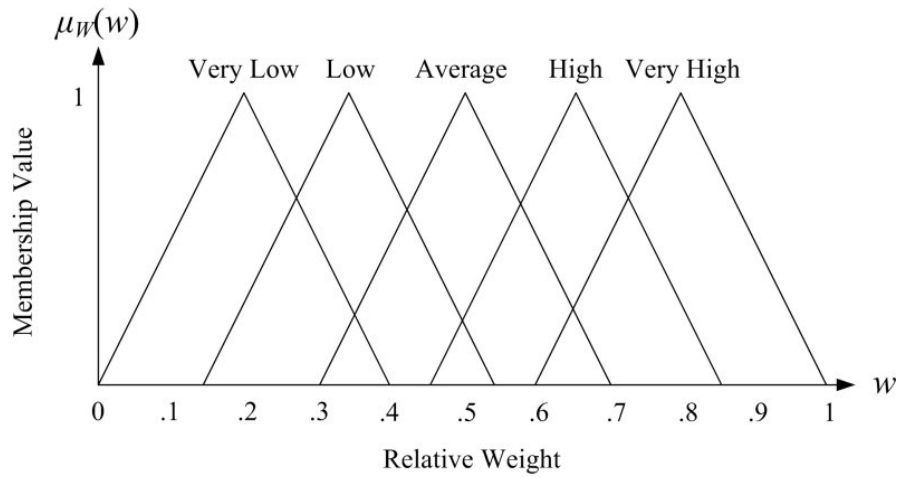
Figure 3. The membership function of relative weight.

Table 1. The definitions of the membership functions

Category	Class	Membership function
Alternative	Full Understanding	$= \begin{cases} 5a, a \in [0,0.2] \\ 2-5a, a \in [0.2,0.4] \end{cases}$
	Understanding	$= \begin{cases} 5a-0.75, a \in [0.15,0.35] \\ 2.75-5a, a \in [0.35,0.55] \end{cases}$
	Average	$= \begin{cases} 5a-1.5, a \in [0.3,0.5] \\ 3.5-5a, a \in [0.5,0.7] \end{cases}$
	Misunderstanding	$= \begin{cases} 5a-2.25a, a \in [0.45,0.65] \\ 4.26-5a, a \in [0.65,0.85] \end{cases}$
	Full Misunderstanding	$= \begin{cases} 5a-3, a \in [0.6,0.8] \\ 5-5a, a \in [0.8,1] \end{cases}$
Rating	Very poor	$= \begin{cases} 5r, r \in [0,0.2] \\ 2-5r, r \in [0.2,0.4] \end{cases}$
	Poor	$= \begin{cases} 5r-0.75, r \in [0.15,0.35] \\ 2.75-5r, r \in [0.35,0.55] \end{cases}$
	Average	$= \begin{cases} 5r-1.5, r \in [0.3,0.5] \\ 3.5-5r, r \in [0.5,0.7] \end{cases}$
	Good	$= \begin{cases} 5r-2.25, r \in [0.45,0.65] \\ 4.26-5r, r \in [0.65,0.85] \end{cases}$
	Very good	$= \begin{cases} 5r-3, r \in [0.6,0.8] \\ 5-5r, r \in [0.8,1] \end{cases}$

Relative weight	Very low	$=$	$\begin{cases} 5w, w \in [0, 0.2] \\ 2 - 5w, w \in [0.2, 0.4] \end{cases}$
	Low	$=$	$\begin{cases} 5w - 0.75, w \in [0.15, 0.35] \\ 2.75 - 5w, w \in [0.35, 0.55] \end{cases}$
	Average	$=$	$\begin{cases} 5w - 1.5, w \in [0.3, 0.5] \\ 3.5 - 5w, w \in [0.5, 0.7] \end{cases}$
	High	$=$	$\begin{cases} 5w - 2.25, w \in [0.45, 0.65] \\ 4.26 - 5w, w \in [0.65, 0.85] \end{cases}$
	Very high	$=$	$\begin{cases} 5w - 3, w \in [0.6, 0.8] \\ 5 - 5w, w \in [0.8, 1] \end{cases}$

In the FPKD model, the alternatives are the concept understanding levels, which consist of five levels. The alternative requiring the highest synthetic testing result with regard to a concept is full understanding, and the lowest synthetic testing result is full misunderstanding. All the alternatives' membership functions are shown in Figure 4.
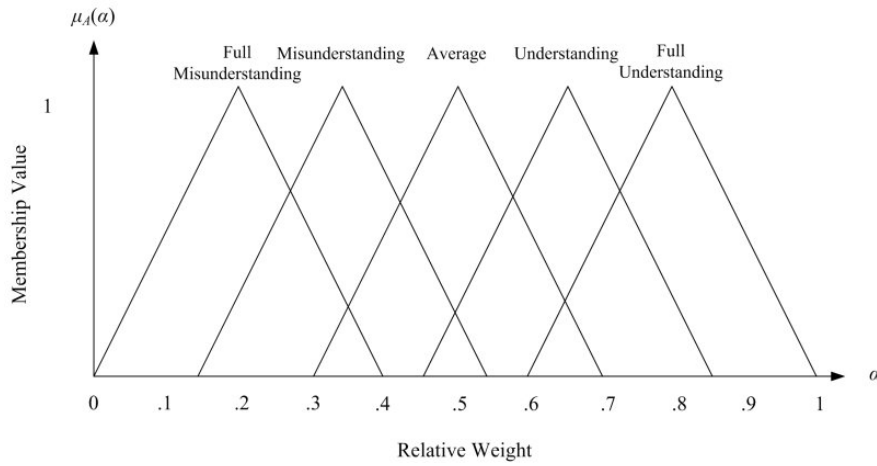
Figure 4. The membership functions of the alternatives.

Based on Figures 2, 3, and 4, Table 1 arranges the membership functions of rating levels, relative weights, and alternatives. The interval of each membership function in Table 1 is used by the EFWA for interval analysis to compute the result, $\bar{r}$. After obtaining the fuzzy weighted average, it then compares the distance between the weighted average and alternatives. The approximate Euclidean distance (Dobois & Prade, 1980; Ross, Sorensen, Savage, & Carson, 1990), as in *Equation* (5), is adopted as the measurement to determine the distance. In *Equation* (5), the parameter X represents the resulting fuzzy membership function ($\bar{r}$), the parameter A represents the pre-defined fuzzy membership function (alternatives), and the function d is the Euclidean distance, which presents the distance between X and A.

$$d(X, A) = \sqrt{(X^{\alpha=0}_{lower-bound} - A^{\alpha=0}_{lower-bound})^2 + (X^{\alpha=1} - A^{\alpha=1})^2 + (X^{\alpha=0}_{upper-bound} - A^{\alpha=0}_{upper-bound})^2} \qquad (5)$$

Therefore, according to the decision goal, the appropriate solution is the alternative, that minimizes the Euclidean distance d. The calculation process is presented in Appendix, which includes an illustrative example to explain the entire decision making process in more detail.

Development of an FPKD-based testing system

Based on the FPKD model, a computer-assisted testing and diagnostic system is implemented in this work. A user-friendly interface is provided for instructors on the teacher side, in which they can select a specific course, subject, and concept to develop a diagnostic assessment, as shown in Figure 5. The system can then pick relevant test items from the test item bank according to the specific criteria. The instructors can thus use the interface to select the necessary test items to make a test-sheet based on their expertise. Figure 6 shows that the instructors can consult the assessment results and learning status of all students, and then use this information to improve their teaching plan before teaching a new course.

From the student side, students can log into the system and then use the student interface to take a diagnostic assessment, as shown in Figure 7. In addition, as shown in Figure 8, the system applies the FPKD model to diagnose the students' test results, and provides diagnostic results to each participant through a diagnostic interface that can clearly show the level of understanding of the students with regard to specific concepts, so that they can know what they need to pay more attention to.

Figure 5. Screenshot of the test-sheet development interface.

Figure 6. Screenshot of the assessment results for the instructor.
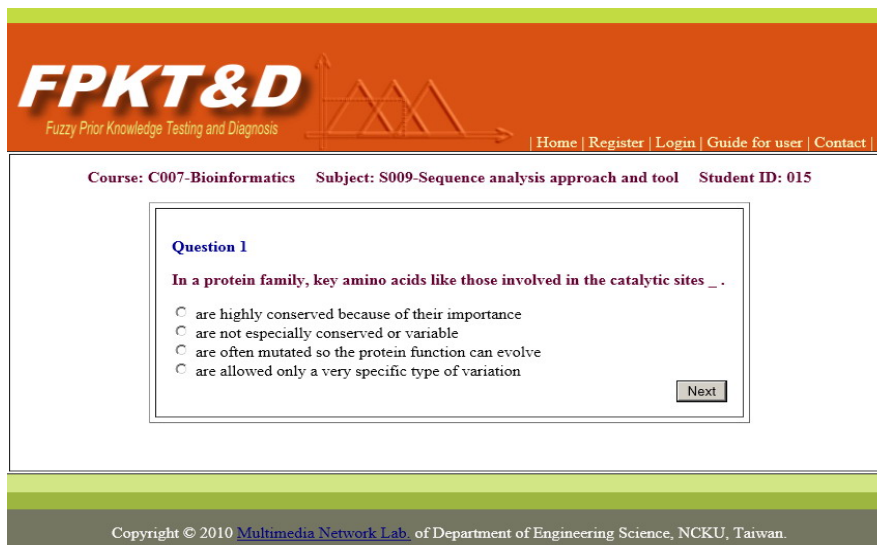
Figure 7. Screenshot of the testing interface.
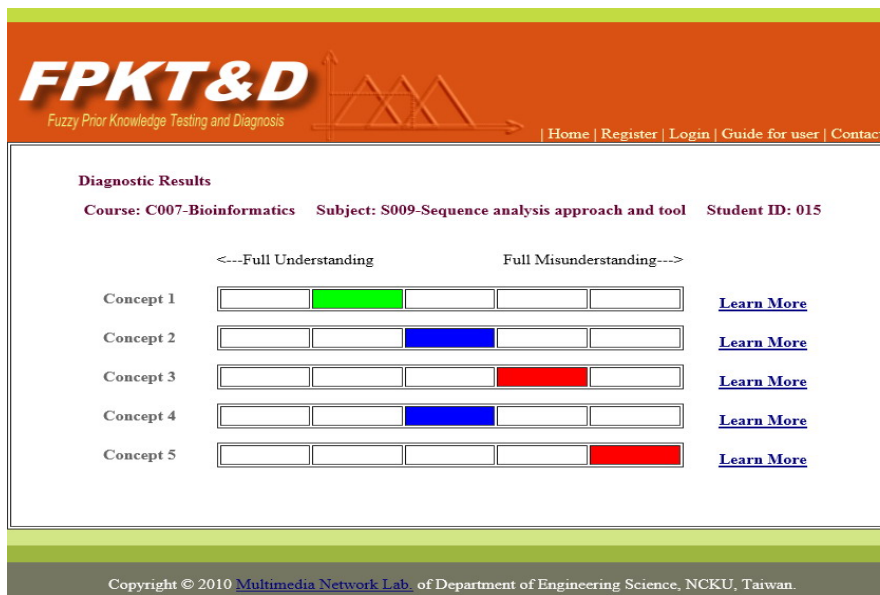
Figure 8. Screenshot of the diagnostic results interface for students.

Experiment and evaluation

Experimental design, participants, and procedure

To investigate the effectiveness of the innovative approach, a quasi-experimental study research was conducted on an interdisciplinary bioinformatics course at a university in Taiwan. The participants in the experiment were a course instructor and 86 university students. The average age of the students was 22. These students were divided into three groups. One group of 26 students served as the experiment group 1 (EG1), which used the FPKD model to diagnose and strengthen their prior knowledge before taking the bioinformatics course. Another group of 28 students served as the experiment group 2 (EG2), which used the PKD model before taking the bioinformatics course. The other group of 32 students served as the control group (CG), and did not use either of the models.

The experiment was conducted on the subject, "sequence analysis approaches and tools". This subject was taught in

the fourth week of the syllabus of the bioinformatics course, and it had a total of 180 minutes of learning activities, including both instruction and practice. The time distribution of each learning activity was planned by the course instructor, and these came in six stages, as shown in Table 2. Prior to learning the subject, the students need to have knowledge of the following five concepts that they were taught in the first three weeks of the course: gene, sequence characteristics and structures, genetics, statistical hypotheses testing, and formula expression format.

Before and after taking part in the learning activities, all the students received pre- and post-tests. The pre-test/post-test were designed to assess the students' knowledge of the sequence analysis techniques presented in the bioinformatics course, including questions about the operation of the BLAST (Basic Local Alignment Search Tool) programs, its application to various problems, and the meaning of the analytical results. Finally, a diagnostic evaluation was conducted to examine the accuracy of the diagnoses derived from the FPKD model.

Table 2. Major teaching and learning activities in the bioinformatics course

Subject: sequence analysis approaches and tools		
Concepts in prior knowledge: Gene, sequence characteristics and structures, genetics, statistical hypotheses testing, and formula expression format		
Unit	Instruction activities	Time (min)
Understanding the importance of similarity	1. A series of guided questions (5) 2. Slide presentation (15) 3. Discussions (10)	30
Introduction to the most popular data-mining tool: BLAST	1. A series of guided questions (5) 2. Slide presentation (15) 3. Practice (10)	30
BLASTing protein sequences	1. A series of guided questions (5) 2. Slide presentation (10) 3. Practice (15)	30
Understanding BLAST output	1. Slide presentation (15) 2. Discussions (15)	30
BLASTing DNA sequences	1. A series of guided questions (5) 2. Slide presentation (10) 3. Practice (15)	30
The BLAST way of doing things	1. Slide presentation (15) 2. Practice (15)	30

Pre-test/Post-test evaluation

Based on a previous investigation, at least two items should be used to measure an objective in order to obtain highly accurate results (Tuckman & Monetti, 2010). Therefore, 20 multiple-choice test items were used in both the pre-test and post-test. Moreover, the two tests were identical, and the maximum score that could be obtained in either of them was 100. The KR-20 reliabilities of the pre-test and post-test were .757 and .778, respectively. The item difficulty index value ranged between 0.35 - 0.85, and the mean difficulty index of items was 0.56. The item discrimination index of most items was greater than 0.35, implying that the items had good discriminative validity (Doran, 1980).

The pre-test results show that the mean and standard deviation of the EG1 (50.38 and 15.61) were similar to those of the EG2 (51.42 and 15.80) and CG (51.87 and 16.15). After preliminary analysis, an ANOVA test was used to determine whether the knowledge level of the three groups was the same with regard to learning bioinformatics. Prior to the ANOVA test, Levene's test of homogeneity of variances was applied to examine whether the variances across samples were equal. The result of this test was not significant ($p = .869 > .05$), which suggests that the difference between the variances for all groups was also not significant. Therefore, ANOVA was performed. As shown in Table 3, the results show that there were no significant differences between the experiment and control groups prior to the experiment ($F(2,83) = 0.065$, $p > .05$). That is, the students in all groups had statistically equivalent abilities before taking the bioinformatics course.

After the bioinformatics course, the course instructor administered a post-test, the results of which show that the mean and standard deviation of the EG1 (75.00 and 8.60) were slightly better than those of the EG2 (66.78 and 11.88)

and CG (59.06 and 13.52). The results imply that the students who worked with the FPKD model achieved better learning performance than the others. Moreover, a Pearson's correlation coefficient was used to measure the strength of the association between the accuracy of the diagnosis of prior knowledge and the learning performance of individual students($r = 0.576$, $p < .01$), and the result reveals a significant correlation between them.

A paired *t*-test was then used to analyze the learning improvement of the three groups, as shown in Table 4 , and the results indicate that the teaching strategy could help the students in all groups to learn about bioinformatics (EG1: $t(25) = -9.631$, $p < .05$; EG2: $t(27) = -9.222$, $p < .05$; CG: $t(31) = -6.411$, $p < .05$). In addition, an ANOVA test was used to examine whether the experimental treatment could really enhance the students' learning performance. The result of Levene's test for equality of variances was not significant ($p = .142 > .05$), which indicates that the variances for all groups were assumed to be equal. A one-way ANOVA was then conducted. As shown in Table 5, the results reveal that there was a significant difference in students' post-test achievements between the three groups ($F(2, 83) = 13.36$, $p < .05$). The Scheffe test was used to make post hoc comparisons to identify statistically significant differences among the three groups with regard to their knowledge of bioinformatics, with the results shown in Table 5, and the significance level for the mean difference was $p < .05$. The results thus indicate that the FPKD model can benefit the students in terms of knowledge acquisition.

Table 3. Pre-test ANOVA on knowledge of bioinformatics of the three groups

Variable	Pre-test			$F(2, 83)$
	N	Mean	Std. dev.	
EG1	26	50.38	15.61	
EG2	28	51.42	15.80	0.065
CG	32	51.87	16.15	

Note. $^*p < .05$.

Table 4. The paired *t-test* results of the learning improvement of the three groups

Group	Tests	N	Mean	Std. dev.	t
EG1	Pre-test	26	50.38	15.61	-9.631[*]
	Post-test	26	75.00	8.60	
EG2	Pre-test	28	51.42	15.80	-9.222[*]
	Post-test	28	66.78	11.88	
CG	Pre-test	32	51.87	16.15	-6.411[*]
	Post-test	32	59.06	13.52	

Note. $^*p < .05$.

Table 5. Post-test ANOVA on the three groups' knowledge of bioinformatics

Variable	Post-test			$F(2, 83)$	Post hoc test (Scheffe)
	N	Mean	Std. dev.		
EG1	26	75.00	8.60		EG1>EG2[*]
EG2	28	66.78	11.88	13.36[*]	EG2>CG[*]
CG	32	59.06	13.52		EG1>CG[*]

Note. $^*p < .05$.

Diagnosis evaluation

To assess whether the diagnoses given by the FPKD model are consistent with expert opinions, an evaluation was conducted using the following evaluation function:

$$CR = \frac{n - (n - m)}{n} \qquad (6)$$

where *CR* represents the correctness rate of the diagnoses, $0 \le CR \le 1$, *n* represents the number of concepts; and *m* indicates the number of matching diagnoses.

A comparison was also conducted to evaluate whether the correctness rates of the diagnoses derived from the FPKD model were superior to those obtained by the PKD model. As noted in the earlier experiment section, the 26 students in experiment group 1 and 28 students in experiment group 2 were asked to use the FPKD and PKD models to diagnose their understanding of five concepts, respectively. In this evaluation, three experts diagnosed the understanding of the 54 students with regard to the five concepts based on the students' test results.

The correctness rates of the diagnoses derived from the FPKD and PKD models were then measured using *Equation* (6). Table 6 shows the correctness rate for each student's diagnosis. It can be seen that the average correctness rates of the results diagnosed by the FPKD model were higher (i.e., 93.26%, 90.38%, and 92.30% for the students) than those diagnosed by the PKD model (i.e., 86.60%, 87.50%, and 88.39%). The results demonstrate that the diagnosis mechanism of the FPKD model is valid, since the diagnoses of the FPKD model were very similar to those from the experts. Moreover, the results of this comparison also revealed that the diagnosis mechanism of the FPKD model is superior to that of the PKD model with regard to diagnosing the learning problem of individual students.

Table 6. Evaluation of the correctness rate results for the five concepts

Student ID	Model	001	002	003	004	005	006	007	008
Expert 1	EG1	100%	100%	100%	50%	100%	100%	75%	100%
	EG2	100%	75%	50%	100%	75%	100%	100%	100%
Expert 2 (Correctness rate of diagnoses)	EG1	100%	75%	75%	75%	100%	100%	75%	100%
	EG2	100%	75%	100%	75%	100%	75%	100%	100%
Expert 3	EG1	100%	100%	75%	75%	100%	100%	75%	100%
	EG2	75%	100%	75%	100%	100%	100%	75%	100%
Student ID		009	010	011	012	013	014	015	016
Expert 1	EG1	75%	75%	100%	100%	100%	100%	100%	100%
	EG2	100%	75%	100%	50%	100%	50%	100%	100%
Expert 2 (Correctness rate of diagnoses)	EG1	100%	100%	100%	50%	100%	75%	100%	100%
	EG2	100%	100%	50%	75%	100%	75%	100%	100%
Expert 3	EG1	100%	100%	100%	75%	100%	100%	100%	100%
	EG2	100%	100%	75%	100%	50%	100%	100%	100%
Student ID		017	018	019	020	021	022	023	024
Expert 1	EG1	100%	100%	100%	100%	75%	100%	100%	100%
	EG2	100%	75%	75%	50%	100%	100%	100%	100%
Expert 2 (Correctness rate of diagnoses)	EG1	100%	100%	75%	100%	50%	100%	100%	100%
	EG2	50%	100%	50%	100%	75%	100%	75%	100%
Expert 3	EG1	100%	100%	75%	100%	50%	100%	100%	100%
	EG2	100%	50%	75%	100%	75%	100%	100%	100%
Student ID		025	026	027	028	029	030	031	032

Expert 1	Correctness rate of diagnoses	EG1	75%	100%	-	-	-	-	-	-
		EG2	50%	100%	100%	100%				
Expert 2		EG1	100%	100%	-	-	-	-	-	-
		EG2	100%	100%	75%	100%				
Expert 3		EG1	100%	75%	-	-	-	-	-	-
		EG2	100%	75%	50%	100%				

Conclusions and discussions

Prior knowledge diagnosis is important for both students and instructors before new instruction is undertaken. Nevertheless, conventional testing systems usually assign only an overall score or grade to instructors and students, giving no adequate way to diagnose any specific problems that they face. Although previous work has developed a prior knowledge testing and diagnosis (PKT&D) system to assist instructors and students in diagnosing and strengthening prior knowledge before new instruction is undertaken (Lin, Lin, & Huang, 2011), it only consider a single attribute to diagnose the learning problems of individual students, and this may lead to inaccurate results .

Therefore, this study applied a multiple attribute decision making technique to develop an innovative prior knowledge diagnosis model, called the FPKD model. The results of the experiment and evaluation show that the proposed model can effectively assist instructors and students in diagnosing students' understanding of prior knowledge in an interdisciplinary bioinformatics course. From a pedagogical perspective, this study applied the FPKD model to a bioinformatics course. However, based on various pedagogical objectives, instructors can use the proposed model in different educational contexts.

Although the innovative approach presented in this work seems to promising, it has some limitations with regard to its practical application. In this study, we applied triangular curves to be the fuzzy membership functions of the rating levels, relative weights, and alternatives. The results of the diagnostic evaluations reveal that this kind of assignment is suitable for our educational context, as the diagnoses that the system produced were very similar to those produced by experts. Nevertheless, in practice, the three functions may have to be adjusted based on the instructors' expertise in different educational contexts.

To enable instructors to more effectively adjust the membership functions, we are currently developing a mechanism to dynamically tune these based on different educational contexts. Moreover, other relevant models or techniques will be taken into account to further improve the diagnosis mechanism of the FPKD model, such as the analytic hierarchy process (AHP) and repertory grid. Finally, to enable instructors to use the FPKT&D system more conveniently, the number of test items in the item bank should be continually increased to address various subject objectives and the different needs of instructors.

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Appendix

The EFWA algorithm

- Definition: the input a, b, c, and d are the intervals of fuzzy membership functions, and the outputs are the intervals of the result fuzzy membership function. Additionally, the δ_{s_i} and the ζ_{s_i} can be calculated by *Equations* (7) and (8) respectively.

$$\delta_{s_i} = \frac{(a_1 - a_i)e_1 + (a_2 - a_i)e_2 + \ldots + (a_{n\_}a_i)e_n}{e_1 + e_2 + \ldots e_n} \qquad (7)$$

$$\zeta_{s_i} = \frac{(b_1 - b_i)e_1 + (b_2 - b_i)e_2 + \ldots + (b_{n\_}b_i)e_n}{e_1 + e_2 + \ldots e_n} \qquad (8)$$

- Description of the EFWA algorithm (Lee and Park, 1997)

(1) Sort a's in non-decreasing order. Let $(a_1, a_2, \ldots, a_n)$ be the resulting sequence. Let *first* := 1 and *last* := n.

(2) Sort a's in non-decreasing order. Let $(a_1, a_2, \ldots, a_n)$ be the resulting sequence. Let *first* := 1 and *last* := n.

(3) Let δ-threshold := $\lfloor (first + last)/2 \rfloor$. For each $i = 1, 2, \ldots, \delta$-threshold, let $e_i := d_i$ and for each $i = \delta$-threshold + 1, …, n, let $e_i := c_i$. For an n-tuple $S = (e_1, e_2, \ldots, e_n)$, evaluate $\delta_{s_{\delta-threshold}}$ and $\delta_{s_{\delta-threshold+1}}$.

(4) If $\delta_{s_{\delta-threshold}} > 0$ and $\delta_{s_{\delta-threshold+1}} \leq 0$ then $L = f_L(e_1, e_2, \ldots, e_n)$ and go to Step 4; otherwise execute the following step.

  (a) If $\delta_{s_{\delta-threshold}} > 0$, then *first* := δ-threshold + 1; otherwise *last* := δ-threshold, and go to Step 2.

(5) Sort b's in non-decreasing order. Let $(b_1, b_2, \ldots, b_n)$ be the resulting sequence. Let *first* := 1 and *last* := n.

(6) Let ζ-threshold := $\lfloor (first + last)/2 \rfloor$. For each $i = 1, 2, \ldots, \zeta$-threshold, let $e_i := c_i$ and for each $i = \zeta$-threshold + 1, …, n, let $e_i := d_i$. For an n-tuple $S = (e_1, e_2, \ldots, e_n)$, evaluate $\zeta_{s_{\zeta-threshold}}$ and $\zeta_{s_{(\zeta-threshold+1)}}$.

(7) If $\zeta_{s_{\zeta-threshold}} > 0$ and $\zeta_{s_{\zeta-threshold+1}} \leq 0$ then $U = f_U(e_1, e_2, \ldots, e_n)$ and stop; otherwise execute the following step:

  (b) If $\zeta_{s_{\zeta-threshold}} > 0$, then first := ζ-threshold + 1; otherwise last := ζ-threshold, and go to step 5.

Illustrative example

Assume that an instructor aims to assess five students (S_1, S_2, S_3, S_4, S_5) to identify their level of understanding with regard to five concepts (C_1, C_2, C_3, C_4, C_5,). The instructor selects five test items (I_1, I_2, I_3, I_4, I_5) from a test item bank to form a test-sheet, that are relevant to concepts one to five, and each test item has its difficulty degree, D_1, D_2, D_3, D_4, D_5. In this test-sheet, each concept is possibly related to the others. The instructor then conducts the test to assess the five students to identify the level of understanding of the individual students with regard to the five concepts. The degree of difficulty of each test item is shown in Table 7. In addition, the relationships among the test items and concepts are shown in Table 8, and the relationships among the concepts are shown in Table 9. After the

participating students have taken the test, their test results for each test item are given, as shown in Table 10.

Table 7. Illustrative example of degree of difficulty each test item

Degree of Difficulty of Test Item	Test Item				
	I_1	I_2	I_3	I_4	I_5
Difficulty Degree	0.2	0.4	0.8	0.2	0.4

Table 8. Illustrative example of the relationships among test items and concepts

Test Item	Concept				
	C_1	C_2	C_3	C_4	C_5
I_1	1	0	0	0	0
I_2	1	0	1	0	1
I_3	0	1	0	0	0
I_4	0	1	0	0	1
I_5	0	0	0	1	0

Table 9. Illustrative example of relationship among concepts

Concept	Concept				
	C_1	C_2	C_3	C_4	C_5
C_1	1.0	0.0	0.4	0.0	0.0
C_2	0.0	1.0	0.6	0.0	0.2
C_3	0.4	0.6	1.0	0.2	0.6
C_4	0.0	0.0	0.2	1.0	0.4
C_5	0.0	0.2	0.6	0.4	1.0

Table 10. Illustrative example of the relationship among students' answers and test items

Test Item	Student				
	S_1	S_2	S_3	S_4	S_5
I_1	1	1	0	1	1
I_2	1	0	1	1	1
I_3	0	0	0	0	1
I_4	0	1	0	1	1
I_5	0	0	1	0	0

Based on the association among Tables 8, 9, and 11, the highest difficulty level of the five concepts answered by the five students can be measured with *Equation* (5). In order to illustrate this clearly, Table 11 shows the association among the five test items and five concepts related to the fourth student (S_4).

Table 11. Illustrative example of relationship of test items, concepts, and the fourth student's answers

Test Item	Concept				
	C_1	C_2	C_3	C_4	C_5
I_1	1	0	0	0	0
I_2	1	0	1	0	1
I_3	0	1	0	0	0
I_4	0	1	0	0	1
I_5	0	0	0	1	0

The gray rows means that the fourth student answered the first, second, and fourth test items (I_1, I_2, and I_4) correctly, as seen in Table 10. Based on Table 11, therefore, the highest difficulty level of the five concepts answered by the five students can thus be measured. For instance, the highest difficulty level of second concept answered by the fourth student is:

$$HDL(S_{4,}C_2) = 0.2$$

Furthermore, based on Tables 9,10, and11 the relevant level of five concepts answered by the five students correctly can be measured using *Equation* (2). Similarly, as shown in Table 12, the relevant level of second concept answered

by the fourth student correctly is:

$$RL(S_4, C_2) = 0.142$$

In addition, based on Tables 9 and 11, the correctness rate of the five students with regard to five concepts can be inferred with *Equation* (3). For instance, the correctness rate of the fourth student with regard to second concept can be measured as follows:

$$CR(S_4, C_2) = 0.5$$

Therefore, the ratings of the fourth student's attributes are shown in Table 13. With regard to the relative weight of each criterion, this example assumes that it is very low, very low, and average for the highest difficulty level, relevant level and correctness rate respectively, as shown in Table 12. Notice that, in Table 13, the values of rating are related to Figure 2 and the values of relative weight are related to Figure 3, and the parameter settings of r_i and w_i are the triangle values of membership functions (Figures 3 and 4) with respect to $\alpha = 0$ and 1 (the α-cuts is the interval analysis technique (Dong & Wong, 1987).

Table 12. The input values related to fourth student's answer with regard to the second concept

Criteria	Rating	Relative Weight
highest difficulty level	Very poor	Very low
relevant level	Very poor	Very low
correctness rate	Average	Average

Before starting the EFWA algorithm, it is necessary to choose two values for α, namely 0 and 1, as the initial input values. For $\alpha = 0$, the intervals of $r_{i=1-3}$ are [$a_1 = 0$, $b_1 = 0.4$], [$a_2 = 0$, $b_2 = 0.4$], and [$a_3 = 0.3$, $b_3 = 0.7$], and the intervals of $w_{i=1-3}$ are [$c_1 = 0$, $d_1 = 0.4$], [$c_2 = 0$, $d_2 = 0.4$], and [$c_3 = 0.3$, $d_3 = 0.7$]. Notice that the r_i shown here have not been sorted yet. The computational procedure is as follow:

Step 1: Sort a's into non-decreasing order, and the resulting sequence is [$a_1 = 0$, $b_1 = 0.4$], [$a_2 = 0$, $b_2 = 0.4$], and [$a_3 = 0.3$, $b_3 = 0.7$]. So $(a_1, a_2, a_3) = (0, 0, 0.3)$, $first := 1$, $last := 3$.

Step 2: δ-threshold $:= \lfloor (1+3)/2 \rfloor = 2$, S = $(d_1, d_2, c_3) = (0.4, 0.4, 0.3)$, then evaluating δ_{s_2} and δ_{s_3}, the evaluation results are as shown in *Equations* (9) and (10).

$$\delta_{s_2} = \frac{(0-0)\times 0.4 + (0-0)\times 0.4 + (0.3-0)\times 0.3}{0.4+0.4+0.3} = 0.01818 \tag{9}$$

$$\delta_{s_3} = \frac{(0-0.3)\times 0.4 + (0-0.3)\times 0.4 + (0.3-0.3)\times 0.3}{0.4+0.4+0.3} = -0.2181 \tag{10}$$

Step 3: Since $\delta_{s_2} > 0$ and $\delta_{s_3} \leq 0$, L = $f_L(d_1, d_2, c_3) = a_1 + \delta_{s_2} = 0 + 0.0818 = 0.0818$. Hence, the min f_L is 0.0818 and go to Step 4.

Step 4: Sort b's in to non-decreasing order, the resulting sequence is [$a_1 = 0$, $b_1 = 0.4$], [$a_2 = 0$, $b_2 = 0.4$], and [$a_3 = 0.3$, $b_3 = 0.7$]. So $(b_1, b_2, b_3) = (0.4, 0.4, 0.7)$, $first := 1$, $last := 3$.

Step 5: ζ-threshold $:= \lfloor (1+3)/2 \rfloor = 2$, S = $(c_1, c_2, d_3) = (0, 0, 0.7)$, then evaluating ζ_{s_2} and ζ_{s_3}, the evaluating results as shown in *Equation* (11) and *Equation* (12).

$$\zeta_{s_2} = \frac{(0.4-0.4)\times 0 + (0.4-0.4)\times 0 + (0.7-0.4)\times 0.7}{0+0+0.7} = 0.3 \tag{11}$$

$$\zeta_{s_3} = \frac{(0.4-0.7)\times 0 + (0.4-0.7)\times 0 + (0.7-0.7)\times 0.7}{0+0+0.7} = 0 \qquad (12)$$

Step 6: Since $\zeta_{s_2} > 0$ and $\zeta_{s_3} \leq 0$, $U = f_U(c_1, c_2, d_3) = b_2 + \zeta_{s_2} = 0.4 + 0.3 = 0.7$.

Hence, the max f_U is 0.7 and stop. The interval for α = 0 is [0.0818, 0.7], in which each point is corresponding to the end points of the triangle representing the membership function.

The above process finds the upper and lower bounds of the synthetic membership function, and the following process will obtain conduct the triangle value with respect to α = 1. For α = 1, the intervals of $r_{i=1\text{-}3}$ are [a_1 = 0.2, b_1 = 0.2], [a_2 = 0.2, b_2 = 0.2], and [a_3 = 0.35, b_3 = 0.35], and the intervals of $w_{i=1\text{-}3}$ are [c_1 = 0.2, d_1 = 0.2], [c_2 = 0.2, d_2 = 0.2], and [c_3 = 0.5, d_3 = 0.5]. Notice that the r_i shown here have not been sort yet.

Step 1: Sort a's into non-decreasing order, and the resulting sequence is [a_1 = 0.2, b_1 = 0.2], [a_2 = 0.2, b_2 = 0.2], and [a_3 = 0.35, b_3 = 0.35]. So (a_1, a_2, a_3) = (0.2, 0.2, 0.35), $first := 1$, $last := 3$.

Step 2: δ-threshold $:= \lfloor (1+3)/2 \rfloor = 2$, S = (d_1, d_2, c_3) = (0.2, 0.2, 0.5), then evaluating δ_{s_2} and δ_{s_3}, the evaluation results as shown in *Equations* (13) and (14).

$$\delta_{s_2} = \frac{(0.2-0.2)\times 0.2 + (0.2-0.2)\times 0.2 + (0.35-0.2)\times 0.5}{0.2+0.2+0.5} = 0.0833 \qquad (13)$$

$$\delta_{s_3} = \frac{(0.2-0.5)\times 0.2 + (0.2-0.5)\times 0.2 + (0.35-0.5)\times 0.5}{0.2+0.2+0.5} = -0.2167 \qquad (14)$$

Step 3: Since $\delta_{s_2} > 0$ and $\delta_{s_3} \leq 0$, $L = f_L(d_1, d_2, c_3) = a_2 + \delta_{s_2} = 0.2 + 0.0833 = 0.2833$. Hence, the min f_L is 0.3884 and according to the $a_i = b_i$ (where i = 1-3, when α = 1), it can conclude that the min $f_L = f_U = 0.2833$. For α = 1, the obtained interval result is [0.2833, 0.2833] which corresponds to the center of the triangle. Consequently, with the intervals for α = 0 and 1, the resulting membership function is determined and is plotted in Figure 9.

As the result shown in Figure 9 is fuzzy membership function, Euclidean distance (as shown in *Equation* (5)) is used to determine the closest membership function (from Figure 4 for performance the decision goal. The following calculation shows how to use the Euclidean distance to determine the appropriate understanding level.
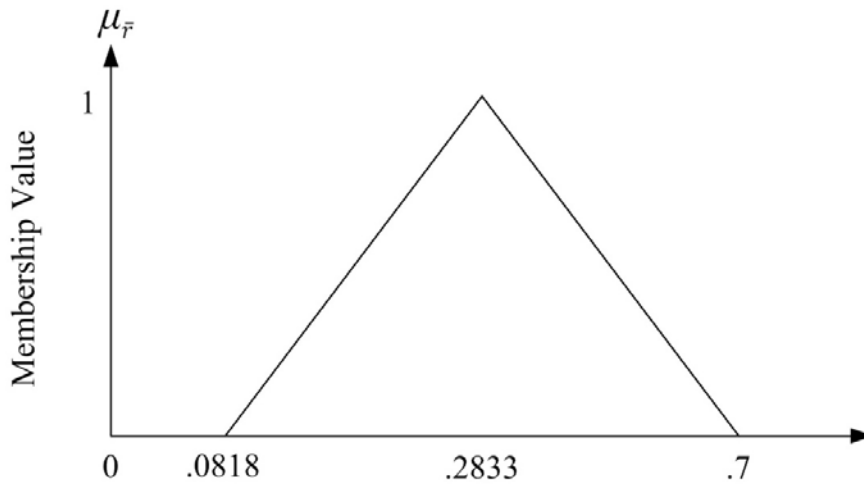
Figure 9. The resulting membership function

$$d(\bar{r}, A_{Misunders\tan ding}) = \sqrt{(0.0818 - 0.15)^2 + (0.2833 - 0.35)^2 + (0.7 - 0.55)^2} = 0.1777$$

Based on the measured results, the other Euclidean distances are $d(\bar{r}, A_{Misunders\tan ding}) = 0.3219$, $d(\bar{r}, A_{Average}) = 0.3075$, $d(\bar{r}, A_{Unders\tan ding}) = 0.5409$, and $d(\bar{r}, A_{Full\ Unders\tan ding}) = 0.7909$. After measuring all of the Euclidean distances between the resulting membership function and all alternatives, the decision model determines that Misunderstanding is the closest alternative, and then presents the corresponding feedback to the students.

Developing and Implementing a Framework of Participatory Simulation for Mobile Learning Using Scaffolding

Chengjiu Yin[1*], Yanjie Song[2], Yoshiyuki Tabata[1], Hiroaki Ogata[3] and Gwo-Jen Hwang[4]

[1]Research Institute for Information Technology, Kyushu University, Fukuoka, Japan // [2]Department of Mathematics and Information Technology, Hong Kong Institute of Education, Hong Kong// [3]Deptpartment of Information Science and Intelligent Systems, University of Tokushima and Japan Science and Technology Agency, Japan // [4]Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taiwan // yin@cc.kyushu-u.ac.jp // ysong@ied.edu.hk // tabata@cc.kyushu-u.ac.jp //ogata@is.tokushima-u.ac.jp // gjhwang.academic@gmail.com
[*]Corresponding author

ABSTRACT

This paper proposes a conceptual framework, scaffolding participatory simulation for mobile learning (SPSML), used on mobile devices for helping students learn conceptual knowledge in the classroom. As the pedagogical design, the framework adopts an experiential learning model, which consists of five sequential but cyclic steps: the initial stage, concrete experience, observation and reflection, abstract conceptualization, and testing in new situations. Goal-based and scaffolding approaches to participatory simulations are integrated into the design to enhance students' experiential learning. Using the SPSML framework, students can experience the following: (1) learning in augmented reality by playing different participatory roles in mobile simulations in the micro-world on a mobile device, and (2) interacting with people in the real world to enhance understanding of conceptual knowledge. An example of the SPSML-based system was implemented and evaluated. The experimental results show that the system was conducive to the students' experiential learning and motivation. Moreover, the students who learned with the proposed approach gained significantly higher accuracy rates in performing the more complicated sorting algorithm.

Keywords

Participatory simulation, Scaffolding , Mobile learning, Experiential learning model

Introduction

More and more participatory simulations have been developed on mobile devices for educational use (Klopfer, 2008; Klopfer & Squire, 2008; Squire & Jan, 2007). They have been used in a way that can provide models of real-world settings for students to construct knowledge through active participation in learning activities (Patten, Arnedillo-Sanchez & Tangney, 2006). Some participatory simulations fall into a context-aware category and are more often found in ubiquitous computing (Gay & Hembrooke, 2004; Naismith, Lonsdale, Vavoula, & Sharples, 2004). A system is considered context-aware "if the system uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task" (Dey, 2001, p. 5). Mobile devices are well suited to context-aware applications due to their sensitivity in gathering and responding to real or simulated data unique to a particular location, environment and time (Klopfer & Squire, 2008). Context-aware applications have been the subject of many studies (Hwang, Kuo, Yin, & Chuang, 2010; Chu, Hwang, & Heller, 2010; Chiou, Tseng, Hwang, & Heller, 2010).

Research into context-aware participatory simulations has led to various innovations. However, less studied in this area is the use of scaffolding in a traditional sense to achieve what students want but are unable to achieve in the simulated environments (Luckin, Looi, Puntambekar, & Fraser, 2011). Moreover, few studies in participatory simulations have employed both scaffolding and fading approaches. Roschelle (2003) classified classroom applications into three categories: classroom response systems, participatory simulations, and collaborative data gathering. Chen, Kao, & Sheu (2003) reported a collaborative data gathering mobile learning system for scaffolding students in a bird-watching exercise. However, there is no scaffolding participatory simulation system reported to date. This research therefore developed an innovative framework called scaffolding participatory simulation for mobile learning (SPSML), premised on participatory simulations and experiential learning principles (Kolb, 1984).

This framework is a context-aware participatory simulation for mobile learning using scaffolding and fading approaches whereby students can be scaffolded when needed, and the fading strategies are initiated when the

students have achieved what they want to learn. An instance of the SPSML-based system was trialed and evaluated. The instance is called learning sorting algorithms with mobile devices (LSAMD) and is designed to help students learn abstract concepts presented in face-to-face classrooms.

The next section presents the theoretical background of the SPSML framework, followed by an introduction to the pedagogical design of the SPSML framework. We then describe and evaluate an example of a SPSML-based system. Finally, we draw conclusions.

Theoretical background of the SPSML framework

Participatory simulations

Participatory simulations provide models of real-world settings in which students can construct knowledge through active participation in learning activities (Klopfer & Squire, 2008; Patten, Arnedillo-Sanchez, & Tangney, 2006). Context-aware participatory simulation encourages more active participation and interaction among students because students "do not just watch the simulation, they are the simulation" (Naismith, Lonsdale, Vavoula, & Sharples, 2004, p. 13). This approach enables students to become immersed in an augmented learning environment in which they take an active role in their learning process and enhance their understanding of abstract concepts in complex learning situations.

In contrast, when engaging in participatory simulations in mixed learning environments (virtual and real worlds), students actively interact with the environments, the teacher, peers, and the other people concerned to construct knowledge and solve authentic problems (e.g., Dunleavy, Dede, & Mitchell, 2009; Klopfer, Yoon, & Rivas, 2004; Klopfer & Squire, 2008). According to Dede (2005), participatory simulations (a) support collaboratively sieving and synthesizing experiences rather than individually locating and retrieving information, (b) enhance active learning based on real and simulated experiences that offer opportunities for reflection, and (c) facilitate the co-design of learning experiences personalized to individual needs and preferences. These features have been taken into account in designing the SPSML framework.

Experiential learning

The pedagogical design of the SPSML is premised on Kolb's experiential learning model, which focuses on experience as the main force driving learning because "learning is the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). Thus, learning is a constructive process in context. It happens in a cyclical model (see Fig. 1) consisting of four stages: concrete experience, reflective observation, abstract conceptualization, and testing in new situations (de Freitas & Neumann, 2009; Kolb, 1984; Lai, Yang, Chen, Ho, Liang, & Wai, 2007).
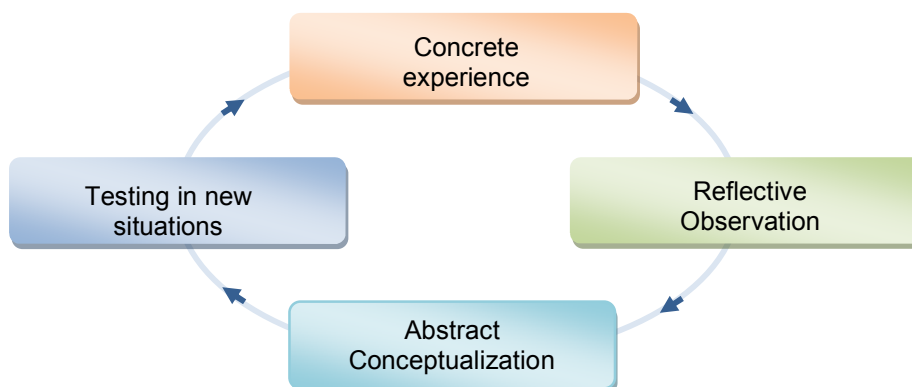

Figure 1. Kolb's experiential learning model

This model requires that learning scenarios, which may be embedded with a series of different objectives, activities, and outcomes, be integrated into the experiential pedagogical design. One issue to be addressed is to move away from a set of sequencing of learning to more options (Barton & Maharg, 2006). These different routes for learning have the potential to increase students' engagement. Participatory simulations using mobile technologies are well suited to experiential learning in that they provide models of real-world domains for students to gain knowledge through active participation, and provide rich data that "augment" users' experience of reality by connecting data on the mobile devices (Klopfer & Squire, 2008). The following describes the four stages of the experiential learning model:

1. *Concrete experience*. Student experiences can fluctuate between the virtual environment and real life by enabling digital simulations in authentic problem-solving situations in which learners play different roles to interact with other entities that have different skills (Dede, 2009).
2. *Reflective observation*. Reflection may involve revisiting learning activities. Although reflection can occur during any stage of the experiential learning cycle, these explicit virtual tasks ensure that students can engage in reflection (de Freitas & Neumann, 2009).
3. *Abstract conceptualization*. Students gain new knowledge by integrating previous observations, interactions and reflections into logically sound concepts, which provides contexts in which they can consciously create structured understandings of their experience. We need to focus on what kinds of abstractions would be most relevant in student learning contexts, using experiential learning models with a view to the particular learning outcomes.
4. *Testing in new situations*. In the on-going iterative cycle, students are expected to be able to test and practise these concepts by actively experimenting, for example, in a follow-up practice in new situations. Thus, as a component of a course curriculum, the participatory simulation provides a virtual space that complements their learning in real life and within which they can engage experientially to construct conceptual knowledge.

However, experiential learning has its drawbacks. First, it lacks a mechanism for making students focus on the learning objectives in context (Miettinen, 2000). Second, students may lack the skills and pay inadequate attention to abstraction of concepts from experience (Lai, Yang, Chen, Ho, Liang & Wai, 2007). We postulate that there are two ways to overcome these hurdles: (a) by adopting Squire's (2006) and Schank, Fano, Bell and Jona's (1994) goal-based approach to participatory simulations premised on constructivist theory, and (b) by scaffolding. The important aspects of the goal-based approach are to focus on the learning goals that should be intrinsically motivating and the role that the learner plays.

The criteria for the design of learning scenarios are as follows:
- Thematic coherence. The process of achieving the goal is thematically consistent with the goal itself.
- Realism. The design must be authentic to produce varied opportunities for learning the target skills and knowledge.
- Empowerment. The design puts students in control to increase the sense of agency.
- Responsiveness. Prompt feedback is provided to help students acquire skills and knowledge.
- Pedagogical goal support. The proposed design is compatible with and supports the acquisition of skills and knowledge.
- Pedagogical goal resources. Students are provided with appropriate help.

The adoption of role play is to reinforce and explore difficult concepts that can be integrated into face-to-face classrooms or be used in complex learning environments. The participatory simulations provide students with a dynamic interactive role-play activity in an experiential learning process so that students get to experience, observe and reflect, form abstract concepts, and test their solutions in new situations. Scaffolding and fading built into the participatory simulations is another important approach to addressing the problem of students' lack of skills in abstracting concepts from experience, which is elaborated on in the next section.

Scaffolding and fading

A number of studies on the design of context-aware participatory simulations using mobile technologies have reported the usefulness of the systems for enhancing student collaborative learning and problem solving (e.g., Dunleavy, Dede, & Mitchell, 2009; Klopfer & Squire, 2008). However, in many cases, there is a recognition-production gap between what students want to achieve and what they are able to achieve themselves in the simulated

environments. This gap can be bridged via scaffolding (Luckin, 2008). Scaffolding, as provided by human tutors, has been well established as an effective means of supporting learning (Soloway, Norris, Blumenfeld, Fishman, & Marx, 2001).

Luckin, Puntambekar, & Fraser (2011) posit that research exploring the use of mobile technologies to support learning rarely involves scaffolding in the traditional sense. Scaffolding enables learners to realize their potential by providing assistance when needed, and then fading out this assistance as meaningful learning takes place (Collins, Brown, & Newman, 1989). The notion of scaffolding is associated with the work of Vygotsky (1978): a novice learns with a more capable peer, and learning happens within the novice's zone of proximal development (ZPD). With the development of technology, scaffolding tools are specially designed to help students learn in the complex learning environment. Different learners in the same class may have different ZPDs.

However, in many cases, support for learning provided by the tools "focuses on providing 'blanket support' (i.e., the amount and type of support is constant for everyone and is not sensitive to the changing level of understanding in learners)" (Puntambekar & Hübscher, 2005, pp. 7–8). To cater to the different needs of students, in designing scaffolding in tools, it is important to consideration (a) the multiple ZPDs of students, (b) building fading into the system so that the tools themselves may be removed when students do not need them anymore, and (c) teacher's orchestration and facilitation of the learning process so that students can make good use of the scaffolding tools and resources for learning (Puntambekar & Hübscher, 2005).

Pedagogical design of the SPSML framework

In this study, we propose a context-aware participatory simulation framework called SPSML for designing learning systems on mobile devices using scaffolding and fading strategies. The SPSML is designed to facilitate students' experiential learning in either complex social contexts or face-to-face classrooms. The scaffolding and fading instructional strategies are used to help students' experiential learning processes. It provides opportunities for students to be involved in active participation and interaction and increases motivation. The SPSML framework consists of five sequential but cyclic steps that use Squire's (2006) goal-based approach and scaffolding and fading strategy use (see Figure 2).
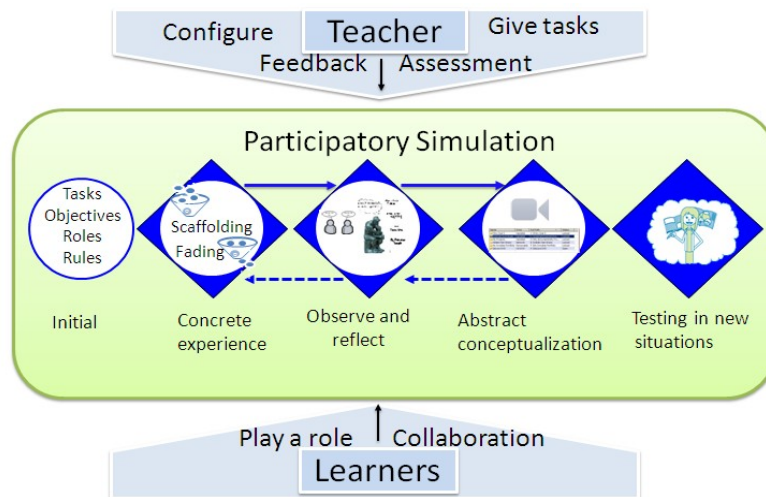
Figure 2. The SPSML framework

Step 1. Initial process

Before implementing the SPSML-based system, the teacher will define: (a) the learning objectives of the activity, (b) the simulation tasks, and (c) the rules and participant roles for playing the simulation (Squire, 2006). The learning

objectives are to help the students to reach their goals, and they need to be identified in order to help the students accomplish the tasks successfully.

To begin the activity, the teacher will set up rules and participant roles to configure the system. The teacher will explain to the students the general ideas of concepts to be learned in face-to-face classrooms and provide examples to guide them. The teacher will also explain to the students the learning objectives of the activity and how to use the system on their mobile devices such as personal digital assistants (PDAs).

Step2. Concrete experience

Concrete experience is composed of scaffolding and fading procedures.

Scaffolding

When students start experiencing and acting during the activity, the teacher will assign different tasks and roles for them to play in the simulation, according to the rules. The system on the mobile device will guide the students in how to do the tasks and play the roles if they need help. This step acts like a bridge used to enable the students to master the conceptual knowledge in face-to-face classrooms. The system assists students by providing information about where the mistakes are and how to correct them so that they are able to achieve the goals of the task. This system is composed of three stages: point out mistakes, help to correct, and discuss (see Figure 3):

1. *Point out mistakes.* The scaffolding system will assist students by providing some instructions about where the mistake is immediately after they make the mistake. It helps the students complete the task effectively.

2. *Help to correct.* When the students cannot solve the problem themselves, the system will facilitate them in this regard. There are three kinds of scaffolds at this stage: hint, illustration and teacher's help, as shown in Figure 3.
- Hint. The system will offer a hint about a solution to help the student find out ways to perform the tasks and play the roles based on an ongoing diagnosis of student learning (Puntambekar & Hübscher, 2005).
- Illustration. The system will describe the goals of the tasks or provide key information about how to play the role with a simple example.
- Teacher's help. If the students want to make an inquiry to a teacher, the system allows the teacher to provide facilitation. The teacher can observe the status of each student's participation and the roles they are playing on the mobile device in order to respond to the inquiry.
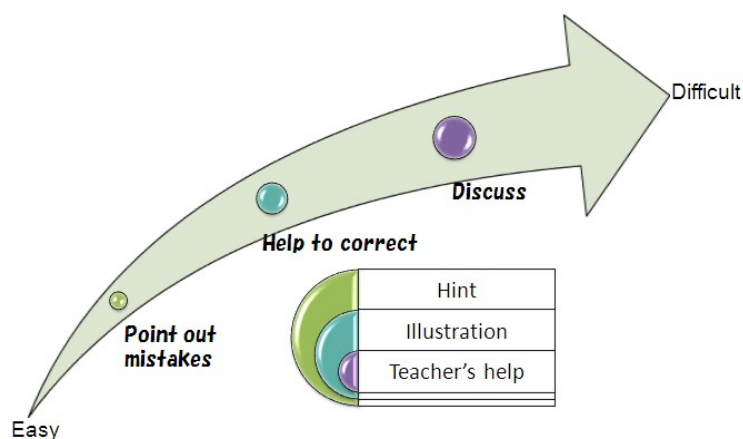
Figure 3. Three stages

3. *Discuss.* The students are allowed to discuss with partners via mobile devices. Discussion is a source of ideas for other students, using evidence in support of claims, getting advice, and providing explanations that others

can understand, as well as a vehicle for some of the reflection necessary to turn one's experiences into well-formed and well-indexed cases in one's memory (Kolodner & Nagel, 1999).

The students will construct the learning goals collaboratively via discussion. They construct initial understandings of the concepts by participating in the discussion after the concrete experience.

Fading

After participatory role play on the mobile device, students will gradually be able to understand the methods and strategies to solve the problems and become more experienced with the conceptual knowledge. At this point, the fading process starts. The students use the fading mode to practise independently. Then, the system reduces the help messages gradually, and more responsibilities are shifted to the students. Finally, they will be able to solve the problems themselves without the scaffolding of the system. In the meantime, the teacher can also help orchestrate the gradual reduction of the system's help function according to the level of understanding of the students.

We have designed the fading mode as three levels depending on the different ZPDs of learners:
- *Level 1.* Point out the mistakes only, but require the students to find out how to correct them. They can discuss with their role-play partners at this level. They can also seek help from the teacher.
- *Level 2*. Do not point out the mistakes, but have the students correct them by themselves. They cannot get help from the teacher, but they can discuss with their partners.
- *Level 3*. Do not provide help and discussion, but have everyone complete the task by him/herself at this level. After all the students pass Level 3, it means that they have mastered the conceptual knowledge.

Step 3. Observation and reflection.

After completing the concrete experience of participatory roles in the simulations, the students carry out discussions and reflections. They reflect on what they have learned, how well they have understood, and what else they want to learn. If they need more experience in participatory simulations, they can restart the simulation from any step such as from the scaffolding or fading step rather than from the initial step because all their prior experience has been saved in the database.

Step 4. Abstract conceptualization

Because the student experience in the participatory simulation is recorded and stored in the database and these records can be converted to a video, the students can review their learning progress by watching the video or looking at the history record. This step helps the students transform their learning experience and construct conceptual knowledge to achieve their learning goals.

Step 5. Testing in new situations

After conceptualizing what they have learned, the students can try out the concepts in their real-life situations to deepen their understanding of the conceptual knowledge.

An instance of implementation of the SPSML-based system

In this section, we describe an instance of the implementation of the SPSML-based learning system LSAMD, which supports the learning of sorting algorithms (abstract concepts). There are four sorting algorithms in the system: bubble sort, insertion sort, selection sort, and quick sort.
Figure 4 shows the LSAMD interface. Using this system, all the students stand in a line with a PDA, and the teacher assigns an array of numbers to the students and asks them to sort these numbers according to a certain algorithm. The

new position of each step is sent to the server. They receive these tasks, collaborate, and exchange physical positions according to the algorithm.
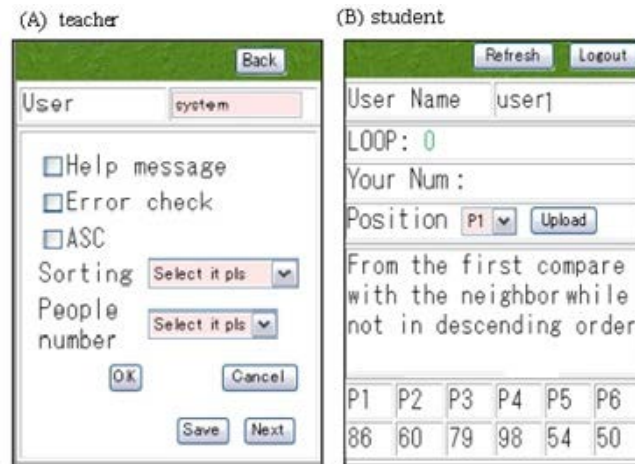
Figure 4. Interface of LSAMD

Simulation description

In LSAMD, the students play the role of data in the simulation of the sorting algorithm to visualize the data flow of the computer in the real world.

Determine learning objectives. The learning objective of the simulation is to help students master the sorting algorithms.

Set up a simulation. The teacher sets up the algorithms to configure the server, then selects a sorting algorithm and sets the number of the students. After the random data are generated, the teacher sends these data to the students. The students will get the data to be arranged from the server according to their ID. The students play the roles of the data in the sorting algorithms. They analyze, compare, discuss, and swap the assigned data. The results will then be sent to the server, and the server will compare the correctness of the results. At the same time, the teacher can view the results, evaluate student understandings of the algorithms, and design new ways to explain the compilation of the data.

Design task. This simulation is provided for students to sort the algorithms together. The students use this system to study the four algorithms in a group.

Set up scenarios for using LSAMD. This is a scenario of the SPSML-based LSAMD system to learn sorting algorithms:
1. The system generates the data randomly and sends them to the students. Following is a sample of the "quick sort" algorithm. In the example, the array list, "78, 35, 22, 67, 56, 38, 15, 11," is sorted in ascending order. All the students stand in a line with a PDA, which displays their numbers and positions in a table and also displays the pivot.
2. The teacher turns on the option with error checking and help messages, and the students can discuss with each other which is in the scaffolding mode. The system will initialize Left to First and Right to Last. It will also give hints and illustrations to solve the problem. In Loop 1, a help message like this will appear initially: "Define the value in position First to be the Pivot and define Left to be First and Right to be Last." After discussion and comparison, the students pick 67 as the Pivot, define Left and Right, and upload them to the server. The results are shown in Figure 5.
3. Then, the system will issue a message such as "Move Left to the first value, which is greater than the Pivot; Move Right to the first value, which is less than the Pivot, then exchange these values." After discussion and comparison, the new position is uploaded to the server. The students will also change their physical standing position in the line.
4. The server will evaluate the change of positions and send an error message if the change is done incorrectly. In the case of making mistakes in the change of positions, the message will then point out the error position and ask the students to correct it.

5. "Then move on to Loop 2." Each student will discuss and compare the result with his neighboring student according to the messages provided by the server in Loop 1, and this process goes on for a few loops depending on the problem until the whole array is sorted.
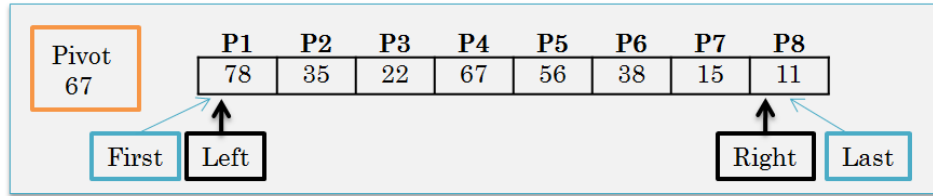
Figure 5. Initialization of the quick sort

When the students master the quick-sorting algorithm at a certain level, the teacher changes the scaffolding mode to fading. For every loop, the student who needs to move first is the leader who takes control of the sorting process in the loop by directing other members to exchange positions. The teacher will turn off the help message option so that the students are situated in level 1 of the fading mode; that is, the system only points out the error position and the learners can discuss with each other to solve the problem. Then, the teacher will turn off both the help message option and error checking option, thus situating the students in level 2 of the fading mode, in which they can discuss with each other to solve the problem. Finally, in level 3, discussion is not allowed; that is, the students are directed by the leader to switch positions to complete the task.

A pilot study

A pilot study was carried out to evaluate the LSAMD system. Twenty-one students participated in the study. They were divided into three groups and were briefed about how to use the system. The procedures of the pilot study are as follows:

Initial stage. The teachers briefed students on the rules of the sorting algorithms and demonstrated how to use the system.

Role-play. The students played the role of data in the simulation of the sorting algorithms. The system guided the students to sort numbers. The system would check the students' sorting and provide feedback if there was a mistake in the positions of the numbers. Then, the students would correct the number positions and send the new positions back to the server. In the meantime, the teacher monitored the students' learning progress and gave comments and feedback. The students could discuss and compare with each other before exchanging positions. When the students mastered the sorting algorithms at a certain level, the system would gradually reduce the help function.

Observe and reflect. Students discussed and reflected on the sorting algorithms together and the teacher acted as a facilitator.

Understand abstract concepts. The students were able to conceptualize the abstract concepts of the sorting algorithms.

Try out new sorting algorithms. The learning history was stored in the server. When they tried a new sorting algorithm, they would review their previous sorting experience to seek better understanding of the new algorithm.

Evaluation

To find out if the SPSML-based system would be helpful for the learning process, we designed an experiment using LSAMD. We set up a control group and an experiment group to compare the accuracy rate of every sort algorithm (every step was recorded).

Participants

A total of 41 master's students with prior algorithm-sorting experience participated in the experiment. The students had learned the sorting algorithms about three years earlier, when they were undergraduate students. However, most of them had not used sorting algorithms for a long time so they had forgotten the rules. The average age of the students was 22 years old. Their past examination on sorting algorithms was used as the pretest. They were divided into two groups according to their average achievement: 21 students were assigned to be the experimental group (average achievement = 72.5), and 20 students formed the control group (average achievement = 73). According to their pretest achievement, it can be inferred that these two groups did not significantly differ prior to the experiment.

Experimental procedure

The students in the control group learned with a sorting algorithm system, which did not provide them with participatory simulations or scaffolding. When using the system, the students first selected a sorting algorithm, and then the system generated numbers in an array. The students performed the sorting operations by exchanging the position of the numbers in the array. If the sorting was wrong, the system only provided an error message such as "There are some mistakes," but did not point out where the mistakes were. These mistakes were stored in the database. The students could also refer to books before using the system.

For the experiment group, the students learned with LSAMD. They stood in a line with a PDA and participated in participatory simulations. They could use the scaffolds "Point out mistakes," "Hint," "Illustration," "Teacher's help," and "Discussion." The mistakes they made as well as the types of scaffolds they used to solve the problem were stored in the database.

Results

Accuracy rate

The accuracy rates of the two groups of students who sorted the data with different algorithms were compared by an independent t-test, as shown in Table 1. For the quick sort, the average accuracy rate and standard deviation were 81.86 and 10.12 for the experimental group, and 52.30 and 9.29 for the control group. The average accuracy rate of the experiment group is higher than that of the control group, and the difference between the two groups is statistically very significant ($t = 9.73$, $p < 0.01$), indicating that the LSAMD system is helpful to students in enhancing their conceptual understanding of this sorting algorithm. On the other hand, for the bubble sort, insertion sort, and selection sort, the average accuracy rates of the two groups do not show significant difference. Because the "quick sort" has been recognized as more complicated than the other sorting algorithms, it could be concluded that the SPSML framework was helpful to the students in improving their learning achievement in terms of complicated conceptual understandings.

Table 1. Accuracy rate

	Group	N	MAR (%)	SD	t-value
Bubble	Experiment	21	93.29	5.60	0.95
	Control	20	91.35	7.34	
Insertion	Experiment	21	90.33	7.91	1.25
	Control	20	86.85	9.94	
Selection	Experiment	21	89.35	8.99	1.78
	Control	20	83.10	12.84	
Quick	Experiment	21	81.86	10.12	9.73**
	Control	20	52.30	9.29	

Note. N: Number of students; MAR: Mean of Accuracy Rate; *SD*: Standard Deviation; ** $p < 0.01$

We also analyzed the records of the mistakes the students made, which were stored in the database. For the quick sort, more identical mistakes were made in the control group than in the experiment group. This may be due to the

fact that the students could not get just-in-time scaffolding when they made mistakes; hence they did not know the reason why they made these mistakes. In contrast, in the experiment group, the students made the same mistakes fewer times because they solved the problems using the scaffolds ("point out mistakes," "hint," "illustration," "teacher's help," and "discussion"), which helped them correct the mistakes in time. The findings also demonstrate that the SPSML framework was helpful to the students in enhancing their learning.

Finally, we worked out the percentage of each type of scaffold used by the students in the experiment group to help them solve their problems (see Figure 6). Figure 6 shows that "discussion" was the most frequently used scaffold (48%). This result is also consistent with the questionnaire results.
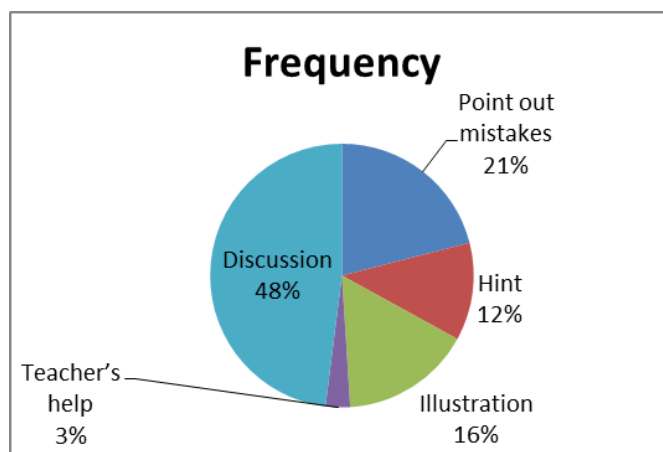
Figure 6. Percentage of each scaffold used by the students

Student attitudes towards scaffolding and fading, and participatory simulations on the SPSML-based system

After the pilot study implementation, a survey was conducted. It consisted of nine closed-ended questions about student attitudes towards the use of the SPSML-based systems (Table 2) on a five-point Likert scale from strongly agree to strongly disagree (5 to 1). All of the students completed the survey.

Table 2. Survey results

Student attitudes towards scaffolds and participatory simulations	SA/A(%)	NN(%)	D/SD(%)	M	SD
Q1 It was helpful to point out mistakes for us.	76.0	24.0	0.0	4.2	0.81
Q2 It was helpful to offer hints.	76.0	24.0	0.0	4.1	0.79
Q3 It was helpful to illustrate the basic outlines of tasks.	62.0	29.0	10.0	3.8	0.98
Q4 The comments from the teacher helped me to improve my understanding.	38.0	38.0	24.0	3.2	0.87
Q5 It was helpful to discuss with partners; the comments from others helped me to improve my understanding.	95.0	5.0	0.0	4.6	0.6
Q6 It was useful to guide us step by step.	52.0	38.0	10.0	3.6	0.92
Q7 It is necessary to reduce the help function when I become more experienced.	86.0	14.0	0.0	4.3	0.73
Q8 I like learning by participatory simulations.	76.0	24.0	0.0	4.2	0.81
Q9 Using these history records and videos, it was helpful to reflect on the learning process.	57.0	24.0	19.0	3.6	1.07

Note. SA/A: strongly agree and agree; NN: neither agree nor disagree; D/SD: disagree and strongly disagree; M: means; *SD*: standard deviation

Table 2 summarizes the results of the student attitudes towards scaffolding and fading and the participatory simulations designed using the SPSML-based systems. The first five questions are related to scaffolding. The results

show that the mean scores of Q1, Q2 and Q3 are close to 4 (agree), which means that the students were satisfied with these scaffolds (point out mistakes, hint, illustration, teacher's help and discussion). Approximately 70% of the students considered that the scaffolds "point out mistakes" (Q1) and "illustrate the basic outlines of tasks" (Q3) were helpful for their learning, while approximately 80% agreed that the scaffold "hint" (Q2) was helpful. Regarding the scaffold "teacher's help" (Q4) however, student attitudes varied. This might be due to the fact that the number of teachers was limited and the students could not get teachers' help in time. On the other hand, 94% of the students agreed that the scaffold "discussion" (Q5) was most helpful for them to improve their understanding among all the scaffolds. The mean score of Q5 is close to 5 (strongly agree). Figure 7 shows a graph of mean scores for each of the scaffolds.

The result of item Q6 shows that over half of the students considered that using the scaffolds to guide them step by step was useful. By examining student use of the scaffolds recorded on the system, it was noted that the students did not use the scaffolds to learn easy sorting algorithms such as "bubble sort," but, rather, they used the scaffolds to guide them to learn complex sorting algorithms such as "quick sort." The results indicate that the SPSML-based systems are suitable for solving complex problems. The findings are consistent with other studies. For example, Klopfer and Squire (2008) found that the students were basically able to solve simple problems on their own, but required additional teacher support to resolve more complex issues.

The results of item Q7 show that it is necessary to reduce the help function when the students were progressing in their learning. In terms of student attitudes towards the participatory simulations (Q8), approximately 84% of the students indicated that they liked learning in this way. Finally, a majority of the students agreed that it was helpful for them to reflect on their learning progress using learning history records and videos (Q9).

Reliability statistics

Reliability analyses were conducted for two SPSML-based systems using SPSS. The Cronbach's alpha of all the survey items (13 Questions) is 0.832, and the Cronbach's alpha of Part 1 (student attitudes towards scaffolds and participatory simulations) is 0.741; thus, we can conclude that the survey items have relatively high internal consistency.
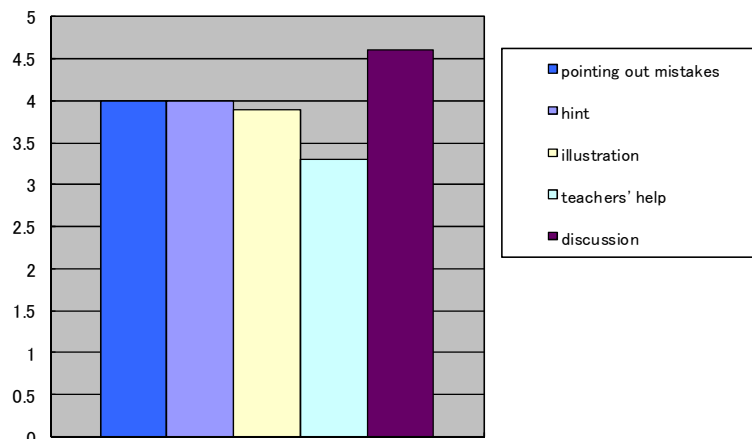
Figure 7. Mean scores for each of the scaffolds

Discussion and conclusions

In this paper, we describe a conceptual framework, SPSML (scaffolding participatory simulation for mobile learning) developed on mobile devices for helping students learn conceptual knowledge in classrooms or in complex social contexts. We adopted an experiential learning model as the pedagogical design of the SPSML framework, which consists of five sequential but cyclic steps: the initial stage, concrete experience, observe and reflect, abstract

conceptualization, and testing in new situations. Scaffolding and fading were designed on the SPSML framework to support experiential learning. Using the SPSML framework, students could play different participatory roles in mobile simulations and understand abstract concepts better.

An instance of the SPSML-based system LSAMD was implemented and evaluated. It was used to engage students in a participatory role-play to learn abstract concepts of sorting algorithms. Student attitudes towards the use of the system were evaluated using both a closed-ended and open-ended survey. The results show that generally the students expressed positive attitudes towards use of the system, and considered that the system helped them deepen their understanding of the abstract concepts more effectively through scaffolding, discussion, and trial and error in the participatory simulations for experiential learning. This indicates that the learning systems under the SPSML framework were conducive to the students' experiential learning, improved their motivation, facilitated collaboration, and advanced their conceptual understanding. Moreover, the experimental results also show that the SPSML framework was helpful to the students in improving their learning achievements in terms of complicated conceptual understandings.

The main contribution of this study is to propose mobile learning with scaffolding approach to improving students' learning performance in the area of computer algorithms. Although mobile learning and scaffolding have been employed in previous studies, the application domains have mainly been natural science, social science or mathematics courses (Chen, Kao, & Sheu, 2003; Chu, Hwang, & Tsai, 2010; Hwang & Chang, 2011). To our knowledge, no mobile learning study with scaffolding has been applied to computer courses, not to mention the learning of computer algorithms, which is fundamental and important for fostering programming skills (Kordaki, Miatidis, & Kapsampelis, 2008). Therefore, the approach of this study is innovative from the perspective of learning computer algorithms.

In comparison with the traditional approach, in which students practise computer algorithms with paper and pencil or a computerized editing system (Lau & Yuen, 2010), the SPSML-based system not only situates the students in a context for experiencing each step of the algorithms, but also provides them with various learning supports (e.g., supplementary materials and feedback). Moreover, those computerized systems developed by previous studies, such as the TRAKLA2 system (Malmi, Karavirta, Korhonen, Nikander, Seppälä, & Silvasti, 2004), an interactive algorithm simulation system with animation, are more like the system used by the control group of this study. That is, in those previously developed systems for teaching computer algorithms, no scaffolding (i.e., fade-in and fade-out of discussion, help, and feedback functions) is provided, not to mention the provision of experiential learning.

To sum up, in this study, the participatory simulations using mobile technologies have situated the students well in experiential learning contexts (Klopfer & Squire, 2008); moreover, the integration of participatory simulations and scaffolding is helpful to the students in significantly gaining a higher accuracy rate in performing complicated sorting algorithms.

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Effect of Reading Ability and Internet Experience on Keyword-based Image Search

Pei-Lan Lei[1*], Sunny S. J. Lin[2] and Chuen-Tsai Sun[1]

[1]Department of Computer Science, National Chiao Tung University, Taiwan // [2]Institute of Education, National Chiao Tung University, Taiwan // pennylei0419@gmail.com // sunnylin@faculty.nctu.edu.tw // ctsun@cis.nctu.edu.tw

[*]Corresponding author

ABSTRACT

Image searches are now crucial for obtaining information, constructing knowledge, and building successful educational outcomes. We investigated how reading ability and Internet experience influence keyword-based image search behaviors and performance. We categorized 58 junior-high-school students into four groups of high/low reading ability and frequent/infrequent Internet usage. Participants used Google Image to complete four tasks: finding four images that match four given sentences. The results indicate that reading ability exerted a stronger influence than Internet experience on most search behaviors and performance. Positive relations were found between search performance and two behavior indicators of search outcome evaluation. Students with better reading ability tended to use/revise appropriate keywords, as well as evaluate/select images that matched multiple aspects of the task descriptions. Students with low reading ability/frequent Internet experience tended to enter a single keyword and carelessly select images, while those with low reading ability/infrequent Internet experience tended to use improper keywords and were unskillful in handling search engines. Combined, our results show that successful keyword-based image searches are strongly dependent on reading ability and search result evaluation skills.

Keywords

Information problem-solving, Image search, Search behavior, Reading ability, Internet experience

Introduction

Many individuals now consider digital cameras, cell phones with photo functions, and online photo-sharing websites to be indispensable information-sharing tools. The adages of "seeing is believing" and "a picture is worth a thousand words" are now prevalent concepts in both daily life and learning. By illustrating abstract ideas through visible/concrete content and spatial arrangement, photos can convey non-verbal messages that texts are incapable or less capable of expressing. In the past two decades, visual image has become predominant form of communication across a range of learning and teaching resources, delivered across various media and formats (Bamford, 2003). Teachers frequently incorporate pictures in lectures and assignments, especially in biology, earth science, art, geography, and history domains. Students are increasingly required to attach supporting photos/figures when writing reports or creating posters to improve readability and learning effectiveness. These trends have increased the need for accurate online image search strategies. Successful image searchers are required to identify subjects, meanings, and/or elements in images, and to make judgments regarding image accuracy, validity, and value.

Many researchers have examined information-seeking behaviors and performance, but have generally focused on text rather than image searches. Text searches require the comprehension of topic-related connotations, as well as the use of associated ideas to formulate keywords. In contrast, picture or image searches require theme formulation and the ability to envision potential results. Given that many current image retrieval systems are keyword based, users must translate their visions into text keywords, and pictures stored in databases must have descriptive words or metadata that match selected keywords (Fukumoto, 2006; Hou & Ramani, 2004). Search systems transmit some pictures for users to compare, assess, and determine whether or not they need to continue a search. Accordingly, keyword-based image searches can be analyzed as complex cognitive processes involving image-text cross-referencing, observation, judgment, decision-making, and correction. Note that the presence of semantic gaps and lack of precise characteristics make keyword-based image searches more abstract and complex than text searches (Choi, 2010; Cunningham & Masoodian, 2006). For keyword-based image searches, descriptive and thematic queries are more commonly used than unique term queries. Most users perform a large amount of query modification yet are still unable to find images they desire in an effective way (Jörgensen & Jörgensen, 2005). Approximately one-fifth of

all image search queries result in zero hits (Pu, 2008). Yet little is known about factors that can improve the odds for successful keyword-based image searches, which is the primary motivation for the present study.

Individuals tend to use distinctly different behaviors to perform identical search tasks—for example, reading multiple pages of search results in detail versus skimming one page of results before trying a new keyword, following multiple links versus stopping after the first webpage, or using one versus multiple search engines. Different individuals thus achieve different search outcomes and learning effects. Regarding differences in text search behaviors and performance, researchers have looked at factors such as cognitive ability (Kim & Allen, 2002; Rouet, 2003), domain knowledge (Park & Black, 2007; Rouet, 2003), thinking style (Kao, Lei, & Sun, 2008), problem-solving style (Kim & Allen, 2002), cognitive style (Ford, Eaglestone, Madden, & Whittle, 2009; Park & Black, 2007), study approach (Ford, Miller, & Moss, 2005), and Internet experience (Ford et al., 2009; Kim, 2001; Lazonder, Biemans, & Wopereis, 2000; Moore, Erdelez, & He, 2007; Park & Black, 2007; Wang, Hawk, & Tenopir, 2000; White & Iivonen, 2001). While it seems obvious that differences in individual characteristics and cognitive development may influence text-search behaviors and performance (Kim & Allen, 2002), few researchers have made the effort to test these ideas or to identify specific factors influence image searches.

Many image searches aim at locating pictures or illustrations that support text, abstract concepts, or other pictures and images. The people's motivations of image searches include a perceived need for illustrations, paintings, maps (geographic or flow), and cartoons while reading textual descriptions or looking at pictures, as well as a requirement for images to interpret abstract contents. For this study we purposefully designed image search tasks associated with texts, since one of the most common motivations is finding images to support paragraphs that lack illustrative examples.

Reading ability seems to play an important role in keyword-based image searches triggered by texts. During the search process, users are required to read sentences, comprehend their meaning, and consider relevant keywords for picture retrieval. Part of their task is comparing multiple search results and evaluating the appropriateness of pictorial information.

In addition, experience with the Internet and/or search engines is another factor that may affect search behaviors and performance (Bilal & Kirby, 2002; Hsieh-Yee, 2001). Internet novices (who are generally less flexible in terms of search strategies) tend to perceive information searches as difficult, laborious, and frustrating (Hölscher & Strube, 2000). More experienced Internet users are more likely to employ a variety of techniques (e.g., Boolean operators) or to experiment with unfamiliar tools in order to achieve better search performance.

To determine the effects of reading ability and Internet experience on keyword-based image search behaviors and performance, we established the following research questions:
1. Given specific search tasks, how do students perform image searches (search behaviors) in terms of total number of keywords, average number of Chinese characters per keyword, maximum number of viewed pages per keyword, total number of viewed pages per task, and search time? How successful are their image searches (search performance)?
2. What are the effects of reading ability and Internet experience on image search behaviors and performance? We collected quantitative indicators of search behaviors and performance as well as qualitative observational descriptions about search process.
3. Do correlations exist between individual search behaviors and search performance?

Literature review

Information and image searches

Marchionini (1995) lists the seven steps of information-seeking as recognizing and accepting information demand, defining the problem, selecting query sources, formulating a query, executing the query, examining the results, and extracting information. Brand-Gruwel, Wopereis, and Vermetten (2005) use the term information problem-solving to describe similar search actions. To achieve resolution, the multi-step and non-linear information-seeking process requires repetitive execution in addition to trial-and-error activities (Marchionini, 1995). Information searches are

considered examples of complex cognitive processes, with individuals adopting different methods and sequences to find information (Hsieh-Yee, 2001; Rouet, 2003; Walraven, Brand-Gruwel, & Boshuizen, 2008).

Search engines have radically altered information-seeking habits. In developed and many developing countries, most high-school and college students (and non-students) immediately turn to the Internet to find information (Brand-Gruwel et al., 2005). They are required to actively seek and evaluate information and to construct knowledge from online searches (Bilal & Kirby, 2002). Users may acquire new concepts emerging from online information (Tsai & Tsai, 2003), which they subsequently integrate with prior knowledge (Brand-Gruwel et al., 2005). The ability to find information is frequently described as a problem-solving skill (Laxman, 2010; Park & Black, 2007; Walraven et al., 2008), one that entails planning, monitoring, evaluating, and revising—activities associated with metacognitive learning strategies (Brown, 1987). Since many search results are now displayed in some form of multimedia, learners have more opportunities to use sound, pictures, and text to construct knowledge, thus making knowledge acquisition a concrete representation of cognitive elaboration (Reigeluth & Stein, 1983). For our purposes, we viewed information searching as an active process of cognition and learning, and then investigated how different users "learn" to look for meaningful information online, and how they locate useful results.

Of all the strategies and techniques that Internet users employ, proper keyword selection is viewed by many researchers as pivotal to online search success (Fukumoto, 2006; Hsieh-Yee, 2001; Pu, 2008; Spink, Wolfram, Jansen, & Saracevic, 2001; Tu, 2005; Wang, Liu, & Chia, 2006; White & Iivonen, 2001). Search engine hits tend to be more relevant as the number of keywords used for an individual search—as Hsieh (2000) observes, the more definitive the query, the more accurate the findings. According to Pu (2008) and Walraven et al. (2008), many Internet users have trouble executing successful searches due to inaccurate statements or inappropriate structure— that is, they select keywords that are too wide or too narrow. A typical keyword-based image search process consists of typing in one or two keywords, viewing the resulting images, and repeating the process (Fukumoto, 2006). Since most search engines require keywords to locate text, pictures, and video or audio files, user selection of appropriate keywords is essential to success. Accordingly, we considered "total number of keywords" and "average number of Chinese characters per keyword" as search-behavior indicators regarding the aspect of keyword usage.

Other focal points include how users compare, evaluate, and verify information in terms of purpose, trustworthiness, and accuracy. Tsai (2004) notes that Internet searchers must evaluate the information they find until they identify the best results. Rouet (2003) suggests users improve their chances of success when they double-check search results, but others observe that most searchers want to use as little effort as possible to find the information they need (Spink et al., 2001). Assuming that judgments of accuracy influence search-result precision, we investigated the ability or motivation of users to accurately assess information. Specifically, we used "the maximum number of viewed pages per keyword," "total number of viewed pages per task," and "search time" as search-behavior indicators regarding the aspect of result evaluation.

Internet experience

Kim (2001), Matusiak (2006), and White and Iivonen (2001) are among researchers describing associations between search behaviors/performance and Internet experience. In a study of search strategies used by college students (ages 21–30) and non-students (ages 35–62), Matusiak (2006) found that students preferred keyword searches to browsing pathways, and felt more confident about their search skills due to their regular Internet usage. According to Yuan (1997), search experience enhances both user speed and the ability to make adjustments in online search approach or technique. Park and Black (2007) describe correlations between search experience and both search time and outcome, and suggest that search experience increases user familiarity with search strategies and supports the development of information search schema. According to Hölscher and Strube (2000) and Wang et al. (2000), the most experienced Internet users tend to apply more advanced techniques and express more complex behaviors in response to not immediately finding what they are looking for. Examples include using advanced search options, trying alternative search engines, and reformulating or reformatting original queries to take advantage of Boolean operators, modifiers, and phrases.

Other researchers assert that experience does not automatically result in better search performance. Wang et al. (2000) report that regardless of experience, participants in their study spent very little time looking at individual pages. Yuan (1997) asserts that experienced users may make the same number of errors as less experienced users, for

instance, not knowing how to navigate around error messages without assistance. According to Lazonder et al. (2000), experienced Web users are very proficient at finding websites, but less successful in finding specific information within websites. Since finding information requires scanning, reading, and evaluation, there may be little difference between Internet novices and experts in terms of these skills or subject matter knowledge. Tu (2005) suggests that students with more Internet experience perform better on close-ended search tasks aimed at finding specific answers, while students with better overall knowledge are more adept at open-ended tasks aimed at finding less specific and more analytical information. Experienced users may be faster in locating answers, but may not be better equipped to deal with complexity and ambiguity. To reexamine the mixed results among previous research, this study investigated the possible influences of Internet experience on search behaviors and performance.

Reading ability

Reading is a complex cognitive process. Just and Carpenter (1980) describe reading comprehension as an ongoing process of identifying words, formulating propositions, and integrating until full sentence or paragraph comprehension is achieved. Gagne (1985) suggests that readers use four comprehension processes: (a) decoding, meaning that readers unlock the codes of printed texts to acquire meaning; (b) literal comprehension, to form propositions by combining the meanings of words after acquiring vocabulary-based connotations; (c) inferential comprehension, including integration, summarization, and elaboration in support of a deeper understanding of context; and (d) comprehension monitoring, referring to the ways that individuals establish reading goals, select appropriate reading strategies, determine goal achievement, and adopt alternatives if necessary. Goodman (1986) describes reading as a dynamic process in which readers interact with visual, perceptual, syntactic, and semantic cycles. He believes readers formulate mental images with visual messages that include what they actually read and what they expect—that is, they determine surface linguistic structures and phraseology before constructing connotations via in-depth structural analyses. Throughout these cycles, readers who encounter barriers re-read their texts to acquire additional messages in an effort to reconstruct meaning.

In multimedia environments, users often read or scan both texts and images. In many situations, learners can now find "help" information in the form of either graphics or text (Mayer & Massa, 2003). Paivio's (1971, 1986) dual-coding theory (DCT) explains how people receive, handle, and integrate information from two subsystems: a verbal system for dealing with language and a nonverbal system for dealing with nonlinguistic objects and events. According to Mayer's generative theory of multimedia learning (1997, 2001), meaningful learning requires the dual construction of a coherent mental representation of verbal and visual systems in working memory, plus systematic connections between verbal and visual representations. Comprehension depends on the successful storage of these connections along with two forms of mental representations of propositions and/or ideas in long-term memory (Plass, Chun, Mayer, & Leutner, 2003). The image search process (e.g., reading topics, comprehending text, generating keywords, building one-to-one maps between verbal and visual representations, and choosing from retrieved images) resembles this multimedia learning process. We believe image searchers must actively select and connect pieces of visual and verbal knowledge in the same manner, which explains why reading ability plays a role in performing successful image searches.

Methodology

Participants

Fifty-eight participants were selected from 227 seventh-grade students in a junior high school in Taiwan. According to past high-school entrance exam records, students from this school generally score well below the top 15% nationally. We selected 33 students identified as having strong reading skills (1 SD higher than the mean of reading ability test described in the Measures section) and 43 with weak reading skills (1 SD lower than the mean). From these 76 students, 28 were identified as frequent Internet users (8 hours or more per week) and 30 as infrequent users (5 hours or less per week). The high reading ability group consisted of 13 frequent and 15 infrequent Internet users; the respective numbers for the low reading ability group were 15 and 15.

Measures

Reading ability test and Internet usage questionnaire

The reading ability test used in this study consisted of items selected from Chinese reading comprehension questions in the Basic Competence Test for Junior High School Students, a national entrance examination used to screen students for high school placement. All test items are created and modified by a group of domain and test experts, with reliability, validity, and Rasch model data regularly monitored by the Basic Competency Test for Junior High School Center. Due to the rigorous design and revision process, we did not make any modifications for our own purposes. Test items measure ability to understand vocabulary in the contexts of factual and narrative passages. A passage consists of 200 to 300 words on a topic such as "advice from a father." For each passage, two questions are created to measure basic understanding plus the ability to make inferences and extend passage meanings. We used 12 passages and 24 multiple-choice questions to measure the reading levels of the 227 students in the original participant pool. The maximum possible score was 24; the mean in our sample was 11.16 ($SD = 4.16$).

Our Internet usage survey was designed to measure weekly Web experiences (including information searches, gaming, chatting, exchanging emails, and downloading files). The response data indicate that the participants spent an average of 7.21 hours per week online.

Image search worksheet

Based on Cunningham and Masoodian's observation (2006) that image searches usually originate from specific information requirements regarding persons, events, or activities, we created two search tasks on the topic of "animal activities" and two on "human activities." Target sentences were (a) "In a thick patch of grass, a fierce giant tiger lies looking off into the distance"; (b) "Two tiny and graceful sparrows clean their feathers in a clear stream"; (c) "A group of young boys jogs energetically on a red oval track"; and (d) "Two carefree elderly men sit at a square brown table, absorbed in a chess game."

To reduce the potential for shortcuts, we made sure that the correct images could not be found by cutting and pasting the four sentences into search engine query boxes. We also tried to maintain a consistent level of difficulty for the four sentences in terms of length, use of terms frequently encountered in daily life, and complexity of structure (Cheng, 2005). First, each of the four sentences consisted of 25 Chinese characters—the basic unit of the Chinese language, with the majority of words consisting of two characters. For example, "tiger" is written as 老虎, two characters with the literal meaning of "old tiger." Second, we used a software program from a Chinese language learning and teaching website (http://nflcr.im.knu.edu.tw/read/modules/working2.php) to analyze vocabulary frequency and found that all of the words in the four sentences were at the 3,000-word level of the 5,056 words said to be used most frequently by Taiwanese elementary school students. Finally, sentences were revised to achieve syntactic consistency.

After the participants finished their search tasks, three raters (including a computer teacher, an art teacher, and a Chinese-language teacher) were asked to individually judge how well the retrieved images matched the topic sentences as a measure of search performance. Total scores for each task ranged from 0 to 9. Students received four points for images that matched the primary subject term—tiger, sparrows, boys, or elderly men. Single points were given when images matched other sentence elements such as the main verb (e.g., lies), noun (e.g., stream), adverb (e.g., energetically), or adjective (e.g., fierce). A Kendall coefficient of agreement was used to examine consistency among the three raters; the results indicated a high level of inter-rater reliability ($W = .75$, $p < .01$). Finally, we looked for correlations between total numbers of search results for certain keywords and search performance; coefficients ranging from −0.25 to 0.06 (n.s.). In other words, no significant connections were observed between numbers of available online images and participant search performance.

Web navigation flow map

In this study, search behaviors refer to the methods used by the participants to perform image searches. We used Lin and Tsai's (2007) web navigation flow map to quantify these behaviors. CamStudio was used to record screen

displays in real time. The authors reviewed these video files and recorded behaviors according to five indicators: (a) the total number of keywords used to search for relevant information (reflecting the amount of keyword revising); (b) the average number of Chinese characters used per keyword (total number of Chinese characters divided by total number of keywords used during a search task); (c) the maximum number of viewed pages per keyword (i.e., surfing search result lists, usually consisting of twenty images per page); (d) the total number of viewed pages per task; and (e) the search time from entering the first keyword(s) to downloading the final image. We used this data to create Web-navigation flow maps, such as the one shown in Figure 1 (in that figure, the total number of keywords equals 4; the average number of characters used per keyword equals 3.5; the maximum number of viewed pages per keyword equals 8; the total number of viewed pages per task equals 18; and the search time equals 332 seconds).
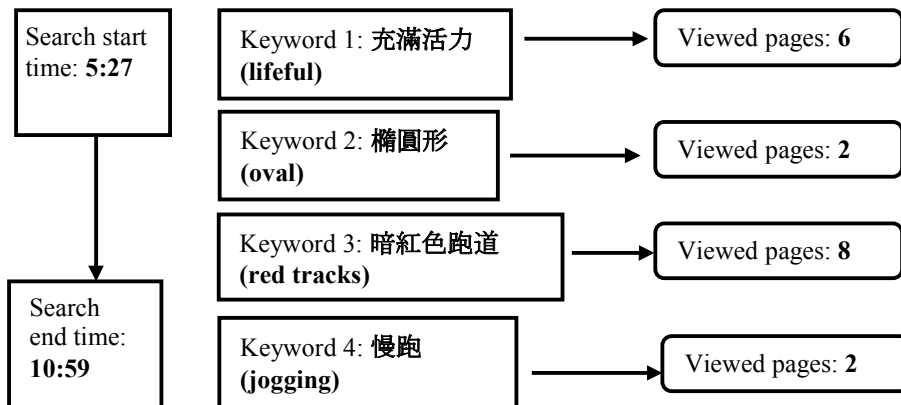
Figure 1. An example of a web navigation flow map. Chinese keywords 1–4 were translated into English in parentheses and bold type

Procedure

The study was conducted over three weeks. The reading ability test was given during week 1 (for 35 minutes). The Internet usage questionnaire was completed and Google Image features and methods were taught during week 2 (40 minutes total). Image search tasks were completed during week 3 (50 minutes). Search processes were recorded in the form of computer screenshots (qualitative data). Following task completion, individual search processes were interpreted and illustrated as Web navigation flow maps (search behaviors, quantitative data), and retrieved images were scored as performance.

Results and discussion

Descriptive statistics

Mean and standard deviation statistics for search behaviors and performance among the four groups are shown in Table 1. On average, the participants used 1.20 to 2.13 keywords per task. Our results are in general agreement with Hsieh's (2000) finding of an average of 1.5 keywords per text search for Taiwanese junior-high-school students. The participants used 2.52 to 3.23 Chinese characters per keyword, and viewed between 1.50 and 3.08 pages per keyword search. The total number of pages viewed per task ranged from 1.72 to 4.17. The average time spent per task was 92.9 to 153.8 seconds. Combined, the participants needed little time and expended little effort completing the assigned tasks. Search performance scores ranged from 2.72 to 8.05.

Table 1. Mean and standard deviation statistics for search behaviors and performance for the four groups

Reading ability	High ($N = 28$)						Low ($N = 30$)					
Internet experience	Frequent ($N = 13$)		Infrequent ($N = 15$)		Subtotal		Frequent ($N = 15$)		Infrequent ($N = 15$)		Subtotal	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*

Total number of keywords	2.13	1.69	1.70	0.56	1.90	1.21	1.20	0.29	1.35	0.54	1.28	0.43
Average number of Chinese characters used per keyword	2.73	0.65	2.77	0.82	2.75	0.73	3.23	2.25	2.52	1.00	2.88	1.75
Maximum number of viewed pages per keyword	2.48	1.47	3.08	2.06	2.80	1.80	1.50	0.78	2.17	1.12	1.83	1.00
Total number of viewed pages per task	4.15	3.36	4.17	2.39	4.16	2.83	1.72	1.15	2.73	1.82	2.23	1.58
Search time	151.29	108.38	153.80	68.64	152.63	87.55	92.95	42.83	153.62	79.85	123.28	70.11
Search performance	8.04	0.87	8.05	0.89	8.04	0.87	3.15	1.47	2.72	1.53	2.93	1.49

Effects of reading ability and Internet experience on search behaviors

We found a significant main effect of reading ability on the total number of search keywords ($F = 7.359$, $p < .01$), but no main effect from either Internet experience or interaction between reading ability and Internet experience. Participants with better reading comprehension skills tended to use more keywords in their searches. According to these data and search process observations, better readers were more likely to find appropriate images from the search engine hits they received from initial keywords, or to quickly and continuously modify keywords when results did not meet their expectations. An example of a search task (b), a high reading ability student conducted six searches using various keywords: "stream," "two sparrows," "sparrow in stream," "clean feathers," "sparrows clean feathers in stream," and "clean feathers & sparrows." This explains why the standard deviation of "total number of keywords" for the high reading ability group ($SD = 1.21$) was significantly larger than that for the low reading ability group ($SD = 0.43$, $F = 2.81$, $p < .01$). Low-ability readers often used keywords that reflected less important aspects of the task sentences (e.g., "grass," "looking off," "clear stream," "red oval track," or "a brown table") or keywords that were irrelevant to the task descriptions (e.g., "bear," "cat," "flower," "waterfall," or "gun.").

Freeman (2001) suggests that during the reading process, continuous changes occur between actual texts and texts constructed in the minds of readers. Even when reading the same article multiple times, readers are sensitive to differences among reading experiences. We observed better readers quickly re-reading topics and constructing new keywords, while poor readers used only one keyword and tended to terminate searches when results did not immediately match the requirements. This suggests that students with poor reading skills have difficulty in interpreting search topics, formulating appropriate keywords, and using correct terms.

No significance was noted for main and interaction effects of reading ability and Internet experience on the average number of Chinese characters per keyword. Keyword lengths among the four groups were very similar—between two and three characters. Students in the high reading/frequent Internet user group used an average of 2.73 characters per keyword, with relatively small dispersion ($SD = 0.65$). Students in the low reading/frequent Internet user group used an average of 3.23 characters per keyword, with a much larger dispersion ($SD = 2.25$, $F = 3.61$, $p < .001$). According to search process observations, better readers tended to use fewer than four characters in their keywords, while poorer readers frequently used whole sentences or longer phrases. In addition, poor readers tended to add (or delete) one or two words to (or from) original keywords when those keywords were unsuccessful. For example, for task (c) one low-ability reader initially used the keywords "red oval track," then added the verb "<jog> red oval track," and finally added the subject "<boy> jog red oval track." These results imply that better readers are more capable of using concise, accurate phrases to perform successful image searches.

We found a significant main effect of reading ability on maximum number of viewed pages per keyword ($F = 6.312$, $p < .05$); other effects were not significant. According to this finding, better readers were more competent in viewing more pages of image search results. We also observed that most students in the high reading group continued checking/rechecking images even after finding pictures that met the task criteria, implying that they took greater care in evaluating retrieved images.

There was a significant main effect of reading ability on total number of viewed pages per task ($F = 10.431$, $p < .01$); other effects were not significant. In other words, better readers viewed almost twice as many search result pages for each task than did poorer readers. According to our observations, better readers were more likely to review a larger number and broader range of images due to their ability to try various keywords and to evaluate whether retrieved images matched the task descriptions.

Significance was not found for main and interaction effects of reading ability and Internet experience on search time. Although time differences were observed between the two groups (152.63 seconds for high reading versus 123.28 seconds for low reading; 122.12 seconds for frequent users versus 153.71 seconds for infrequent users), between-group differences were not significantly larger than within-group differences. In short, each search task required between two and three minutes for completion.

Effects of reading ability and Internet experience on search performance

The data indicate a significant main effect of reading ability on search performance ($F = 243.747$, $p < .001$); other effects were not significant. Search performance was measured as the degree of relevance between a downloaded picture and the concepts expressed in the task sentence. According to search process observations, pictures selected by poor readers frequently matched a single feature of the search requirements (e.g., general pictures of tigers, sparrows, stream, boy, or track), but did not reflect other features such as verbs, adjectives, or adverbs in the topic sentences. For example, task (a), the two pictures (Figures 2A and B) were chosen by two high-ability readers. Both were given 9 points (the highest score) because they matched multiple aspects of the text descriptions, while the three pictures (Figures 3A, B and C) chosen by three low-ability readers received scores of 4, 4 and 1 because they matched only the terms "tiger" or "grass." The results indicate that better readers evaluated texts and images carefully and critically. They tended to discriminate, analyze, and interpret texts and images to ascertain meaning, and to understand the subject matter of texts and images. Then they cross-referenced and integrated visual and textual actions, objects and symbols.

Students in the low reading ability/infrequent Internet user group had more difficulty choosing keywords and were less familiar with Google Image—two factors that affected their search efforts and the time required for task completion. In contrast, students in the low reading/frequent Internet user group tended to type in any single keyword, randomly scan search results, and show less care in completing tasks. They were less likely to make the effort to verify information. This observation is consistent with Shenton and Dixon's (2004) assertion that teenagers are less likely than older Internet users to evaluate information quality, and more likely to believe that the most easily accessed information is sufficient for answering inquiries.

Figure 2. Examples of pictures chosen by high-ability readers in response to the prompt, "In a thick patch of grass, a fierce giant tiger lies looking off into the distance."

Figure 3. Examples of pictures chosen by low-ability readers in response to the prompt, "In a thick patch of grass, a fierce giant tiger lies looking off into the distance."

Correlations between search behaviors and performance

Significant positive correlations were found between performance and both the maximum number of viewed pages per keyword ($r = .362$, $p < .01$) and total number of viewed pages per task ($r = .386$, $p < .01$), but not for any other indicator. These two indicators signify student ability or motivation to view and evaluate image contents. The more effort the participants allocated to reviewing and evaluating search results, the greater the potential that their images would be relevant to all perspectives of task concepts.

No relationship was found between performance and keyword-based behavior indicators. These results are not consistent with those reported by Tu (2005) for text searches. Tu found positive relationships between search performance and both the total number of keywords and the average number of Chinese characters per keyword. We believe the difference lies in the distinction between image and text searches—that is, the requirement for keyword-based image searches that search engines compare keywords with image topics, image file names, and/or text attached to images. There are many examples of image descriptions that do not accurately reflect image content; therefore, users may not be able to find corresponding pictures even when they make good decisions regarding keywords. For example, although many participants used identical keyword "sparrows," they selected very different pictures from the search results. Figures 4A and B were retrieved from page 7 and 8, respectively, of the returning search results, both were given 9 points because they matched all text descriptions of task (b), while Figures 4C and D were both retrieved from page 1 of the returning search results both received scores of 4 because they only matched a single element "sparrows." In such cases, in order to obtain accurate pictures, users must be careful when evaluating pictures. These results support our assertion that the maximum and total numbers of viewed pages serve as indicators of image search success.
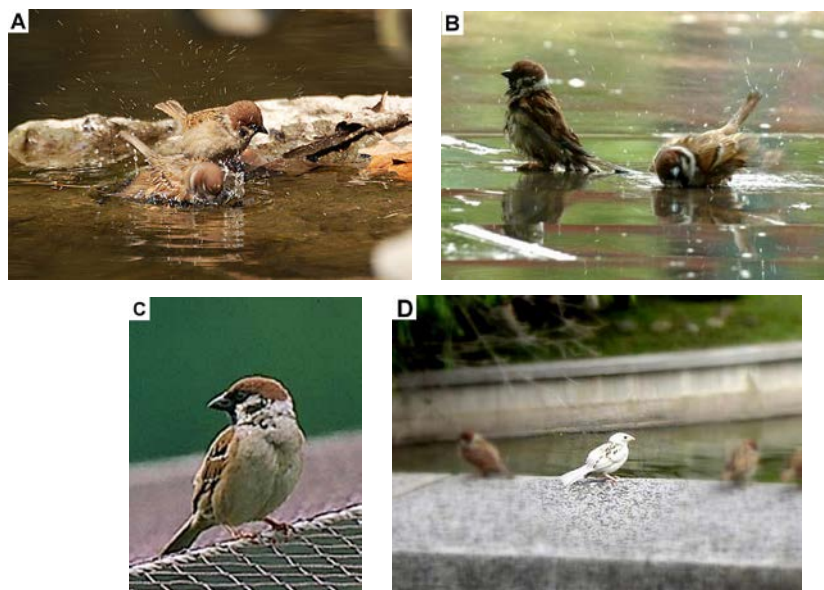
Figure 4. Four pictures, A to D, were found via the identical keyword "sparrows" for search task (b) "Two tiny and graceful sparrows clean their feathers in a clear stream."

Conclusions

Our data support the notion of reading ability being an important factor influencing keyword-based image search success. Compared to less skilled readers, better readers were more likely to find appropriate images based on effective keywords, or to be more adaptive in changing keywords when results were inadequate. Better readers were also more effective in terms of selecting and evaluating search results to obtain quality images. Our data also support the notion that successful image searches (including understanding textual intention, generating mental image, making inferences, generating accurate keywords, evaluating pictorial intention, and comparing image content with text descriptions) require the incorporation of both verbal and pictorial systems. Image search success represents a

manifestation of visual literacy; according to our results, reading comprehension is probably a fundamental factor in visual literacy.

Internet experience did not exert a strong influence on image searches, a finding that agrees with text search results reported by Wang et al. (2000), Lazonder et al. (2000), and Tu (2005). Since learning how to use image and text search engines is an easy task for most Internet users (Wang et al., 2006), we believe the key to teaching image search skills resides in task description and evaluation. This would explain why online experience does not directly add to or detract from search behaviors and performance.

The use of computer technologies for problem-solving is fast becoming a required daily life skill for students and non-students alike. This transformation is affecting education in terms of knowledge transfer and construction because students are increasingly required to take the initiative to seek and construct their own knowledge pools. Accordingly, learning effectiveness is increasingly impacted by information collection, analysis, assessment, and integration. Educators must focus on teaching Internet search and website information assessment skills, and helping students use information contained in various types of images. For example, computer teachers must introduce how Web search results could be ranked and remind students that the most useful/correct knowledge or quality information does not necessarily be placed at the top. Even though keyword-based image searches may appear simple to execute, we observed sharp distinctions between students at various reading skill levels. A lack of reading ability affects students' ability to search effectively. Therefore, how to modify instructional approaches for students with specific characteristics such as good/poor reading skills, improve student's reading abilities further, and build up their visual literacy are missions for teachers to continue pouring in more efforts.

We found that most participants surfed the Web following the sequence of search result lists and became bored or frustrated after viewing a small number of links. Only good readers were capable of selecting satisfactory images facing a bunch of retrieved outcomes; hence the ranking and clustering functions of search engines seem to need certain improvement. The authors suggest that search engine algorithms can be modified to include functions that reorganize content from search results or classify search results according to correlation. Furthermore, when creating new information retrieval products, exploring specialized technologies aimed at various types of information embedded in websites, and working with the unique features of Web 3.0 semantic content tagging, search engine developers need to consider how users construct mental representations when performing image searches. Technology designers need to consider more personalized functions in terms of inquiry strategies, filtering techniques, and multiple media indexing. For example, AI technologies can be used to differentiate individual abilities (e.g., reading, spatial or visual literacy) and Internet usage habits (e.g., result page and keyword usage), so as to provide appropriate auxiliaries. However, it remains to be examined whether these new functions support greater search result accuracy or simply impose additional cognitive burdens.

We acknowledge at least two study limitations. First, the small sample size and limited ranges of age, educational level, and Internet experience mean that the results cannot be generalized to non-junior-high-school populations. Second, we used short texts (sentence-length) as prompts for searches, whereas image searches can also be triggered by abstract concepts or other images. Whether reading ability still plays an important role in such situations requires further study.

Acknowledgements

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Using Magic Board as a Teaching Aid in Third Grader Learning of Area Concepts

Wen-Long Chang[1], Yuan Yuan[2], * Chun-Yi Lee[3], Min-Hui Chen[4] and Wen-Guu Huang[5]
[1]Shih Chien University, No.70, Dazhi St., Zhongshan Dist., Taipei City 104, Taiwan // [2]Chung Yuan Christian University, N0 200, Chung-Pei Road, Chung-Li, Taiwan 32023, Taiwan // [3]National Taipei University, No. 151, University Rd., San-Shia, New Taipei City, 23741 Taiwan // [4]Taoyuan Ping-Jen Bei-Shi Elementary School, No.330, Sec. 2, Jinling Rd., Pingjhen City, Taoyuan County 32471, Taiwan // [5]National Taiwan Normal University, 162, Heping East Road Section 1, Taipei City, Taiwan // wenlong@mail.usc.edu.tw // yaun@cycu.edu.tw // chunyi.lii@gmail.com // pses088@pses.tyc.edu.tw // wenguu@mail.cto.moea.gov.tw
*Corresponding author

ABSTRACT

The purpose of this study was to explore the impact of incorporating Magic Board in the instruction of concepts related to area. We adopted a non-equivalent quasi-experimental design and recruited participants from two classes of third-grade students in an elementary school in Taoyuan County, Taiwan. Magic Board was used as a teaching aid in the experimental group, and physical manipulatives were employed as teaching aids in the control group. Both groups took the Basic Area Concept Test as a pretest, followed by the Area Concept Test to evaluate retention two weeks later. Results demonstrate the effectiveness of Magic Board over that of physical manipulatives on three subscales of immediate learning performance and all four subscales of retention performance. We also discuss the implications of these results and provide recommendations for future research.

Keywords

Virtual manipulatives, Mathematics teaching, Elementary school students

Introduction

The use of Physical manipulatives

Physical manipulatives are physical objects, such as base-ten blocks, algebra tiles, Unifix Cubes, Cuisenaire rods, fraction pieces, pattern blocks, and geometric solids, which are commonly used in mathematics education to make abstract ideas and symbols more meaningful and comprehensible to students (Durmus & Karakirik, 2006). Clements (2000) proposed physical manipulatives to help students construct, develop, and integrate a variety of concepts and their mathematical representations. Many studies have found that students who use physical manipulatives to explore mathematical concepts outperform those who do not (Fennema, 1972; Zacharia & Olympiou, in press). Through meta-analysis, Suydam and Higgins (1976) verified that lessons involving physical manipulatives can lead to more significant achievements than lessons without. They suggested the following guidelines for the use of physical manipulatives: (1) frequent use in a comprehensive mathematics program, consistent with program goals; (2) use in conjunction with other aids (such as pictures, diagrams, textbooks, films, and similar materials); (3) use in a manner appropriate to the nature of the mathematical content; (4) use in conjunction with exploratory and inductive approaches; and (5) use with programs that encourage symbolical recording of the results. Moyer (2001) identified a number of reasons for the infrequent use of physical manipulatives to teach mathematics in the classroom. First, teachers are typically required to purchase physical manipulatives, which can be costly, or to make them themselves, which takes considerable time. Second, using physical manipulatives in a real classroom poses a number of difficulties, including classroom control, cleaning, and storage (Yuan, Lee, & Wang, 2010). For teachers who would otherwise not use physical manipulatives, information technology enables the creation of virtual learning environments in which to address these problems.

The use of virtual manipulatives

Moyer, Bolyard, and Spikell (2002) recently defined a virtual manipulative as an interactive, web-based visual representation of a dynamic object that facilitates the development of mathematical concepts in students. Virtual manipulatives are generally more than just electronic replications of their physical counterparts. Clements and

McMillen (1996) considered virtual manipulatives as useful tools for learning when they possess the following features: (1) allow students to change, repeat, and undo actions in a straightforward manner; (2) allow students to save configuration and action sequences; (3) dynamically link various representations and maintain a tight connection between pictured objects and symbols; (4) allow students and teachers to pose and solve problems; and (5) enable students to control flexible, extensible tools for the development of mathematical concepts. Such virtual manipulatives serve many purposes and help in the formation of connections between mathematical ideas (Lee & Chen, 2009). However, studies have identified a number of limitations and disadvantages of this approach (Highfield & Mulligan, 2007; Hunt, Nipper, & Nash, 2011). First, the computer skills required to use virtual manipulatives have proven challenging for students. Without teacher support, scaffolding, and practice, students are unable to manipulate virtual objects on screen. Second, virtual manipulatives can distract some students from the problem at hand. Finally, students are unable to actually touch virtual manipulatives, which deprives students of the tactile experience available to students using physical manipulatives (Olkun, 2003).

Introduction of magic board

Magic Board, developed by Yuan, Chen, and Chang (2007), is a well-known web-based virtual environment for teaching elementary mathematics, based on experience obtained in the development of virtual manipulatives (it can be accessed at http://163.21.193.5). The English version of Magic Board is available from the upper-right corner of the website home page by clicking the "Try English version" button. Magic Board comprises three important components: Magic Board Software, Problem Posing Center, and Instructional Material Center. Users that register as members of Magic Board are eligible to use all of the components to construct and share instructional materials on the Magic Board platform. Users can access shared materials and adapt them to their own classes. Non-registered users (guests) can open and use Magic Board Software to adopt existing instructional materials for implementation into their instruction. All components and graphic files in Magic Board are directly downloadable for use with related worksheets.

Magic Board Software (MBS)

Magic Board Software provides a tool box that includes a wide range of frequently used elementary mathematics manipulatives that instructors may access instantly while teaching (Fig. 1). Clicking the tool box button in the function button area hides or shows the tool box in the display area. Teachers can drag these objects to the display area and a right-click allows the user to control the properties. In the function button area, word addition is used to enter text to present word problems, the doodle pen to scribble or mark up anything on the screen, and the clean doodles button for erasing. The cheering button is used to encourage students who are doing well or to motivate students who are struggling. The background change enables a rapid change of backgrounds. Clicking the rubbish bin clears all components from the display area.

Figure 1. Magic Board software interface

Problem Posing Center (PPC)

Users can log into the Magic Board platform to access resources from the PPC and search for shared problems according to the level of their students and mathematical content. Users can save and upload teaching materials by clicking on Edit and Upload, and following the instructions to enter the grade of the target students and the content used in their lessons. Users can search for problems based on these pre-set search values. Clicking on My Posed Problems lists past problems uploaded by Magic Board members (Fig. 2).

Figure 2. Length measurement problem posed by a user

Instructional Material Center (IMC)

The Search function enables users to search for shared instructional materials under various classifications, such as the grade of the students the material is intended for and the nature of the mathematical concepts being discussed. Clicking on Organize Instructional Materials enables users to browse through problems and select suitable source materials with which to personalize curricula. My Instructional Materials reveals a list of lessons and materials previously uploaded by Magic Board members. After entering Organize Instructional Materials (Fig. 3), users search through problems numbered according to their selection order. Clicking on Set Posing Problems and entering the classification information of the instructional materials completes the compilation. The arrows in the Function Button Area control the presentation of the comprehensive instructional materials available at the IMC.

Figure 3. Operating interface of organized instructional materials

Learning of area concepts in elementary-school mathematics

The measurement of area is an important topic in school mathematics, closely associated with real-world applications in science and technology (Huang & Witz, 2011). However, recent assessments of mathematical achievement indicate that elementary-school children are failing in tests on the measurement of area (Martin & Strutchens, 2000). Traditionally, instructors have taught the formulas required to measure the area of basic shapes, with an emphasis on performing these tasks efficiently. An overemphasis on the calculation of area using formulas prevents students from gaining adequate experience visualizing geometric figures and becoming familiar with the properties on which the formulas are based. The instruction procedures employed in tiling activities do not directly demonstrate multiplication (Van de Walle, 2004). A failure to provide children with guided exploration often prevents students from grasping the significance of array structures directly through tiling operations. When children are unable to see multiplication properties embedded in array structures, they tend to add the units on the sides of the figures without considering the units within the edges (Schifter, Bastable, Russell, & Woleck, 2002). Educators in mathematics (Fuys, Geddes, & Tischler, 1988; Burns & Brade, 2003) suggest that 2D geometry, including knowledge of the properties of basic shapes, congruence, and geometric motions (flips, turns, translations, decomposition, and re-composition) should form the basis of constructing concepts related to the measurement of area. They also advocate strengthening the understanding of 2D geometry to develop children's knowledge of the formulas used for the measurement of area and an understanding of the relationships among them. Manipulatives often aid in strengthening the concepts of congruence and transformation and facilitating an understanding of the rationale underlying the common formulas used to measure area (Yuan, Lee, & Huang, 2007). The current study designed materials integrated with physical or virtual manipulatives for teaching the measurement of area. The teaching materials covered four topics: the preservation of area, comparison of area using a nonstandard unit, indirect comparison of area, and measuring area using multiplication.

Comparisons between virtual and physical manipulatives

Empirical evidence related to the use of virtual manipulatives for the instruction of mathematics and science in the classroom is still new and somewhat limited. Yuan, Lee, and Wang (2010) examined the influence of polyomino exploration by junior high-school students using virtual and physical manipulatives. In that study, the group using virtual manipulatives learned as effectively as the group using physical manipulatives; however, students in the physical group reduced their strategy more than those in the virtual manipulative group. Manches, O'Malley, and Benford (2010) also indicated that differences in manipulative properties between virtual and physical groups might influence the numerical strategies of children. Triona and Klahr (2003) found that students internalize objects related to science equally when taught using either virtual or physical materials, as long as the method of instruction is preserved. Zacharia and Olympiou (in press) investigated whether physical or virtual manipulative experimentation can differentiate physics learning using four experimental conditions: physical manipulative experimentation (PME), virtual manipulative experimentation (VME), and two sequential combinations of PME and VME, as well as a control (i.e., traditional instruction without PME or VME). Results reveal that the four experimental conditions were equally effective in promoting the conceptual understanding of heat and temperature and all four approaches outperformed the conventional (control) approach.

Reimer and Moyer (2005) reported that third-grade students learning fractions with virtual manipulatives showed statistically significant gains in the development of conceptual knowledge. Student surveys and interviews indicate that manipulatives provided immediate and specific feedback, were easier and faster to use than traditional methods, and enhanced student enjoyment while learning. A comparison of the aforementioned studies provided mixed results, and fewer studies have examined retention as a learning outcome resulting from the use of virtual and physical manipulatives. Although virtual manipulatives generated an exciting range of new possibilities to support learning, fewer studies showed how this more indirect form of virtual representations influence children's interaction compared with direct manipulation of physical objects. Understanding the properties of virtual manipulatives and how these relate to learning is not only important in trying to predict which material will be more beneficial but can help inform the design of new learning material. Therefore, this paper explores the effects of using Magic Board as a teaching aid on the conceptual learning of third-grade students in Taiwan. Teacher observations and class journals are used to explain the learning outcomes between virtual and physical manipulatives and to provide more details about how these materials impact on students' understanding of mathematics concepts. The current research focuses on the following two questions:

1. Does the use of Magic Board have a more positive effect than physical manipulatives on the immediate learning performance of students studying concepts related to area?
2. Does the use of Magic Board have a more positive effect than physical manipulatives on the retention performance of students studying concepts related to area?

Methodology

Research design and participants

This study applied the non-equivalent group pretest/posttest quasi-experimental design to compare learning outcomes (immediate learning and retention) between physical and virtual manipulatives in the study of concepts related to area. Participants included 59 third-grade students (32 boys and 27 girls), from two classes in an elementary school in Taoyuan County, Taiwan. Researchers randomly selected one class as the experimental group (32 students in the virtual manipulative group) and the other class as the control group (27 students in the physical manipulative group). Both groups studied identical materials and engaged in the same learning activities. The only difference was that the experiment group used the Magic Board, while the control group used physical manipulatives. All participants took the Basic Area Concept Test as a pretest and the Area Concept Test as a posttest. Two weeks later, both groups were administered the same Area Concept Test to evaluate retention. One-way analysis of covariance (ANCOVA) was conducted to examine the effects on the immediate learning and retention of concepts related to area between the groups using physical and virtual manipulatives, with the pretest as the covariate. The observations of teachers and a class journal based on video recordings of each teaching session were collected to help explain or elaborate on the quantitative results.

Materials

The teaching materials in this study were adapted from the mathematics textbook used by third-grade students. The content of the instructional material was reviewed by five experienced elementary-school teachers with pedagogical and professional knowledge of mathematics teaching. Minor revisions to the design of instructional materials were made according to the suggestions of the teachers. Table 1 shows the course content and course schedule for each week. Magic Board was used as a teaching aid in the experimental group, and concrete manipulatives were used as teaching aids in the control group. Table 2 shows the differences between the virtual and physical tools.

Table 1. Course content and study schedule

Week	Activity	Content
Week 1	Introduction to area	Understanding the concept of area
Week 2	Cutting and combining	Preserving area
		Direct comparison of area
Week 3	Comparing area	Indirect comparison of area
		Comparison of area using a nonstandard unit
Week 4	Understanding one square centimeter	Understanding the meaning of one square centimeter
Week 5	Calculating area	Counting the area with a multiplication approach
Week 6	Applying the concept of area	Estimating the area of an object using the unit of one square centimeter

Table 2. Comparison between the physical and virtual manipulative environment

Tools	Virtual manipulative environment	Physical manipulative environment
Area board	Changes can be made to the color and size of the area.	Changes cannot be made to the color or size of the area.
Grid board	Changes can be made to the color and size of the grid.	Changes cannot be made to the color or size of the grid.
Nail board	Changes made to the color and the size of the object can be examined.	Changes made to the color and the size of the object cannot be examined.
Ruler	The shape of the ruler can dilate and	The shape of the ruler cannot be

	shrink.	changed.
Hints and Show buttons	Pressing the buttons at any time reveals the instructional materials.	Prearranging the instructional materials in a suitable manner.

Instruments

Basic Area Concept Test (BACT)

The BACT was employed to evaluate the prior knowledge of students related to basic concepts of area prior to the experimental program. BACT was based on the task analysis of prior experiences of materials for third-graders dealing with concepts of area. The content of BACT did not include the intervention materials for third-graders. This instrument comprised twenty questions that measure the basic concepts of area required for experimental instruction, including four types of questions: identifying and classifying simple 2D geometric figures; cultivating a sense of length; estimating and preserving the concept of area; and comparing the size of various areas. For each type of question, students were presented with five questions and each correctly answered question scored five points. A number of sample items from BACT are shown in Appendix 1. The content validity of BACT was ensured by expert reviews from three elementary school mathematics teachers and two professors in a related domain. A pilot test had been conducted on BACT the previous academic semester with a group of students, including 62 third-graders with academic backgrounds similar to those of the target audience in this study. Minor revisions to test items were made according to the results of the pilot study. The reliability coefficient of BACT was 0.83 (Cronbach's alpha); therefore, BACT was adopted as the pretest of this study.

Area Concept Test (ACT)

The ACT was used to examine the learning outcomes (immediate learning and retention) of students following the instructional program. The ACT was based on materials for third-graders dealing with concepts of area. The test comprised 20 questions based on the following four subscales: (1) Preserving area: students understand that the area of the object remains the same under translation and rotation, as well as after flipping the object or cutting the object and recombining it; (2) Area comparison using a nonstandard unit: students use the area of one object as a unit to compare the area of other objects; (3) Indirect comparison of area: students copy the area of one object and compare it with the area of another object when the areas of two objects cannot be compared directly; (4) Measuring the area using multiplication: students calculate the area of objects using multiplication rather than addition. Each subscale comprised five questions and each question scored five points. A number of sample items of the ACT are shown in Appendix 2. A pilot test had been conducted on the same group of students using the ACT in the previous academic semester. This included 28 third-grade students with academic backgrounds similar to those of the target audience in this study. Minor revisions to test items were made according to the results of the pilot study. The reliability of ACT was 0.85, as measured by Cronbach's alpha; therefore, ACT was used as an immediate posttest and retention posttest in this study.

Results

Research Question 1: Does the use of Magic Board have a stronger positive effect than physical manipulatives on the immediate learning performance of students studying concepts of area?

This study conducted ANCOVA to examine the immediate learning achievements (preserving area, indirect comparison of area, comparison of area using a nonstandard unit, and measuring area with multiplication) of the groups using virtual and physical manipulatives. The tests for homogeneity of covariate regression coefficients for various types of manipulatives were not significant for any of the four subscales, suggesting that a common regression coefficient was appropriate for the covariance portion of the analysis. Therefore, the data of the four subscales were appropriate for further parametric analysis. The ANCOVA results indicate that students in the virtual group performed better than those in the physical group in the following three concepts of area in the immediate posttest (see Table 3): preserving area ($F = 5.657$, $p = .021$, partial $\eta^2 = 9.2\%$), comparison of area using a nonstandard unit ($F = 6.268$, $p =. 015$, partial $\eta^2 = 10.1\%$), and measuring area using multiplication ($F = 6.989$, p

= .011, partial η^2 = 11.1%). Although no significant difference in indirect area comparison was found between the experiment group and the control group (F = 3.584, p = .064), a trend was observed in which students in the virtual manipulative group had a higher mean score (23.51) on indirect comparison of area than those in the physical manipulative group (22.02).

Table 3. Summary of adjusted group means of immediate learning outcomes of participants

Subscales	The virtual group (n = 28)	The physical group (n = 31)
Preserving area	21.10 (4.81)	17.94 (6.98)
Indirect comparison of area	23.51 (2.69)	22.02 (5.73)
Comparison of area using a nonstandard unit	22.97 (3.00)	20.66 (5.88)
Measuring the area using multiplication	20.36 (4.01)	17.96 (6.66)

Research Question 2: Does the use of Magic Board have a more positive effect than physical manipulatives on the retention performance of students studying concepts of area?

This study conducted ANCOVA to examine the retention learning achievements (preserving area, indirect comparison of area, comparison of area using a nonstandard unit, and measuring area with multiplication) of the groups using virtual and physical manipulatives. The tests for homogeneity of covariate regression coefficients for various types of manipulatives were not significant for any of the four subscales, suggesting that a common regression coefficient was appropriate for the covariance portion of the analysis. Therefore, the data of the four subscales were appropriate for further parametric analysis. ANCOVA results indicate that students in the virtual group outperformed those in the physical group for all four concepts of area on the retention posttest (see Table 4): preserving area (F = 10.323, p =.002, η^2 = 15.6%), indirect comparison of area (F = 4.908, p =. 031, η^2 = 8.0%), comparison of area using a nonstandard unit (F = 13.021, p = .001, η^2 = 18.9%), and measuring area using multiplication (F = 13.510, p =. 001, η^2 = 19.4%).

Table 4. Summary of adjusted group means of retention learning outcomes of participants

Subscales	The virtual group (n = 28)	The physical group (n = 31)
Preserving area	20.97 (5.18)	17.19 (5.40)
Indirect comparison of area	22.98 (3.34)	19.96 (6.78)
Comparison of area using a nonstandard unit	23.02 (2.38)	19.18 (6.20)
Measuring the area using multiplication	19.91 (4.02)	16.27 (6.14)

Discussion

This study developed teaching materials for Magic Board and compared immediate learning and retention performance between the use of Magic Board and physical manipulatives. The use of Magic Board has a more immediate positive effect than physical manipulatives in three of the four indicators of student performance when studying concepts of area (preserving area, comparison of area using a nonstandard unit, and measuring area using multiplication). The use of Magic Board has a more positive retention effect than physical manipulatives in all of the four indicators of student performance when studying concepts of area (preserving area, indirect comparison of area, comparison of area using a nonstandard unit, and measuring area using multiplication). The results are not consistent with those of Olkun's study (2003), indicating that solving geometric puzzles using manipulatives, both virtual and physical, has a positive effect on geometric reasoning with regard to two-dimensional geometric shapes, particularly in spatial tasks. However, the overall difference between the virtual and physical groups was not statistically significant. One explanation for the results in Olkun's study is that the functions of physical and virtual versions of tangrams were nearly the same for students learning 2D geometry. However, the virtual group gained more from intervention than did the physical group in our study. This suggests that virtual manipulatives might be more appropriate for studying aspects of 2D geometry. Students did not learn more about planar geometry by touching physical representations. Alternatively, it may occasionally be preferable to use a virtual manipulative instead.

Based on teacher observations and class journals, possible explanations for the significant gains in the immediate learning and retention among students in the virtual manipulative group are as follows. First, for preserving area, students in the virtual group could move objects to a new position and still see the shape of the objects in the original position; however, those in the physical group were unable to do this. Second, virtual tools could record the processes of comparing area indirectly, but physical tools did not provide this function. Third, the virtual group could easily identify the quantity and shape of nonstandard units used for the comparison of area; however, the physical group could not always clearly identify the quantity or shape of nonstandard units because parts of the objects were often covered by their hands. Finally, students in the virtual group were able to cover the object using a row of squares or a column of squares for measuring area using multiplication; however, students in the physical group could only cover the object with one square at a time.

Magic Board provides a good layout for presenting materials, such that learners can pay more attention to learning concepts of area. Presenting teaching materials using physical manipulatives tends not to be as clear, which prevents students from tracing the processes involved in moving objects. Teachers can use Magic Board to quickly and easily pose problems, which gives students in the virtual group more time to discuss the main concepts. Teachers in the physical group have to spend more time using physical manipulatives to pose problems, which reduces the time available for discussion of the teaching materials. Yuan, Lee, and Wang (2010) observed that students perform active thinking and engage in more discussion in a virtual manipulative environment, which may explain the immediate learning and retention performance of using Magic Board. Although no significant difference in indirect area comparison of the immediate posttest was found between the virtual group and physical group, students in the virtual group outperformed those in the physical group for indirect area comparison on the retention posttest. One possible reason for the inconsistent results may be that students in the virtual group had actually absorbed and understood the materials rather than merely relied on short-term memory as compared with those in the physical group.

This research has a number of implications. First, modifying the physical environment to enable students to easily observe the processes involved in moving objects might result in outcomes similar to those demonstrated using Magic Board. In other words, whether the materials are virtual or physical might make little difference as long as the method of instruction is preserved (Yuan, Lee, & Wang, 2010). This is an interesting issue for further investigation. Second, the sample size of this study was small; therefore, generalized findings may be limited to similar samples, and are not necessarily applicable to other groups of learners with diverse educational or cultural backgrounds. Third, the characteristics of the course on Concepts of Area differ considerably from those of other domains such as biology or social sciences. Thus, the conclusions of this study cannot be generalized to other disciplines. Finally, prior experience in areas such as mathematics epistemology or computer self-efficacy may influence learning outcomes when using virtual or physical manipulatives. Future studies would need to deeply examine the role of prior experience on learning with virtual manipulatives.

Magic Board has the potential to improve the learning outcomes (immediate learning and retention) of students in the construction of mathematics knowledge. Magic Board is a tool that provides many of the common virtual manipulatives found in mathematics textbooks, without providing any instruction in mathematical concepts. Therefore, teachers must pay more attention to the instructional design to apply virtual manipulatives appropriately. In the future, educators in mathematics should select mathematical topics that are difficult to present using traditional instruction methods and adapt these lessons to Magic Board to help students learn more effectively and efficiently.

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*Identifying and classifying simple 2D geometric figures
Please see the figures below and measure them with a ruler. Which figure is a square? (1) CDH (2) BEFG (3) CH (4) H
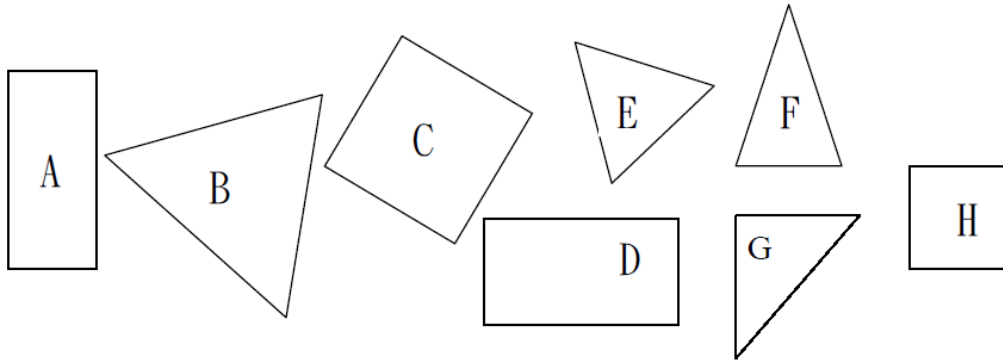
*Cultivating a sense of numbers, length, and estimation
What could be the length of a normal eraser? (1) 5cm (2) 1m (3) 5m (4) 10m
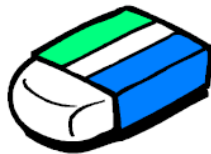
*Preserving the concept of area
Cut figure A along the straight line and combine the two parts of A into figure B. If the area of A is 4 cm^2, what is the area of B? (1)3 cm^2 (2) 4 cm^2 (3) 5 cm^2 (4) 6 cm^2

A   B
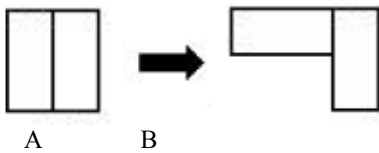
*Comparing the area of various shapes
Which of the following figures has the largest area? (1) B (2) C (3) D (4)E
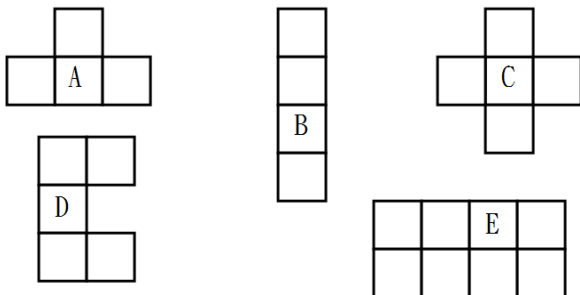
Appendix 2 Sample items of ACT

*Preserving area

The area of figure ㄅ is equal to the area of figure ㄆ. Fold up figures ㄅ and ㄆ to obtain figures 甲 and 乙, respectively. Which statement is true for the area of 甲 and 乙? (1) 甲>乙 (2) 甲=乙 (3) 甲<乙
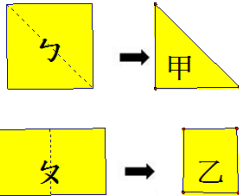
*Comparison of area using a nonstandard unit

How many of the gray triangles do we need to completely cover the geometric shape on the left? (1) 10 (2) 12 (3) 14 (4) 16
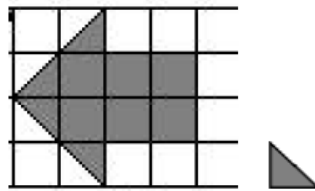
*Indirect comparison of area

The area of 乙 is 2 cm^2. Which of the following statement is true? (1)The area of 甲 is 7 cm^2 (2) The area of 丙 is 5 cm^2 (3) The area of 甲 is 6 cm^2 (4) The area of 丙 is 4 cm^2
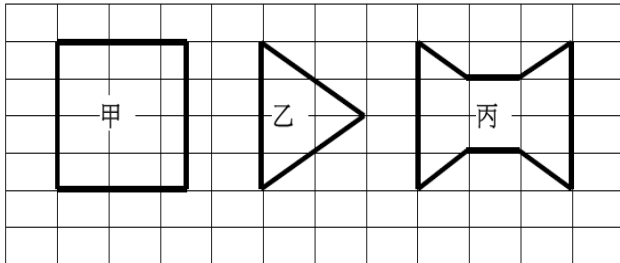
*Measuring the area using multiplication

Please see the figure below. Which of the following statements is true? (1) The area of ● is 45 (2) The area of ◆ is 31 (3) The area of ★ is 24 (4) The area of ★ >The area of ◆ >The area of ●
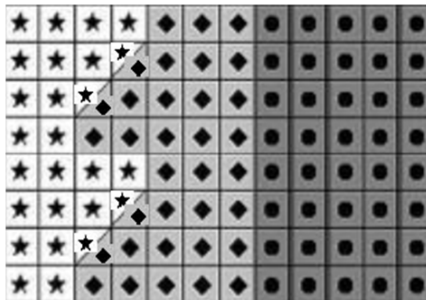
How Flexible Grouping Affects the Collaborative Patterns in a Mobile-Assisted Chinese Character Learning Game?

Lung-Hsiang Wong[1*], Ching-Kun Hsu[2], Jizhen Sun[3] and Ivica Boticki[4]
[1]Learning Sciences Lab., National Institute of Education, Nanyang Technological University, Singapore //
[2]Department of Technology Application and Human Resource Development, National Taiwan Normal University, Taiwan // [3]School of Continuing Education, Chinese Culture University, Taiwan // [4]Faculty of Electrical Engineering and Computing, University of Zagreb, Croatia // lunghsiang.wong@nie.edu.sg // chingkun.hsu@gmail.com // ccsun@sce.pccu.edu.tw // ivica.boticki@fer.hr
*Corresponding author

ABSTRACT
This paper reports the impacts of spontaneous student grouping to develop young students' orthographic awareness in the process of learning Chinese characters. A mobile-assisted Chinese character forming game is used to assign each student a Chinese character component on their smartphones through a wireless network. Fifteen Singaporean students, all 3rd graders (10-year-old) studying Chinese as a second language (L2), were required to negotiate with their peers to form groups that could assemble eligible Chinese characters by using their respective components. The game process data and the transcriptions of focus group interviews were qualitatively analyzed in order to investigate the dynamics of student collaboration and competition during the games. In turn, the patterns of social interactions during the activities were identified, with a special focus on the varied impacts of the two grouping modes (allowing versus not allowing each student to join more than one group at one time) on the students' game habits.

Introduction

Chinese characters have always been considered by both teachers and learners a significant challenge for beginners of Chinese as a second language. One major challenge to the learners is the complexity of the logographic configuration of Chinese characters (Shen, 2005; Wong, Chai, & Gao, 2011). Most Chinese characters are composites made up of multiple components that fit into a square space with one of the 15 general spatial configurations. Taking 口 as an example, there are many Chinese characters that fit this pattern (spatial configuration), such as 堆, 吐, 汉, and so on. The source of the difficulty in learning characters largely comes from not treating them as a unique linguistic system in their own right. Instead, rote memorization of characters and strokes is still the most practiced method of teaching Chinese as a second language. Shen (2004) attributed this challenge of teaching to the combination of the three elements of any character; namely its sound, shape, and meaning. Internalizing this information in learner's long-term memory and supporting the instant retrieval and application of these three elements from learner's mental lexicon represent a significant hurdle to the rote memorization-based pedagogy. Therefore, many Chinese language educationists favor instructions on the structure and form of characters that require students to pay attention to the association between character, form and meaning. Students are encouraged to figure out such associations using their imagination and creative thinking (Li, 1989).

Informed by the above-stated expositions, we developed a game-based learning approach for collaborative Chinese character formation, namely, "Chinese-PP" (汉字，拼一拼). PP refers to 拼一拼 (pronounced as "Pīn yì Pīn") in Chinese, which roughly means "trial assembling," and also colloquially means "striving for better (outcomes)." The game is targeted on students of Chinese as a second language (L2). To play the game, the students are assigned smartphones on a 1:1 (one-device-per-student) basis. In each game round, a set of Chinese character components is randomly assigned by the system server via 3G connections to individual students. They are required to recognize and compose eligible characters by grouping with their peers who have different components. This paper focuses on analyzing the social interactions, collaborative patterns and learning strategies that emerged during several game playing sessions. In particular, we will discuss the different impacts of the two grouping rules (allowing or not allowing the players to join more than one group at a time) on the students' emergent interactional patterns and

learning strategies, and their implications to Chinese character learning. This investigation was guided by the following research questions,

RQ 1. Is there any overall game-playing pattern that occurs in all the game rounds?

RQ 2. What are the levels of contributions (i.e., proposing Chinese characters to their peers) of the students with different levels of competencies in Chinese Language?

RQ 3. Do the two grouping modes, Single Group Mode (SGM) and Multi Group Mode (MGM), result in different emergent game-playing and collaborative patterns among the students?

RQ 4. What are the competitive and/or collaborative behaviors that the students are displaying during the game?

Related literature

Chinese character learning

A Chinese character consists of three tiers: the whole character, component and stroke, as shown in Figure 1. In particular, the component is the core and the base for the formation of a Chinese character (Tse, 2001). Many studies have emphasized the importance of Chinese character recognition in Chinese L2 learning. Allen (2008) argued that novice Chinese Language learners should focus on learning character recognition which is more important than writing. Research found that learners' ability to recognize different components and identify their semantic, phonetic, and structural functions in a character is predictive of their reading and language proficiency (Fang, 1996). Li (1992) also found that understanding the structure of a character is essential for the young learners to identify specific characters and to discriminate among different ones. Both studies point out that the cognitive aspect of recognizing a character lies on its contour and structure rather than its strokes, in a top-down order.

Components are composed into characters following a limited set of orthographic rules. The number of commonly used characters is much larger than the number of component types (< 120). Seventy-eight of these basic components account for more than 70 % of the 3,500 frequently used characters that are considered as the threshold of literacy (Huang, 2009). Therefore, as compared to traditional ways of memorizing each character as a whole or focusing on the strokes of a character and their sequences, teaching the structure of characters and addressing the relationship between components and wholes generates positive impacts on character learning (Anderson et al., 2002; Nagy et al., 2002). This is relevant to orthographic awareness, which refers to the awareness of individual Chinese characters' internal structures and therefore being able to infer meaning and pronunciation (Ho & Bryant, 1997; Jackson, Everson, & Ke, 2003; Shen, 2005). When learners start to cultivate this orthographic awareness, which is a metalinguistic awareness, they also start the process of transforming their knowledge of characters from explicit to implicit (Jiang, 2006), from performance towards the competence.
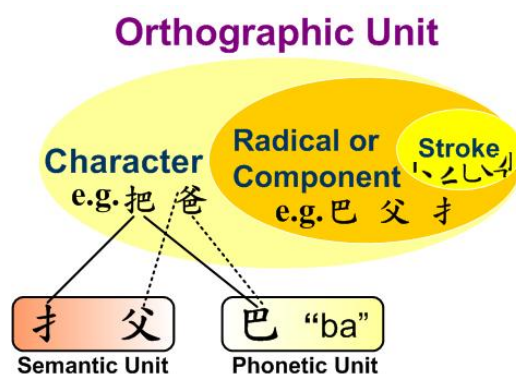
Figure 1. The three-tiered orthographic structure of written Chinese words

Cooperative Learning and mCSCL

Collaborative learning (or cooperative learning – both are different but overlapping learning models) is much more than competition and individualistic learning although does encompass some of these. The main difference is that in collaborative/cooperative learning students must learn how to "sink or swim together" (Johnson & Johnson, 1987).

Johnson and Johnson (1994) identified eight main principles for cooperative learning: heterogeneous grouping, collaborative skills, group autonomy, maximum peer interaction, equal opportunity to participate, individual accountability, positive interdependence and cooperation.

Here, we will discuss four of these cooperative learning principles which are arguably more tightly associated with our proposed study: maximum peer interaction, equal opportunity to participate, individual accountability and positive interdependence. Positive interdependence exists when group members are linked with other group members in a way that they cannot succeed without each other. There are several ways of structuring it: devising a clear group goal (positive goal interdependence), rewarding the group if all members achieve a set criterion (positive reward), by combining distributed resources (positive resource interdependence) and by assigning complementary and interconnected group roles (positive role interdependence).

Maximum peer interaction refers to the transformation of the normal classroom interaction pattern which is mainly sequential. A typical interaction pattern consists of the teacher talking, stopping in order to allow for student responses and evaluating students' responses. Cooperative learning disrupts that pattern by transferring agency to the students who form groups working in parallel. Therefore, peer interaction is maximized with more students talking to each other.

Each student should have equal opportunity to participate in the activity. That means the activity design should not allow any student to dominate the activity and impede the participation of others. By receiving their portion of the task and being aware of their role(s), students should be able to fully demonstrate their abilities. In order to prevent social loafing (some group members "hitchhiking" on the work of others), cooperative learning activities must come with individual accountability, which means each student is held responsible by group mates for contributing his or her fair share to the group's success.

Latest developments in the field of mobile Computer-supported Collaborative Learning (mCSCL) extend the idea of handheld technology mediated learning with the collaborative scaffolding in order to encourage small group participation (Nussbaum et al., 2009). The facilitation of collaborative scaffolding should encourage social interactions, expedite joint problem solving, lead to richer knowledge construction and in the same time take into account different and emerging roles, joint group goals and actions and facilitate verbal explanations (Boticki, Wong, & Looi, 2013).

Indeed, mobile learning strategies support innovative instructional and learning methods in effective and efficient ways. Scholars have noted that mobile-assisted language learning (MALL) provide students with rich, real-time, convenient, social contact, collaborative, contextual learning opportunities, both inside and outside the classroom (Kukulska-Hulme & Shield, 2008). Nevertheless, in terms of ICT-mediated Chinese character learning, regardless of being in web-based and/or mobile technology solutions, the majority of existing studies have been leveraged on individualized instructivist and behaviorist learning activity designs, with the fairly consistent goal of assisting learners in memorizing the shapes, stroke sequences, pronunciations, and/or meanings of as many characters as possible (e.g., Chuang & Ku, 2011; Chung, Leung, Lui, & Wong, in press; Hsieh & Fei, 2009). A more recent attempt (Tian et al., 2010) in designing for collaborative Chinese character learning came in the form of several mobile-assisted learning games inspired by traditional Chinese children's games (which originally had nothing to do with language learning). Another classroom-based activity design requires students to work in small groups in brainstorming and recalling Chinese characters with similar pronunciations or "shapes" from a given character through Group Scribbles, a wireless Computer-supported Collaborative Learning (CSCL) platform (Looi, Chen, & Wen, 2009).

We argue that all these learning designs did not place an emphasis on addressing the need of fostering learners' in-depth orthographic awareness in their journey of Chinese character learning, and instead focused more on content memorization and retrieval. Therefore, we intend to address the research gap by developing a collaborative Chinese character learning approach that aims to reinforce the application of orthographic rules. According to our game design, by randomly assigning a component to each learner via mobile device and encouraging them to collaborate with their peers to form characters using different combinations of components through student-centered negotiation and discussion of meaning and form, our approach changes the traditional rote learning to a more constructive, learner-centered, and meta-cognitive model of character learning. Thinking "aloud" collaboratively about how a character should or might be constructed, and going through this group-focused experience several times with

different components and different peer groups, results in a learning environment where the students are constantly engaged in an active learning mode which requires that they comprehend, analyze and apply applicable linguistic rules to their creative composition of proposed characters. We believe this is a potentially effective strategy for young learners than the traditional passive learning mode of copying, repeating and memorizing without an understanding the logic underlying the creation of the characters they are being taught.

Method

Procedure

Fifteen Primary 3 (3rd grade) students who were learning Chinese as second language in a primary school in Singapore participated in the empirical study during April-October 2011. The entire intervention was comprised of six learning sessions conducted every fortnight (unless pre-empted by school exams or holidays). Specifically, the intervention aimed to progressively establish and enhance the students' orthographic awareness. Each learning session consisted of three sections, namely, warm up (15 minutes), game playing (30 minutes), and recalling (15 minutes).

Pre-task: Warm up

Each warm-up section began with the teacher going through a quick review of what had been covered in the previous Chinese-PP sections. She then made a brief Powerpoint presentation to introduce new knowledge of Chinese character structure (orthographic knowledge). One example is pictophonetic character, which refers to a character that is comprised of a component indicating the pronunciation and another representing the semantics. For example, 晴 (means "sunny," pronounced as "qíng"), with 日 ("sun") hinting the semantic meaning or 'picture' of the character, while 青 (similarly pronounced as "qīng") indicates the pronunciation. Another type of knowledge that the students need to pick up are the eligible locations where individual components should appear. For example, 氵 can only be placed at the left （e.g., 清）or middle （e.g., 衍）part of a character. There is no eligible character with this component at its right side. However, certain components such as 日 can appear at almost any part of a character, e.g., 晴, 阳, 晕, 暂, 借. The intent of these exercises was to equip students with prerequisite knowledge for the subsequent game playing section. Due to the space limits and since this paper focuses on the analysis of students' game playing patterns and strategies, we will not present the details of the domain-specific curriculum design.

Main-task: Chinese-PP game playing

In a general classroom, we rearranged the chairs and desks to set aside an empty space. We encouraged the students to walk around, form and re-form ad-hoc physical clusters where they could ardently discuss their assignment with different peers and explore alternative possibilities of characters. The students played two 15-minute game rounds in different modes, namely, single-group mode (SGM – a student can only join one group at a time) and multi-group mode (MGM – a student can join multiple groups at a time) (see below for an elaboration). The teacher facilitates the game to ensure tight linkage between activity and content (i.e., the Chinese character structure covered in the warm up section). Typically, the teacher's facilitation tasks included controlling the game pace, on-the-fly hints to students concerning possible groupings, verifying students' groupings (the correctness of the formed characters), and determining when to terminate a round.

Post-task: Recall and reinforce all the characters composed during the game

After the game, the teacher facilitated a recalling activity where students were asked to relate the characters that they had composed during the game to the character structure knowledge that they learned in the present and past warm-up sections (e.g., relating 晴 to pictophonetic character).

Design of game-based learning activities for motivating collaborative learning

The Chinese-PP game approach can be characterized as a spontaneous, flexible grouping model as no fixed student groups are pre-determined. Each student is equipped with a smartphone in which they can see what components they have and what components are assigned to other classmates. The students identify their partners in order to collaboratively compose the components into an eligible Chinese character. When a game advances to the next round, the existing groups are disbanded and a new set of components are assigned to the individual players.

The setting and the devices used in the study consisted of a projector, the 3G wireless connection, a laptop with the Chinese-PP teacher console installed, and 15 smartphones installed with the client application of Chinese-PP. The facilitator prepared several sets of Chinese components equal to the number of participating students in advance. When a game round starts, the client application on the smartphone displays all the components for a student to select and configure (spatially) in order to form a Chinese character (see the left of Figure 2). Upon submission of her composed character to the server, the other students who "own" the components that she has selected will receive the character on their "My Groups" windows as an invitation for grouping (see the right of Figure 2). However, the proposing student cannot take for granted that the invitees will join her group as they might have also formed their own characters or received other invitations. This is where she will need to negotiate with the peers to join her group. The students are free to move around in the classroom for these discussions with different classmates.

A scoring scheme is applied in the game. Students earn and accumulate scores by forming eligible characters – 10 points for a 2-component character, 20 points for a 3-component character, 30 points for a 4-component character, and so on (same score to be awarded to each member of the group). This is to encourage the students to form bigger eligible groups for identifying more complex characters. During the MGM, a student who joins more than one group will earn accumulated scores from all the groups creating eligible characters.
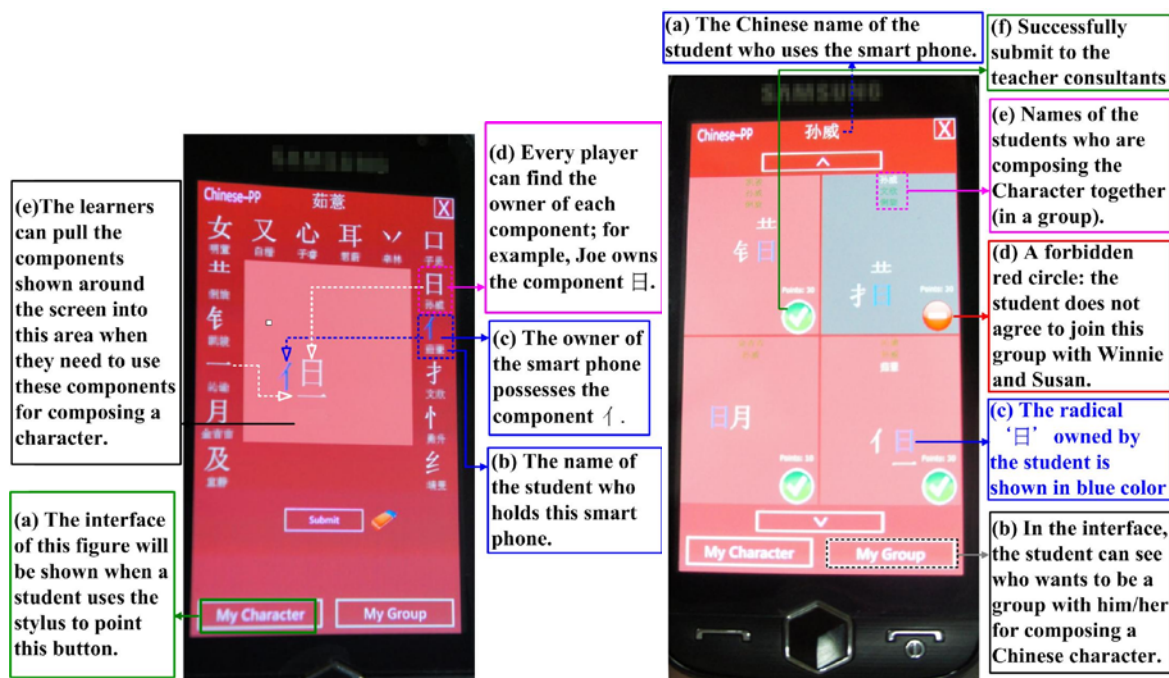
Figure 2. "My Character" interface (left) and "My Group" interface (right)

This system allows the teacher to select whether to play each game round in SGM or MGM. Consider this illustrative scenario: a student, Sam, who is assigned the component 日 ("sun") submits a character 但 ("but") to Rita who owns the component 亻 ("person") and Lisa who owns the component 一 ("one"), similar to the left of Figure 6. At the same time, John who owns the component 月 ("moon") proposes 明 ("bright") and invites Sam to join him. If such a scenario takes place in SGM, Sam will have to choose one of the two options; for example, if he joins the "但" group and passes on the "明" group, he will win 20 points; or 10 points if he chooses otherwise. If these options are

presented in MGM, Sam may choose to join both. In turn, he will earn 20 points for correctly composing "但" plus 10 points for composing "明" respectively (see Figure 1). During our empirical study, the teacher complied with our advice by alternating between the two modes across different game rounds in order to experiment with their impacts on the students' collaborative patterns and game strategies.

Figure 3 depicts a moment in the middle of the game where the teacher made use of the projected teacher console UI to give just-in-time feedback about the characters (correct or incorrect ones) formed by the students. Moreover, the students can check out the characters composed by other students and the scores they win (see Figure 2) on the teacher console.
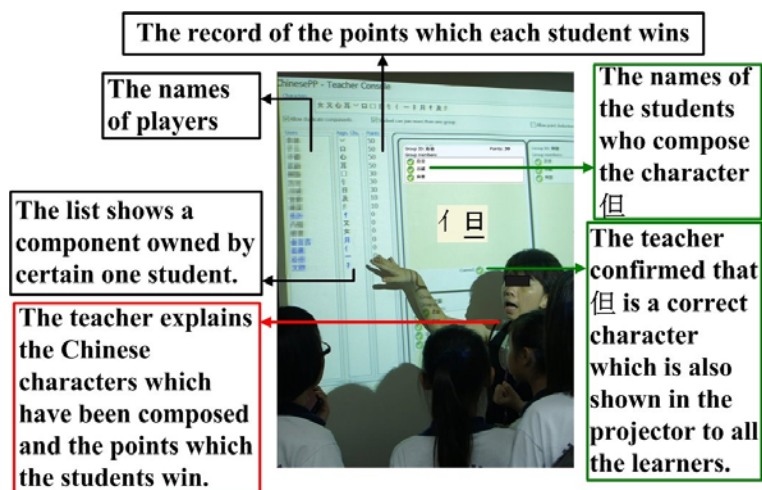
Figure 3. The interface of teacher console projected on the shared display

Data collection

In order to relate the participating students' game behaviors and their academic performances in the formal Chinese class in our data analysis, we ranked the 15 students based on their academic results for the subject and divided them into three bands – the top-5 students are known as high achievement (HA) students, the next 5 are medium achievement (MA) students, and the last 5 are low achievement (LA) students.

Throughout the interventions, we carried out video and audio recording, and took field notes of all the games to document the students' game behaviors and collaborative patterns. The software logs of the students' interactions and the automated screen captures of the teacher console during the phone games were also used for triangulation with the recorded material. By the end of the sixth session, we conducted a focus group interview with six students (including two randomly chosen HA students, two MA students and two LA students) to triangulate our game process analysis and probe them for the reasons behind their game habits.

In this paper, we concentrate on analyzing the student-student interactions during the last three Chinese-PP sessions. The reason is that while the participating students had been more reliant on the teacher in the first three sessions, the teacher's persistent strategy of advising the students to discuss with their peers had progressively transformed the students' help seeking behaviors. The students became more independent and willing to help each other, thus achieving more effective peer interactions towards the last three sessions while the teacher-student interactions were gradually fading out. Due to the space limit, we have decided to focus on making sense of how the more frequent peer interactions led to improved learning outcomes.

We carried out open coding and constant comparisons (Strauss & Corbin, 1990) on the collected data. Due to the space limit, we will only provide a synoptic view of our findings in the next section. All the student names reported hereafter are pseudonyms in order to protect their identity.

Findings

The students exhibited high energy levels during the last three Chinese-PP sessions. They walked around and carried out quick discussions about what combinations would be viable in forming eligible characters. The dynamic grouping strategy enabled by mobile information exchange and face-to-face interactions had motivated them in game playing. We will present our findings in four themes, identified through our qualitative analysis. They are: (1) overall patterns of individual game rounds; (2) initial character forming and invitation for grouping; (3) impacts of SGM and MGM on students' game playing and collaborative patterns; and (4) competition versus collaboration. The four themes are our answers to RQ1, RQ2, RQ3 and RQ4 respectively.

Hereafter, we refer to students who figured out Chinese characters and sent group invitations as "student-leaders," while those who were invited to join a group as invitees. Due to the flexible grouping nature of the game, an individual student might rapidly switch her role and even assume both roles at the same time. For example, during a game round, a student might send out an invitation and then realize that she is also invited by two other groups. It is up to her to decide whether she wants to stick to her own proposed group or join another group in SGM, or join more than one group with eligible characters being proposed in MGM.

Overall patterns of individual game rounds

We observed a consistent pattern in the last three game sessions. At the beginning of each round, instead of going straight to peer interactions, the students took time to assemble characters individually on their phones, as though they were playing a one-player game. The trial-composing stage usually lasted about two minutes while they stood or sat in their original positions. Subsequently, as invitations were sent out one after another, they began to move around with their phone and look for their potential group-mates who had the components that they needed to discuss proposed characters, and perhaps switch between different clusters of peers to explore other possibilities. Occasionally, they approached HA peers for quick advice even though they did not intend to form a group together. They remained active until the end of the game round. Figure 4 depicts an instance of such a transformation in one of the game rounds.

Figure 4. Beginning with individual pondering (left), then walking around to discuss with others (right).

Initiating character forming and invitation for grouping

We cross-examined the invitation data in the server log and the inviters' academic achievements. Based on the data from the last two Chinese-PP sessions, the accumulated frequencies of HA, MA, and LA students (n = 5, respectively) in proposing eligible characters were 18, 21 and 11 respectively. The figures show that the HA students did not dominate the games. The MA/LA students had also made their share of contributions. We traced back to the data in the first three sessions and found that although HA students tended to be more proactive in these earlier sessions, the MA/LA students were not left alone. The HA students often invited them to join their groups as the MA/LA students were assigned the components that the HA students needed. In inviting the MA/LA students, the HA students needed to explain to them on the formed characters and the orthographic knowledge. Such emergent peer coaching (Wong, Chen, Chai, Chin, & Gao, 2011) seemed to have elevated the MA/LA students' competencies and self-efficacy. Thus, the gaps between the HA and MA/LA students were gradually narrowed.

Impacts of SGM and MGM on students' game-playing and collaborative patterns

A finer-grained analysis of the intra- and inter-group interactions has shed light on the varied game playing patterns of the students in playing SGM and MGM. During the game rounds in the MGM, the students were more motivated to trial composing alternative characters. They would not mind composing either a simple or complex character to start with and the time they spent in working out and submitting their first characters tended to be shorter. Conversely, during the SGM, the students were more inclined to deliberately compose the most complex Chinese character possible in one shot, and then gave up exploring other possibilities in composing alternative characters with their own components. In this regard, they often took more time to form their first characters. Even though the game mechanism of the SGM mode does allow them to disband their submitted group if they change their mind, they were generally not keen to do so but tended to stick to their first (and only) formed characters throughout the game round. It was observed that there were more discussions but fewer characters were formed and submitted.

We discovered several emergent game patterns (or strategies) that were specific to either game mode. For example, during the SGM games, the students often delayed their decision or commitment in joining one group that they were invited so they could spend more time exploring other possibilities of forming more complex characters and earn higher scores. During the MGM games, members of a particular confirmed group might proceed to explore more character forming opportunities with one or a combination of the strategies as shown in Table 1, as every additional eligible group that a student joined would bring her more scores. In fact, we did not directly teach them these strategies. Instead, they figured these out by themselves, perhaps as part of their socio-constructivist process of internalizing the Chinese character knowledge learned from their teacher. Thus, this strategy table is not definitive or exhaustive. More emergent strategies may emerge as we facilitate more game sessions and analyze the game process data in the future. Based on our current data, we characterize the first four strategies as basic ones. The last two are derived from the basic strategies, which often involved more sophisticated student-student interactions.

Table 1. Student strategies for figuring out alternative characters during Chinese-PP games

Strategy Label	Description	Example
Expansion	To add new component(s) owned by non-group member(s) in order to form a more complex character	且 → 担
Reduction	To remove one or more components in order to form a simpler character	警 → 苟
Replacement	To replace one or more components of the group character in order to form another group with another similar character	借 → 错
Reshuffling	To reuse all the components in a character but alter their positions to form a new character	叶 → 古 (the reshuffling of the two components: 口 and 十) 胃 → 胡(the reshuffling of the three components: 口，十 and 月)
Splitting	To split a character into multiple components or component sets, each forming new characters with other component(s) respectively	Splitting 堆 into components 土 and 佳, and form 推 and 垃 respectively (i.e., double replacements)
Reassembling	To take one or more components from at least two characters and form a new character	Taking 扌 from 拉, 土 from 里, and 寸 from 讨; and form 持

We observed a sequence of component manipulations in each MGM game round. During the first three Chinese-PP sessions, the students tended to be content in figuring out simple two- or three-component characters, and occasionally moving on to the possibility of replacing or adding one component to form another character. However, as they were gradually developing the skills of composing the most complex character possible in one shot during the SGM game rounds, they transferred this strategy to the MGM game rounds in the last three Chinese-PP sessions. They then extended it into a "top-down," character reduction approach. In the process, they might have also picked up the meta-skills of generalization, i.e., they needed to generalize their emergent strategies from instances of successful character composing and re-composing in earlier rounds, thereby re-use such strategies in the future game rounds.

We take two instances of character compositions in session 4 as an example. During the SGM, four students formed a group and put forward the character 福 ("fortune"). They earned 30 points each and just stopped there. However, when they proceeded to play in the MGM, two of the four students formed the five-component Chinese character 警 ("caution") with three other peers. They then moved on to take one component out each time and subsequently formed 敬 ("respect"), 苟 ("thoughtless") and 句 ("sentence") (see Figure 5). Should they construct the character 警 during the SGM mode instead, they might not bother to carry on with further reductions of the character as it would not increase their scores.
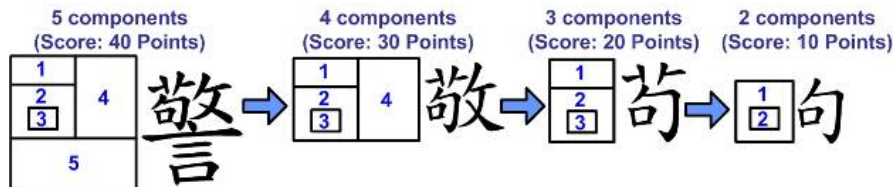
Figure 5. An example of students in multi-group mode composing characters in a top-down manner

Apart from sticking to the reduction strategy, the students were getting more adept in applying multiple strategies to construct more alternative characters towards the last two Chinese-PP sessions. Such character altering sequences could be represented in the form of tree structure. Figure 6 depicts an example of a sequence that occurred during Chinese-PP session 5, with numbers in the circles indicating the order of characters being formed. It started with two students grouping together to form the character 讨 ("ask for …", with the components 讠 and 寸) and earned 10 points each; while another three students assembled the character 但 ("but", with the components 亻, 日 and 一) and earned 20 points each. The first two students then split up and grouped with two different peers to form 该 ("that") and 付 ("pay") respectively, which is an application of the splitting strategy. However, the formation of 付 is considered an application of the replacement strategy in the eyes of the student who owned the component 亻, as he previously joined the group that formed 但, and now he replaced the components of 日 and 一 with 寸. Next, two students who were possessing the components 口 and 一 respectively formed the character 日 (note that 日 itself is another component that was possessed by another student). Similarly, 里 ("inside") was formed by the students who carried 田 and 土 respectively. Subsequently, three students picked up one component from each of the characters 该, 付 and 里 to form 诗 (reassembling). Meanwhile, the two students who formed 日 invited the student who possessed 阝 to expand their character to 阳 ("sun") (expansion). More instances of replacements and reassembling took place later, which resulted in the identification of 刻 ("moment"), 细 ("slender") and 福 ("blessing").
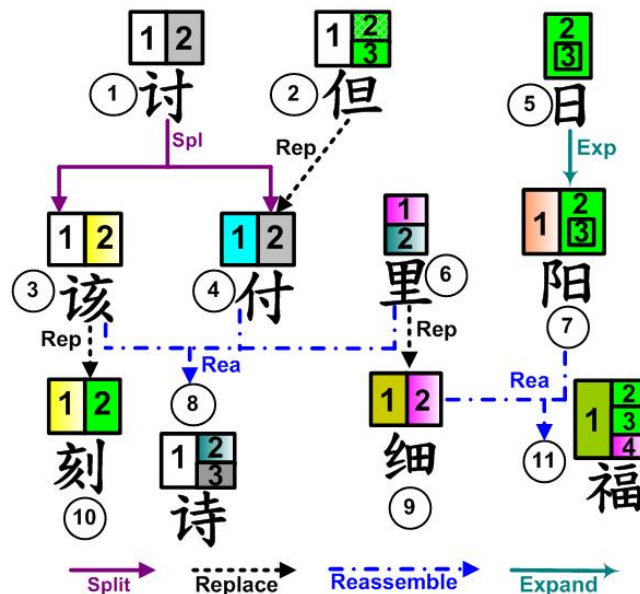
Figure 6. A character altering sequence during session 5

In addition, we observed several instances of correct relocations of components in this sequence: (1) the relocation of the component 亥 from the right to the left (该→刻); (2) 寸 from the right to the bottom right (付→诗); (3) 土 from the bottom to the top right (里→诗); (4) 田 from the top to the right (里→细); and (5) 田 from the right to the bottom right (细→福).

In a nutshell, the varied gaming and collaborative patterns exhibited by the students in different game modes can be attributed to their strategizing of earning more scores. During the SGM games, as the invited students tended to spend more time to consider whether to join a proposed group (i.e., to save their only chance to commit to a bigger group), the student-leader of the proposed group often approached individual invitees or brought the potential group members together to persuade them to join. During the MGM games, however, students often committed to a group faster, with less persuasion took place. Members of the confirmed group usually proceeded to discuss within the group about various ways of altering the formed character. They did so by applying the strategies reflected in Table 1, which lead to forming new groups with different members, thus boosting their game scores.

Competition versus collaboration

During the Chinese-PP sessions, we observed both competitive and collaborative behaviors displayed by the students. The scoring mechanism worked well in motivating the students to strive for composing a greater number of characters (usually in MGM games), or more complex characters (usually in SGM games), which we have reported in the previous sub-section. The teacher console provided automated, 'live' updates of individual students' scores and their rankings. Most of the students checked their scores and rankings from time to time during the game rounds. When they found out that they were lagging behind other peers, they tried harder to improve their situation. In a related note, some of the students initially found multiple invitations at a time irritating and, as a result, felt their decision making was made more difficult. Nonetheless, they became excited when they realized that these invitations might help their scores to be elevated—they would either be able to choose the most complex character during a SGM game, or join multiple groups during a MGM game.

Much to our surprise, such a competitive mindset neither hindered student collaborations nor distracted them from assisting their peers who needed help without benefit to themselves. Most of the students, when asked to confirm or alter specific characters by their peers who belonged to different groups, offered their help as far as they could. Two HA students, Sally and Ray, often took the initiative to assist other groups in their game playing after they had formed their own groups. In particular, Sally paid special attention to her "left-out" peers who had yet to identify any character or be invited to join any group. Subsequently, their peers became more inclined to seek their assistance. We learned from the focus group interview that the reason behind this was their sense of self-esteem; bringing the best out of themselves through the process of helping others.

The social relationships among the students did not play a prominent part in their groupings. For example, they exhibited gender-shy behaviors during the first two Chinese-PP sessions. However, towards the last few sessions, they seemed to ignore the social factors (gender or personal affiliation) and instead focused on optimizing their groupings during the games. Notwithstanding in a few rare occasions during the SGM games, some students opted to join a group with a simpler character being proposed. They did so because of their personal affiliations with certain potential group members (especially if the latter was a "left-out" student, i.e., no other grouping option yet), despite having the chance to join other groups to form more complex characters.

Discussion

The flexible, rapidly altered grouping model of the Chinese-PP game is a novel approach in mobile gaming. A somewhat similar mobile learning approach is participatory simulation (e.g., Lonsdale, Baber, & Sharples, 2004; Tomlinson, Baumer, Yau, & Black, 2008; Yin, Ogata, & Yano, 2007), although such a setting usually does not involve explicit student grouping. Even within the more general CSCL field, existing studies have been focusing on fixed, often pre-determined student groupings (such as the mCSCL approach reported by Zurita & Nussbaum (2004a, 2004b)), perhaps for easier classroom/learning management by the facilitators (e.g., teachers) or more robust execution of collaboration scripts.

In designing Chinese-PP, we instead intended to leverage more on emergent peer scaffolding to keep the learning activities going (related to the principle of maximum peer interactions in Johnson & Johnson's (1994) model of cooperative learning). Each student possesses a resource (a character component) and assumes full control on it (corresponding to the cooperative learning principles of positive resource interdependence). Nevertheless, in order to achieve the game goal (the cooperative learning principle of positive goal interdependence) of forming characters with the rest of the available resources (the 14 components possessed by other students), she will not only need to draw upon her own knowledge of Chinese characters, but also her social and collaborative skills to negotiate with her peers to identify and form groups (reinforcing the cooperative learning principles of individual accountability, equal opportunity to participate, and maximum peer interactions). In the process, she might be persuaded to join a group proposed by a different student-leader and in turn learn from the latter where the proposed character is unfamiliar to her.

One important evidence of effective collaborations in the Chinese-PP games is that towards the last three sessions, there was no significant difference in the accumulated frequencies of "student-leadership" (i.e., proposals of eligible characters) among the HA, MA and LA students. Instead, participants across all the rankings had become more interactive and collaborative. Such broader-based participation had apparently led to learning gains and improvement in collaborative spirits and skills.

We argue that the key to achieving such effective collaborations is the game feature of "distributed resources." In existing CSCL studies/solutions with fixed group settings, all members of a group typically share a piece of work. This may lead to pitfalls relevant to the sense of ownership, such as the HA students of the group dominates the collaborative learning process or no one wants to assume ownership. In Chinese-PP, however, the limited ownership of a piece of resource (i.e., one character component per person) and the need of grouping with the peers (but with multiple possible solutions available) to earn more game scores for themselves had worked well in boosting peer interactions and peer assistance. Such a game mechanism may work especially well for juvenile students with limited attention spans. This is because they could rapidly form and re-form groups, and then be rewarded (earning scores) of their efforts (in composing eligible characters) almost instantly. The mechanism seems to be a potential solution to the issues of "group development impediment" (inadequacy of group development skills) or "ability impediment" (deficiency of background ability) in typical CSCL groups (see: Liu & Tsai, 2008), which is worth further investigation.

Indeed, we observed a healthy balance of competition and collaboration among the students throughout the last three Chinese-PP sessions. When they were engaged in the games, they had the clear goal of forming complex characters or multiple characters in order to improve their scores and rankings. However, they usually would not hesitate to help their peers who did not belong to their groups even though that would bring the latter some competitive advantage. They did so for the sake of self-esteem and game-induced enjoyment in figuring out more eligible characters.

During the Chinese-PP games, we set aside some space in the classroom and allowed the students to move around with their phones to discuss with different individual or cluster of peers. This is the power of mobility – for both the devices and the students—that resulted in a greater diversity in the students' explorations of alternative solutions (the submitted characters). In particular, we facilitated two student-student interactional modes of the game, namely, technology mediated interactions (sending invitations and the visualization of the proposed characters) and face-to-face interactions (negotiation of group forming, peer coaching and discussions on the alterations of the characters). We observed that both interactional modes complimented each other so well that the students found no trouble in smoothly and rapidly switching between them.

Another inspiring discovery was the variation of the game-playing patterns/strategies and the content of the discourses that emerged during the SGM and MGM game rounds. The students adapted well to playing Chinese-PP games in both modes by figuring out different strategies to maximize their winning chances. That is, in the SGM games, the students spent more time composing the most complex characters possible in one shot while in the MGM games, they worked faster and more rapidly in composing and altering characters. Again, the two modes seemed to complement each other as students who engaged in both modes were able to develop both types of skills. Occasionally, they applied these skills across games where they found them helpful. Therefore, although the students involved in the focus group interview unanimously indicated their preference for MGM over SGM, future teachers should continue to facilitate both game modes to strive for a more robust range of benefits.

From Chinese character learning point of view, the students demonstrated their orthographic awareness (Jiang, 2006) through their character alteration activities. Using Figure 4 as an example, we found that all the strategies they collaboratively used follow the orthographic rules of composing characters from different types of components. For instance, when they split 堆 into 隹 and 土, and reassembled them with 扌 and 立 to form new characters 推 and 垃, they needed to have implicit or explicit knowledge of a number of orthographic rules. Not only did they need to know that the semantic component 扌 (meaning: hand) and the phonetic component 隹 can only be placed on the left and right side respectively, they also needed to know that both 土 and 立 could function as either a phonetic or semantic component depending what combinations of components they might consider The group that formed 借, a three-component character, needed to know that component 2 and component 3 had to be structured in a specific way, with 日 placed on the bottom of the character, not at the top. Finally, it was not by chance that they reduced 错 to 昔, rather than 钅, since they had to know that 钅, a semantic component, can only be placed on the left side.

This Chinese-PP game applies object teaching via graphics, embedding the fundamental orthographic theory and rules in hands-on practice through collaborative learning, therefore enabling learners to implicitly grasp the concepts and rules of character structure through trial and error (Sun, 2006; Wong, Boticki, Sun, & Looi, 2011). The flexible grouping model encourages learners to contrast, associate, and discriminate different components in order to generate more eligible characters. Paired with a sound pedagogical design, this type of learning approach can effectively raise learners' awareness of the principles of character structure and their ability to use this logical comprehension to learn characters in a more active and autonomous fashion.

Conclusions

We have systematically analyzed the emergent game playing patterns and strategies exhibited by the students during the Chinese-PP activities in our empirical study. Through our analysis, we discovered some significant patterns in overall individual game rounds, spontaneous student groupings, the balancing of competition and collaboration, as well as the varied impacts between SGM and MGM to the students' socio-cognitive and collaborative patterns. All these patterns are pointing to the achievement of the desired learning outcome of the Chinese-PP learning approach—to establish the students' orthographic awareness in Chinese characters. The novel spontaneous grouping feature, the mobility of both the smartphones and the students in the game, the joyfulness of game playing, and the individual students' resulting self-esteem from both winning the game and assisting their peers are some of the critical success factors for the students' performance in the last three Chinese-PP sessions. In the future, we plan to analyze the full set of qualitative data (i.e., the game playing process data in session 1-6) at the lower level details to trace and uncover the transformations of the students in both socio-cognitive (the establishment of the orthographic awareness) and socio-constructivist (the improvement of game playing through emergent strategies) aspects. We will do so through both the lenses of CSCL and second language acquisition theories. In turn, we hope to achieve better understanding in the general nature of such a flexible grouping model and how it may be applied to the learning in other subject domains (see also: Boticki, Looi, & Wong, 2011). Furthermore, we will identify more conducive interactional patterns and game strategies, and incorporate them into our refined pedagogy in order to help future Chinese-PP players to become better learners and gamers.

Acknowledgements

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A Learning Style Perspective to Investigate the Necessity of Developing Adaptive Learning Systems

Gwo-Jen Hwang[1*], Han-Yu Sung[2], Chun-Ming Hung[3] and Iwen Huang[3]

[1]Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taipei, Taiwan // [2]Graduate Institute of Applied Science and Technology, National Taiwan University of Science and Technology, Taipei, Taiwan // [3]Department of Information and Learning Technology, National University of Tainan, Taiwan // gjhwang.academic@gmail.com // hanyu.sung@gmail.com // hcm@live.htps.tn.edu.tw // huangi@mail.nutn.edu.tw

*corresponding author

ABSTRACT

Learning styles are considered to be one of the factors that need to be taken into account in developing adaptive learning systems. However, few studies have been conducted to investigate if students have the ability to choose the best-fit e-learning systems or content presentation styles for themselves in terms of learning style perspective. In this paper, we aim to investigate these issues by using two versions of an educational game developed based on the sequential/global dimension of the learning style proposed by Felder and Silverman. The experimental results showed that the choices made by the students were not related to their cognitive process or learning style; instead, most students made their choices by intuition based on personal preferences. Moreover, the students who learned with learning style-fit versions showed significantly better learning achievement than those who learned with non-fit versions. Consequently, it is concluded that students preferring one game over another does not necessarily mean that they will learn better with that version, revealing the importance and necessity of developing adaptive learning systems based on learning styles.

Keywords

Learning styles, Cognitive process, Human factors, Educational computer games, Adaptive learning

Introduction

The provision of personalized or adaptive learning support for individual students has been recognized as being one of the most important features of e-learning systems (Tseng, Chu, Hwang, & Tsai, 2008). By referring to personal information, adaptive learning systems can either present personalized content for individual students or guide them to learn by providing a personalized path (Brusilovsky, 2001). In the past decade, many personalized or adaptive learning systems have been developed based on a range of students' personal information, such as their profiles (e.g., gender, age, knowledge level, and background data), learning portfolios, and preferences (Chen, 2008; Wang & Liao, 2011; Wang & Wu, 2011). For example, Huang and Yang (2009) designed a semantic Web 2.0 system to support different types of knowledge and adaptive learning. They found that combining the advantages of blogs and wikis enabled students to comprehend various types of knowledge and improve their learning performance. Tseng et al. (2008) developed an adaptive learning system to plan personalized learning paths for individual students by selecting and linking the learning units based on their knowledge levels. It was found that the students who learned with the adaptive learning materials had significantly better learning achievement than those who learned with the non-adaptive materials.

Among those factors that affect the provision of personalized learning contents or paths, learning styles have been recognized by researchers as being an important factor (Filippidis & Tsoukalas, 2009). Keefe (1987) stated that "learning style is a consistent way of functioning that reflects the underlying causes of learning behavior." He further indicated that learning style is both a characteristic which indicates how a student learns and likes to learn, as well as an instructional strategy informing the cognition, context and content of learning (Keefe, 1991). Previous studies have reported that students' learning performance could be improved if proper learning style dimensions could be taken into consideration when developing adaptive learning systems (Filippidis & Tsoukalas, 2009; Graf, Liu, & Kinshuk, 2010; Hauptman & Cohen, 2011).

Although adaptive learning has been widely discussed and has been recognized as being an effective approach for helping students improve their learning performance, few studies have been conducted to investigate whether

students can choose the best-fit e-learning systems for themselves. In this study, an experiment has been conducted which provided students with two versions of an educational computer game based on the sequential/global learning style dimension proposed by Felder and Silverman (1988) to investigate the following research questions:
1.   Can students choose educational computer games that fit them best from the learning style perspective?
2.   Is there any difference between male and female students in choosing educational computer games?
3.   What are the factors that affect students' choice of educational computer games?

Moreover, the learning achievement of the students who learned with learning style-fit versions is compared with that of those who learned with non-fit versions. From the experimental results, we aim to show the importance and necessity of developing adaptive learning systems based on learning styles; that is, if students of both genders are incapable of choosing a game that best fits their learning style, and if learning styles do have a significant impact on students' learning achievements, it is then inferred that the development of adaptive learning systems based on learning styles is needed.

Literature review

Adaptive learning systems refer to the computerized learning systems that adapt learning content, presentation styles or learning paths based on individual students' profiles, learning status, or human factors (Chen, Liu, & Chang, 2006; Tseng et al., 2008). Brusilovsky (1996) has presented several strategies for developing adaptive learning systems, such as the Curriculum Sequencing method that provides individual students with the most suitable sequence of learning the subject units, the Intelligent Analysis method that identifies students' solutions and provides learning supports accordingly, the Interactive Problem-Solving Support strategy that provides students with personalized assistance in each problem-solving step, the Example-based Problem-Solving approach that suggests the most relevant cases or examples to students, the Adaptive Presentation approach that adapts the learning content based on each individual's knowledge level or personal characteristics, and the Adaptive Navigation Support approach that provides personalized learning paths (or links) to students based on their knowledge levels or personal characteristics. In the past decades, researchers have developed adaptive learning systems based on these approaches and have shown the effectiveness of the developed systems (Karampiperis & Sampson, 2005, 2009; Klašnja-Milićević, Vesin, Ivanović, & Budimac, 2011; Romero, Ventura, & de Bra, 2009).

Among various human factors, learning styles have been considered as an important factor for developing adaptive learning systems (Filippidis & Tsoukalas, 2009). There have been several learning style theories proposed by researchers, such as those proposed by Keefe (1979), Kolb (1984) and Felder and Silverman (1988). In the past decade, several studies have attempted to develop adaptive learning systems based on learning styles. For example, Tseng, Chu, Hwang and Tsai (2008) developed a personalized learning system by taking both the knowledge levels and the learning styles of students into account. Later, Kinshuk, Liu and Graf (2009) proposed an adaptive learning approach by analyzing the interactions between students' learning styles, behaviors, and their performance in an online course that was mismatched regarding their learning styles to find out which learners needed more help, such that proper learning supports could be provided accordingly. Graf, Liu and Kinshuk (2010) further investigated the navigational behavior of students in an online course within a learning management system to look at how students with different learning styles prefer to use and learn in such a course. They found that students with different learning styles used different strategies to learn and navigate through the course.

Furthermore, several studies have reported positive effects of employing learning styles in developing adaptive learning systems. For example, Hauptman and Cohen (2011) examined whether students with a certain learning style would benefit more from learning 3D geometry than other students. Their findings indicated a differential impact of virtual environments on students with different modal and personal learning styles. Bolliger and Supanakorn (2011) examined the effects of learning styles on learner perceptions of the use of interactive online tutorials by categorizing the students into five learning style categories and four learning modalities. The responses to a questionnaire regarding survey dimensions were analyzed in order to ascertain differences based on learning style dimensions, gender and class standing.

Among those learning style theories, the Felder–Silverman learning style has been widely adopted and has been validated by various studies (Mampadi, Chen, Ghinea, & Chen, 2011; van Zwanenberg, Wilkinson, & Anderson,

2000). For example, Filippidis and Tsoukalas (2009) developed a web-based adaptive educational system based on the sequential-global dimension of Felder–Silverman's learning style theory. The adaptive learning system provides different versions of images to present the same content with different detailed levels; that is, a detailed version of the images is given for sequential learning style students, while a non-detailed version is presented to global learning style students. Recently, Hwang, Sung, Hung and Huang (2012) developed an adaptive learning system based on this similar learning style approach for an elementary school natural science course. From a practical application, they reported that the students who learned with the adaptive learning system showed better learning achievements and attitudes than those who learned with a conventional e-learning system.

In this study, two versions of an educational computer game were developed based on the sequential/global dimension for investigating the students' ability and decision-making process in choosing the best-fit learning system.

Experiment design

Participants

As the educational computer games were developed for an elementary school natural science course, a total of 288 students in an elementary school in southern Taiwan voluntarily participated in the study. All of the students were taught by the same instructor who had taught that natural science course for more than ten years.

Measuring tools

The measuring tool adopted in this study was the Index of Learning Styles (ILS) Questionnaire developed by Soloman and Felder (2001) based on the learning styles proposed by Felder and Silverman (1988). The ILS measure consists of four dimensions, that is, sensing/intuitive, visual/verbal, active/reflective and sequential/global, each of which contains 11 items. In this study, the "sequential/global" dimension was adopted. Some of the questionnaire items of this dimension are "I tend to (a) understand details of a subject but may be fuzzy about its overall structure; (b) understand the overall structure but may be fuzzy about details." and "Once I understand (a) all the parts, I understand the whole thing; (b) the whole thing, I see how the parts fit." Choosing "a" indicates that the "sequential" tendency degree is increased; otherwise, the "global" tendency degree is increased.

In addition, a pre-test and a post-test were conducted to evaluate the learning achievements of the students. Both the tests were developed by two experienced natural science teachers. The pre-test aimed to evaluate the students' basic knowledge of the natural science course content, while the post-test aimed to evaluate the students' knowledge in identifying and differentiating the plants on the school campus after the learning activity. The pre-test contained both multiple-choice and fill-in-the-blank items; its perfect score was 100. The post-test contained twenty multiple-choice items; its perfect score was 60.

Sequential and global style educational computer games

Educational computer games have been recognized as being a good way of providing a more interesting learning environment for acquiring knowledge (Cagiltay, 2007; Hwang & Wu, 2012; Papastergiou, 2009; Tüzün, Yılmaz-Soylu, Karakus, Inal, & Kızılkaya, 2009; Wang & Chen, 2010). Various studies have shown that educational computer games can enhance students' learning interest and motivation (Burguillo, 2010; Ebner & Holzinger, 2007; Hwang, Sung, Hung, Yang, & Huang, 2012; Hwang, Wu, & Chen, 2012; Liu & Chu, 2010; Dickey, 2011; Harris & Reid, 2005). For example, Prensky (2001) pointed out that the purpose of combining games with teaching is to provide learners with interactive learning chances as well as to trigger their learning motivation. Inal and Cagiltay (2007) investigated the flow experiences of children in an interactive social game environment, and found that the challenge and complexity elements of the games had a greater effect on the flow experiences of the children than clear feedback.

In this study, two versions of an educational computer game were developed for the "knowing the plants on the school campus" unit of an elementary school natural science course based on the sequential/global dimension of the

Felder–Silverman learning style. The objective of the subject unit is to foster the students' competence in identifying and differentiating a set of target plants.

The game was implemented by employing the RPG Maker developed by Enterbrain Incorporation. The background of the game is an ancient kingdom in which the people are infected by poisoned water in a river. Following the hints from an ancient medical book, the king decides to look for the plants that are able to cure his people.

The game designed for sequential style learners provides a "step-by-step" interface to guide the students of this style to complete the learning missions, since they tend to think linearly and learn in small incremental steps (Felder & Silverman, 1988). Figure 1 shows the interface of the sequential style game. The learners are guided by this version of the game to the next mission only after the present mission has been completed.

Figure 1. The sequential style game

On the other hand, the global style game provides a "global mission map" that enables the students to select any mission or jump to any game scene, since they tend to learn with holistic thinking processes in large leaps (Felder & Silverman, 1988). Figure 2 shows the interface of the global style version of the educational computer game.

It should be noted that there is no specific logical order suggested by the teacher for learning about the plants. The only difference between the two versions of the game is the way of presenting the learning materials. In the sequential style version, the students learn about one plant at a time in the Chinese character order. Only after they complete the learning tasks of one plant (i.e., they have learned all of the features and details of that plant), are they guided to the next plant; that is, they learn the details of individual plants sequentially. On the other hand, the global version presents all of the plants related to the learning activity via the map; that is, the students learn with a global view of the whole content. Such a style-based interface design is based on the suggestions given by Mampadi et al. (2011). Following such a design principle, the students of both styles receive the same learning content and an equal

amount of information about the learning content and learning tasks, and hence the challenges of the two versions can be viewed as equal.

Figure 2. The global style game

Experiment procedures

Before the experiment, the students completed the learning style questionnaire so they could be categorized according to sequential or global style. Following that, a one-hour presentation was made by the teacher to show them the two versions of the educational computer game, including the differences and similarities between the two versions; moreover, the students were informed that the two versions of the game had identical content related to the "knowing the plants" unit of the natural science course. After the presentation, the students were asked to make the choice between the two versions of the game and write down their reasons for the choice.

Results

Relationships between students' learning styles and their choices of the e-learning systems

From the learning style questionnaire result, it was found that 134 of the participants were sequential style students, while 154 were global style learners. Table 1 shows the ratio of the choices made by the different learning style students. It is found that 86.1% of the students chose the global style system, while only 13.9% chose the sequential style system; that is, most of the students preferred the global style version of the game. Moreover, 86.5% of the sequential style students chose the global style system while only 14.3% of the global style students chose the sequential style system.

Table 1. Descriptive data of students' learning styles and their choices of the educational computer game

		Choices of the educational computer game		Total
		Sequential	Global	
Students' Learning Style	Sequential	18 (13.5%)	116 (86.5%)	134
	Global	22 (14.3%)	132 (85.7%)	154
Total		40 (13.9%)	248 (86.1%)	228

To further investigate the relationships between students' learning styles and their choice of educational game, Chi-Square analysis was applied to the questionnaire data, as shown in Table 2. It is found that the correlation between the students' learning styles and their choice of the learning systems was not statistically significant (r = 0.44, *p* > .05). Consequently, it is concluded that the choices made by the students were not related to their learning styles; that is, the students did not choose the educational games by considering their underlying needs for learning effectiveness.

Table 2. The Chi-Square result of students' learning styles and their choices of educational games

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.044	1	.835
Likelihood Ratio	.044	1	.835
Linear-by-Linear Association	.043	1	.835
N of Valid Cases	288		

Relationships between genders

Table 3 shows the descriptive data of male (N = 158) and female (N = 130) students in choosing the two versions of the educational computer game. It is found that 137 out of 154 male students and 121 out of 130 female students chose the global style system, indicating that both the male and the female students preferred the global style version of the educational computer game. Moreover, it was found that 81.1% of the male sequential style students (60 out of 74) and 93.3% of the female sequential style students (56 out of 60) chose the global style game.

Table 3. Descriptive data of students of different genders in choosing the educational computer games

Gender			Choices of the educational computer game		Total
			Sequential	Global	
Male (N = 154)	Learning Style	Sequential	14 (18.9%)	60 (81.1%)	74
		Global	17 (20.3%)	67 (79.7%)	84
Female (N = 130)	Learning Style	Sequential	4 (6.7%)	56 (93.3%)	60
		Global	5 (7.2%)	65 (92.8%)	70
	Total		40 (13.9%)	248 (86.1%)	288

Table 4 shows the Chi-Square analysis results. It is found that the correlations between the choices of the educational computer games and the learning styles of male and female students are r = 0.43 (*p* > .05) and r = 0.11 (*p* > .05), respectively, which were not statistically significant. Consequently, it is concluded that, for both genders, the choices of the educational computer games were not related to their learning styles.

Table 4. The Chi-Square result of the choices of educational computer games for male and female students of different learning styles

Gender		Value	df	Asymp. Sig. (2-sided)
Male	Pearson Chi-Square	.043	1	.835
	Likelihood Ratio	.043	1	.835
	Linear-by-Linear Association	.043	1	.835
	N of Valid Cases	158		
Female	Pearson Chi-Square	.011	1	.915
	Likelihood Ratio	.011	1	.915
	Linear-by-Linear Association	.011	1	.915
	N of Valid Cases	130		

The factors that affected the students in choosing the educational computer games

In order to investigate the factors that affected the students in choosing the educational computer games, their feedback was analyzed. Table 5 shows descriptive statistics of the feedback from the students in stating the reasons for making their choices. It was found that 73.9% of the participants responded that "The game I chose looks more interesting than the other;" 71.7% of the participants made choices because they felt that "The game I chose looks more relaxing;" 65.2% of the participants commented that "Such an operational interface conforms to my previous experiences of playing games" and 66.7% stated that "The design of the game seems to be easier to operate."

To sum up, the factors that affect the students' choice of game include "interesting," "relaxing," "easy to use" and "conforming to previous experiences," which are all irrelevant to the cognitive process of individual students with different learning styles. Consequently, it is necessary to develop adaptive learning systems for guiding students to learn in an appropriate way, including providing a personalized learning interface or paths to present learning content in the most beneficial manner for individual students with different learning styles.

Table 5. Descriptive statistics of factors that affect students in choosing educational computer games

	Factors	Global style students who chose sequential style game (N = 116)		Sequential style students who chose global style game (N = 22)		Total (N = 138)	
1.	The game I chose looks more interesting than the other.	86	(74.1%)	16	(72.7%)	102	(73.9%)
2.	The game I chose looks more relaxing.	84	(72.4%)	15	(68.2%)	99	(71.7%)
3.	Such an operational interface conforms to my previous experiences of playing games	74	(63.8%)	16	(72.7%)	90	(65.2%)
4.	The design of the game seems to be easier to operate.	75	(64.7%)	17	(77.3%)	92	(66.7%)

Learning achievements of the style-matching and non-matching groups

An extended experiment was conducted to further investigate the effect of learning styles on the learning achievement of the students. As a number of the students failed to participate in this extended activity, the pre-test and post-test scores of 127 style-matching and 125 non-matching students were analyzed.

From the pre-test, it was found that the mean values and standard deviations were 88.20 and 6.73 for the experimental group, and 87.73 and 8.60 for the control group. The t-test result ($t = .483$, $p > .05$) shows that there was no significant difference between the two groups, implying that they had equivalent prior knowledge before the learning activity.

After the learning activity, ANCOVA was conducted by using the students' pre-test scores as the covariate and the post-test scores as the dependent variable to exclude the impact of the pre-test on their science learning. Table 6 shows the ANCOVA results of the post-test. It is found that the learning achievement of the style-matching students was significantly better than that of the non-matching students, indicating that learning style could be an important factor in developing adaptive learning systems or providing personalized learning supports.

Table 6. Descriptive data and ANCOVA result of the post-test results

Variable	Group	N	Mean	S.D.	Adjusted Mean	Std. Error.	*F*
Post-test	Experimental group	127	34.50	12.21	34.35	.97	6.18*
	Control group	125	30.78	11.73	30.94	.98	

Note. *$p < .05$

Discussion and conclusions

In this study, we investigate students' perceptions in choosing the most-beneficial educational systems from the perspective of learning styles. The participants were asked to select one of two versions of an educational game developed based on the sequential/global dimension of the learning style proposed by Felder and Silverman.

For the first and the second research questions, the experimental results of 288 students showed that the students were unable to choose educational computer games that fit them best from the learning style perspective; moreover, there was no difference between male and female students in choosing the games. In terms of the third research question, it was found that the choices they made were not related to their cognitive process or learning styles; instead, most students chose the e-learning systems based on intuition or preference, such as "interesting," "relaxing," "easy to use" and "conforming to previous experiences."

Furthermore, the pre-test and post-test results showed that the learning achievements of the style-matching group outperformed those of the non-matching group. Therefore, it is concluded that students preferring one game over another does not necessarily mean that they will learn better with what they choose, revealing the importance and necessity of developing learning systems that are able to provide individual students with personalized learning content to best benefit them. That is, this study provides evidence for supporting the development of adaptive learning systems, in particular, for those studies that employ learning styles as a factor for adapting learning content, presentation styles and learning paths for individual students.

To sum up, this study contributes several interesting findings to the community of technology-enhanced learning: (a) Students learn better with the version which has been designed for their learning style. This demonstrates the importance of adaptive learning systems which are based on learning styles. (b) Students do not necessarily choose the version which has been designed for their learning style. This is very important, because most adaptive systems create an initial user model based on individual students' answers to a questionnaire or choices of a set of parameters which are always assumed to be "reasonable." The results of the experiment demonstrate that this might be unsafe since users' choices are likely to be irrelevant to their learning performance. This can have a significant impact to the design of adaptable and adaptive learning systems.

On the other hand, although this study provides some significant experimental results, the use of the computer educational games in this study might not be able to represent the common features of most learning systems; moreover, the implications of this study are limited owing to the investigation being conducted on only one dimension of a learning style. Some researchers have attempted to investigate the issues concerning game-based learning from different aspects in different application contexts, such as user participation (Hoffman & Nadelson, 2010), learning interactivity and challenges (Susaeta et al., 2010), learning attention (Russell & Newton, 2008), collaborative learning (Huang, Yeh, Li, & Chang, 2010; Paraskeva, Mysirlaki, & Papagianni, 2010), gender differences (Kinzie & Joseph, 2008) and the teachers' considerations (Kebritchi, 2010). In the future, it would be worth conducting further studies to investigate those relevant issues by taking different learning dimensions into account.

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Analysis of Students' After-School Mobile-Assisted Artifact Creation Processes in a Seamless Language Learning Environment

Lung-Hsiang Wong

Learning Sciences Lab., National Institute of Education, Nanyang Technological University, Singapore //
lunghsiang.wong@nie.edu.sg

ABSTRACT

As part of a learner's learning ecology, the informal, out-of-school settings offer virtually boundless opportunities to advance one's learning. This paper reports on "Move, Idioms!", a design for Mobile-Assisted Language Learning experience that accentuates learners' habit of mind and skills in making meaning with their daily encounters, and associating those with the language knowledge learned in formal learning settings. The students used smartphones on a 1:1, 24x7 basis to capture photos in real-life contexts as artifacts related to Chinese idioms, made sentences with the idioms, and then posted them onto a wiki space for peer reviews. In this paper, we focus on investigating students' cognitive processes and patterns in artifact creations in informal settings. Our analysis and interpretation of such student activities is framed by the notion of Learner-Generated Context (LGC) (Luckin, 2008), a reconceptualization of 'learning contexts' that implies greater learner autonomy. Through two case studies, we gained better understanding in the impact of LGC and how it is crystallized in seamless learning processes with the interplay of physical settings, parental involvements and the mediation of mobile technology.

Introduction

How can learners' motivation and competencies in making meaning with their daily encounters, and associating those with their formal learning gains, be nurtured through their participations in (teacher-)facilitated seamless learning processes? This is one of the major research issues of our design-based research (DBR) study in exploring a seamless learning design for Mobile Assisted Language learning (MALL), "Move, Idioms!" Seamless learning, the overarching learning notion of our study, is defined by Chan et al. (2006) as an approach through which a student can learn whenever and wherever she is keen to learn in a variety of scenarios. Using the personal mobile device as a mediator, she can easily switch from one context to another (formal and informal learning, personal and social learning, physical and digital realities, etc.) in her learning journey.

In the study, we facilitated a Primary 5 (11-year-old) class in Singapore to study 48 Chinese idioms (with 8 additional conjunctions to experiment on the versatility of the learning design) over 10 months. Apart from on-campus idiom/conjunction lessons with contextualized and small-group learning activities (formal/collaborative/physical-space), the students were each assigned a smartphone for their 24x7 access. With the smartphones, they took photos in daily lives and made sentences with the idioms/conjunctions (informal/personal-or-collaborative/physical-space). They then posted those artifacts onto a wiki space for peer review (informal/collaborative/digital-space).

In this paper, we focus on the students' processes and products of the artifact creation in informal, out-of-school settings, supported by mobile technology. We consider all these learning experiences as forms of personal or social meaning making. That is, students interpreted their daily encounters and improvised the contexts either alone or with other people's participations. Subsequently, they articulated their renewed understanding of such authentic contexts by associating them with the vocabularies (idioms and conjunctions are special forms of vocabularies) that they learned in formal lessons. Our analysis and interpretation of such student activities is framed by the notion of Learner Generated Context (LGC) (Luckin, 2008). Through our investigation of the roles of physical settings and the technology in mediating children's out-of-school activities, we hope to advance the research field's understanding in the nature of seamless learning, through articulating: (1) the boundless learning opportunities that informal learning settings may potentially bring to the learners and (2) what it takes for the students to be able to identify and seize such latent opportunities to advance their learning.

Literature review

The sum total of the child's learning experience is not just what happens within the walls of the school. Many studies highlight that external factors such as experiences in the informal learning environments (Falk & Dierking, 1998; Hull & Schultz, 2001) have an impact on a young learner's overall learning success. Barron (2006) defined a learning ecology as "the set of contexts found in physical or virtual spaces that provides opportunities for learning" (p.195). Based on the same perspective, Barab and Roth (2006), and Luckin (2008), advocated the establishment of individual learners' cross-context and perpetual learning ecology that is genuinely learner centric.

A particular significant aspect of learning ecology is the notion of learning contexts. The definition of "context" according to the Merriam-Webster Dictionary is, "The interrelated conditions in something exists or occurs." Past educational research studies, including research in mobile and ubiquitous learning, tended to treat contexts an external "shell" surrounding the learners. That is, learners are traditionally consumers in (relatively static) contexts created for them (Whitworth, 2008). Lonsdale, Baber, Sharples and Arvanitis (2004) challenged this conventional view by redefining "context" as a *dynamic* process with historical dependencies. The new perspective prompted Luckin (2008) to put forward the notion of learner-generated contexts (LGC). The reconceptualized "learning context" embodies learners' relevant prior knowledge and experience, their personal or group-level learning goals, and their *emergent* interactions with each other and with the environment. Therefore, the environment (e.g., a ubiquitous-enabled botanic garden for students' field trip) is no longer equivalent to the context, but merely the learning space that facilitates learners in generating their learning contexts on-the-fly. This reconceptualization is congruent with Wong, Chen and Jan's (in press) exposition that learners ought to assume greater autonomy and agency in deciding what and how to learn, and being able to self-identify and appropriate learning resources across different learning spaces to mediate their learning, rather than always being inhibited by predefined learning goals and resources within externally (e.g., the teacher or the adaptive technology) imposed learning contexts.

Among all the potential learning resources that the younger learners can access to, parental involvement is a crucial but often neglected element in educational research studies (exceptions are, e.g., Beals & Snow, 1994; Hill & Tyson, 2009). Parental involvement in children's learning may come in different forms, such as monitoring their children's home learning with the aid of technologies, and perhaps communicating with the teachers to share their observations in the children's learning. The technology advancement opens up new opportunities for the parents to actively experience what and how their children learn, apart from lower level learning regulation purposes. In particular, Lewin and Luckin (2010) posited that in order to engender parental involvement, activities need to be designed in a manner that encourages parent-child collaboration. As such strategies may pose additional challenges to both the researchers and practitioners, it is not surprising that the aspect of parental involvement had been underexplored in the existing studies on mobile seamless learning, according to Wong & Looi's (2011) analysis of the relevant literature.

The notion of LGC provides a new outlook to teachers' learning design and learners' autonomous learning. It offers the potential to facilitate more open-ended and personalized learning that aims to transform students to become autonomous learners who can create their own learning contexts from their learning spaces. Such a notion has been well-articulated in the literature (e.g., Dourish, 2004; Luckin, 2008; Whitworth, 2008) but has not yet been applied to interpret and analyze authentic learning processes. It is timely for us to scrutinize the potential of LGC to be employed in designing or analyzing seamless learning experiences.

Study description

The design of the seamless language learning process

As a fundamental component of language learning, vocabulary learning is often delivered in conventional ways, such as providing abstract definitions and sentences taken out of the context of normal use (Jiang, 2000). Such pedagogical strategies may pose a greater problem for learning of context-dependent vocabularies, such as conjunctions and idioms. The complex nature of such vocabularies may result in highly context-dependent appropriateness of their usage. There are many possible real-life contexts where such vocabularies could suitably, or unsuitably but often mistakenly, be used. These are almost impossible to be prescribed in a simple definition (Wong & Looi, 2010).

Recognizing both the importance and the limitation of formal, in-class language learning, language learning theorists have been advocating the integrations of formal and informal (Titone, 1969), and personal and social (Noel, 2001) language learning. Such advocates mesh well with the notion of seamless learning. Informed by the theories, we developed a cyclic, customizable learning experience design of "Move, Idioms!" (see Figure 1). As such a learning experience emphasizes *production* of linguistic artifacts (i.e., language output activities), it is known as productive language learning in the literature.
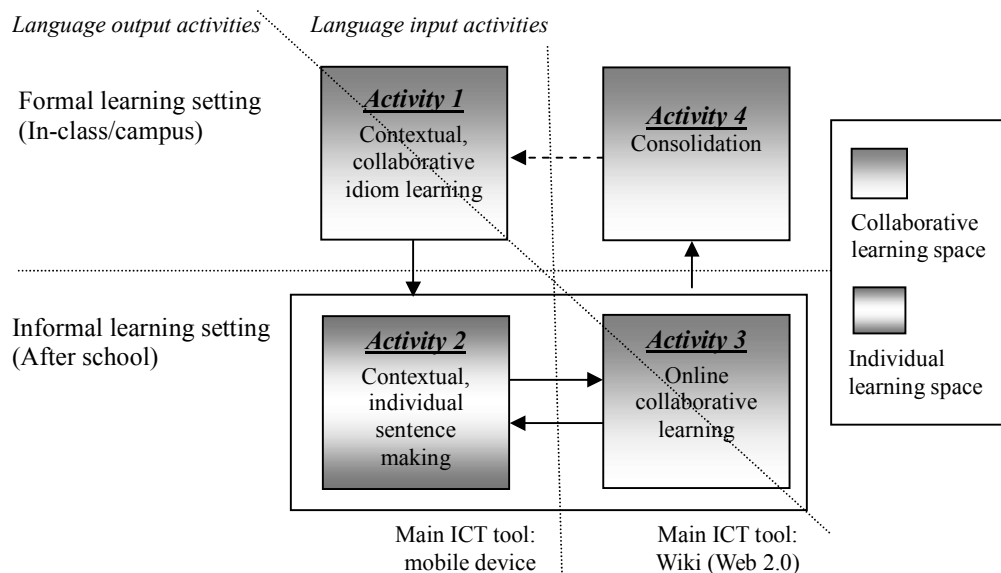
Figure 1. The "Move, Idioms!" learning experience design

The processes of the four activities are described below:

Activity 1 – In-class/on-campus contextual idiom learning: The activities are conducted to motivate and prepare students to engage in subsequent Activity 2 on their own. During each lesson, new idioms are introduced to the students via multimedia presentations. The teacher then facilitates contextualized learning activities, such as facilitating the students to work in small groups to take photos in the campus to illustrate the idioms. Strategies of artifact creation are also introduced by the teacher, such as sentences should incorporate suitable contexts. For example, albeit grammatically correct, the sentence (with the idiom being underlined) 我在手舞足蹈 (I am dancing for joy) is undesirable since it is decontextualized in use. However, e.g., "I am dancing for joy for winning the top prize at the dance competition." is contextual and therefore acceptable.

Activity 2 – Out-of-class, contextual, independent sentence making *(the focus of this paper)*: Students carry the mobile phones assigned to them 24x7 in order to identify or create contexts in their daily lives which can be associated with the idioms. They then take photos, make sentences by using the idioms to describe the photos, and post them onto a class wiki space. We create one wiki page for each idiom for students to post their artifacts. This offers convenience for comparing student-generated contexts pertaining to the same idioms.

Activity 3 – Online collaborative learning: Students perform peer reviews on the wiki by commenting on (with the comment tool of wiki), correcting or improving their peers' sentences (by modifying the sentences posted on the wiki pages).

Activity 4 – In-class consolidation: Each student group is assigned a few existing student artifacts on the same wiki page with a mixture of correct, ambiguous and erroneous usages of an idiom. The groups compare the artifacts and revise the sentences where necessary. Subsequently, teacher-facilitated classroom discussion helps clarify contradictory views and facilitate class-wide debates.

One of the core learning activities in "Move, Idioms!" is photo taking and sentence making in daily life, supported by smartphones. Although similar activities can be carried out with the aid of photos found on the Internet or picture

clippings from printed materials, we instead leverage mobile technology to motivate the students to become active meaning maker on the encounters in their daily life, and even creating contexts out of the informal spaces. This is an important learning-anywhere-and-anytime-*ish* habit of mind not just for the "Move, Idioms!" study, but for all general seamless learners. In this case, the student artifacts are directly arisen from their very own life experiences; they would therefore assume greater ownership in their self-generated artifacts. Our design decision can be further justified by the need of language learning, as traditional second language classroom practices have been criticized by the scholars (e.g., Jiang, 2000; Tedick & Walker, 2009) for the excessive amount of "secondhand" experiences (e.g., contexts in the textbook passages, or teacher-supplied printed/downloaded materials) being employed in the instructions. Learners ought to apply, and reflect upon, their target language in the authentic environment to enhance learning internalization.

Research design

In view of the complex interplay between the students' learning experiences as well as the technology and pedagogy involved, we adopted the Design-based research (DBR) methodology (Brown, 1992) to conduct our study. This method stresses upon the systematic study on the interdependence of design elements, and the importance of examining emerging issues through iterative refining processes. It allows us to collect and analyze rich and relevant data to bear on the many simultaneously interacting factors that shape the learning we envisage. This will then help to improve the design and shape the development of the pedagogy (Design-Based Research Collective, 2003; Wong, Boticki, Sun, & Looi, 2011).

To date, we have implemented two DBR cycles of "Move, Idioms!" The first cycle was a pilot study which took place during July-September 2009 that involved a Primary 5 (11-year-old) class. Through post-intervention student interviews, we obtained data on how students and parents co-created artifacts. The second cycle (this paper's focus) took place in January-November 2010. Another class of 34 Primary 5 students, with mixed abilities in Chinese Language, participated in the study. Each of them was assigned a Samsung Omnia II smartphone running MS Windows Mobile 6.5. The phone comes with built-in camera, Wi-Fi access, Internet browser and English/Chinese text input. The researchers and a group of Chinese teachers co-designed eight "Activity 1" and two "Activity 4" lessons which were then enacted by the teacher of the experimental class. The lessons were paced the way that there were 2- to 4-week intervals in between them. Meanwhile, students carried out "Activity 2" and "Activity 3" continuously at their own time. We developed and installed a simple application on their smartphones so that they can perform the following tasks on one interface: (1) taking photos; (2) assembling photos; (3) constructing sentences or paragraphs; (4) posting the artifacts onto the wiki pages of their choice; (5) pick and mix existing photos saved in the smartphone photo album to create new artifacts.

Recognizing such a seamless learning design as an opportunity to better involve parents in advancing their children's learning during "Activity 2," we decided to further investigate and enhance this aspect. We organized a "meet-the-parents" session prior to the second cycle. In the session, we briefed the parents of the participating students about the benefits and challenges of mobile seamless learning in general, and suggested to them some strategies to regulate or participate in the students' after-school use of smartphones. A mother-daughter dyad from the first cycle was invited to share with other parents their fond experiences of working together in co-creating artifacts, mostly in a spontaneous and opportunistic manner. Some parents who attended the session found the sharing inspiring and indicated their willingness to give it a try.

Informed by the DBR methodology and due to the cross-context nature of seamless learning, we employed a variety of data collection and analytical methods. Among them, we conducted pre- and post-tests to assess students' learning gains in idiom-context associations, and administered two post-questionnaires. Questionnaire 1 is for the students to self-report facts and perceptions of their learning experiences across various contexts, including those pertaining to learning in the informal settings. Furthermore, to collect data on the students' artifact creation processes in informal settings, we periodically compiled the artifacts that individual students shared online to become Questionnaire 2, and asked the students to self-report their processes in creating each artifact. Due to the space constraint, we will not describe the complete design and findings of the questionnaires, but will only focus on those related to our analysis on students' Activity 2 tasks in this paper.

Student responses were coded based on our classification of "three types of cognitive processes in artifact creation" as our findings in the first cycle (see: Wong, Chin, Tan, & Liu, 2010), namely,

- Type-1: with an idiom in mind → object finding/manipulation or scenario enactment → photo taking;
- Type-2: Object/human/scenario encountering → associating with an idiom (immediate association) → photo taking;
- Type-3: Object encountering/manipulation or scenario encountering/enactment → photo taking → associating with an idiom (delayed association).

Our further analysis of the three types of processes, as reported in our prior publication (Wong et al., 2010), suggests that each type of these processes would correspond to a vocabulary learning strategy. We consider Type-1 the easiest, perhaps an assignment-minded process which could serve as an entry-level activity for newcomers to such activities. Type-2 is the highest level process as such immediate retrieval of the relevant idioms required the students' internalization of their learned idioms. Type-3 could serve as a bridging strategy between the first two. Descriptive statistics were analyzed to help us understand the trends, which will be reported in the subsequent section.

In our analysis, we distinguished the real-life context and the artifact context. The real-life context is the authentic physical context that that facilitates student's artifact creation. The artifact context is the context that is portrayed by a student artifact and reflects the student's literal, extended or even creative meaning making of the real-life context where this artifact creation is based on—this is congruent with the notion of LGC. Therefore, the two contexts may or may not be consistent. For example, a student returns home and finds her teddy bear being tossed to the sofa by her younger sister, which is the real-life (authentic) context. She takes a photo of it and composes a sentence, "Exhausted, the bear falls asleep on the sofa." The sentence reflects an artifact context, which defers from the real-life context since a toy cannot fall asleep—the act of "falling asleep" is merely in her imagination, i.e., "creative meaning making."

Furthermore, by referring to students' responses to the questionnaire, we identified several students who went through complex artifact creation processes and generated quality artifacts. We conducted additional one-to-one interviews with them in order to find out the processes of creating individual artifacts and the sources of inspiration. We then interviewed their parents for data triangulation. Due to space constraint, we will only present cases of artifact creation processes of two students, Colin and Jane (pseudonyms), and associating the processes with the above-stated three-type classification. They essentially represent two different types of "habits" in Activity 2, which we will explicate in the following section.

Findings

Descriptive statistics of students' artifact creations

Throughout the second cycle, the students generated 853 sets of artifacts in total. We performed various descriptive statistical analyses on the students' artifact creations to investigate relevant patterns. Table 1 presents the cross-tabulation of the settings where artifacts were created versus the cognitive processes of artifact creation engendered by the entire class of participating students.

Table 1. Cross tab of settings where artifacts were created vs. cognitive process of artifact creation

Settings where artifacts were created	Type-1	Type-2	Type-3	Not sure	Total
During 8 "Activity 1" lessons (small-group co-creation)	52	8	22	3	85
Within the school, not during Activity 1	23	20	20	5	68
At individual students' home	193	44	134	5	376
Other locations	37	164	110	13	324
Total	305	236	286	26	853

Note. whole class; n = 853.

Table 1 was generated on the basis of Questionnaire 2. There were 26 artifacts where the students could not recall the processes behind when they filled up the questionnaire, and were therefore categorized under "not sure". We distinguished the physical settings where the artifacts were created into four categories—during Activity 1 (teacher-

facilitated group co-creation activities); within the school but not during Activity 1 (e.g., at recess time); at students' home; and at other locations. The last three settings are considered the contexts where students created artifacts spontaneously or by self-initiation, because the teacher did not directly facilitate individual instances of such activities. As stated in the previous section, we are in favor of Type-2 artifacts, since it is an indication of vocabulary internalization, followed by Type-3 artifacts.

Table 1 indicates that the students created the greatest amount of Type-2 artifacts at "other locations." Through our interviews with the students, we found out that the real-life contexts of "other locations" such as their neighborhoods, shopping malls or other places where they visited during family outings, etc., are less accessible to them in daily life. Students usually did not stay long at such places and might not be able to go wherever they wanted to without adults' company. Henceforth, they were more inclined to apply Type-2 or Type-3 processes in creating artifacts, mostly in an opportunistic, "hit-and-run" manner. In contrast, when they were in school or at home – two familiar locations where they have frequent access to – they tended to apply Type 1 process. This is because they could decide on target idioms upfront and took their time to identify real-life contexts or create artifact contexts (by manipulating objects or getting other people to enact scenarios) for artifact creations.

With this, we argue that carrying out artifact creation activities at "other locations" is the most natural strategy to boost the generations of Type-2 and Type-3 artifacts. Nevertheless, according to what we found out through Questionnaire 1, 11 parents out of the 34 target students forbad their children from bringing the smartphones out of home other than the school due to the fear of their child losing or damaging the devices. That had seriously limited those students' opportunities in creating more artifacts for greater learning gains. However, compared to the first cycle of our study where 21 out of 40 target students' parents imposed the same prohibition, the situation had improved, perhaps due to more parents' buying-in to the notion of seamless learning practice after the "meet-the-parents" session.

We have also run a paired-sample t-test to investigate the difference between the students' scores in our pre- and post-tests. The results ($t = 8.37$, $p < 0.01$) show that the post-test scores are significantly different (improvement) from the pre-test scores.

Case Study 1: Colin's experiences of artifact creations in informal setting

Colin came from an English speaking family comprising his parents and a 13-year-old elder sister. Prior to our study, his Chinese Language proficiency was low and he disliked the language. His parents checked with him about "Move, Idioms!" only once at the early stage of our study. They then let him carry out the learning activities on his own. Sometimes, Colin requested his parents and sister to be his photo models and enacted specific artifact contexts. His sister usually declined. Therefore, Colin was not keen on involving family members to generate artifacts, other than occasionally asking them to be the photographer.

妈妈见我闷闷不乐，买了各种各样的文具给我。我开心得手舞足蹈，兴高采烈地向前对妈妈道谢。
Seeing me depressed, mum bought me a variety of stationery. I danced for joy and thank mum with great delight. (May 20, 2010)

Figure 2. Two artifacts created by Colin (pseudonym)

Despite that, Colin extended his creativity to overcome the limitation of working alone. Apart from taking photos of objects in their natural settings, such as the furniture and decorations at home, personal encounters in the school and at the neighborhood, and what he came across during family outings, he was good at improvising artifact contexts at home with the physical resources available. Figure 2 features an artifact created by him. The original idioms are underlined in the students' Chinese sentence. To benefit international readers, we translated the sentences into

English with the translations of the idioms underlined. We will do likewise on the student artifacts featured in Figure 3 and Figure 4.

In Figure 2, the photo of Colin at the left was taken five years ago by his father with a digital camera when the family visited the USA. His cognitive process in creating this artifact is described below (interview with Colin, November 9, 2010),

1. He casually browsed through the digital photo album of the tour, encountered this photo and instantly associated it with the idiom 闷闷不乐 (depressed). [Cognitive process Type-2]
2. Having told by the teacher that he should give his artifact a proper context, he could either explain the reason of being depressed, or make a twist in the plot. He went for the latter by imagining his mother gave him something to cheer him up. He saw a variety of stationery on his table and decided to use that as a prop to take a new photo. He associated that with the idiom 各种各样 (a variety of). [Type-2]
3. He brought the two photos together and wrote the first sentence. He then extended the story to incorporate two more idioms: 手舞足蹈 (dance with joy) and 兴高采烈 (with great delight), and wrote the second sentence. [Type-3]

In a separate note, Figure 3 depicts how Colin manipulated different combinations of his (and his sisters') toys to create multiple artifact contexts over a period of seven months. Often, whenever he got hold of a new toy, the first thing that came across his mind was to create artifacts out of it or combined it with his existing toys to create artifacts. In some cases (such as the artifact at the bottom right corner of Figure 3), his artifact contexts were inspired by his earlier real-life experiences or encounters elsewhere.

Table 2 presents the overall statistics of Colin's artifacts. From the table, we observe that although Colin was allowed to bring his smartphone out of home to take photos at "other locations", he generated more artifacts at home, most of which belonging to Type-1 and Type-3 artifacts. The number of his Type-3 artifacts (110) had exceeded the sum of his Type-1 and Type-2 artifacts (61+39=100).

三五成群的车子正在等进去动物园。
The cars in groups of three or four are waiting for entering the zoo. (April 7, 2010)

这里人山人海，真热闹！
There is a sea of people here. It's so crowded! (May 20, 2010)

发生车祸了，三五成群的路人都在看。
It's a car accident. Passers-by are gathering in groups of three or four to watch it. (May 20, 2010)

这些人争先恐后地争着过马路。
These people are scrambling to cross the road. (May 20, 2010)

这两个人看起来一模一样的，可能是双胞胎。
They look alike as two peas. They are probably twins. (May 20, 2010)

一位路人看到了车祸，吓得目瞪口呆。
A passer-by witnessed the car accident and was dumbfounded. (May 20, 2010)

他目不转睛地看着这辆车。
He never took his eyes off the car. (May 20, 2010)

这些车子争先恐后，很容易发生意外。
These cars are scrambling and are therefore prone to accidents. (October 13, 2010)

这几辆车争先恐后地驾进打油站，非常危险。
These cars are <u>scrambling</u> into the gas station. This is so dangerous. (September 10, 2010)

我们通常会在巴士站看到<u>三五成群</u>的车，它们这样做会阻挡巴士进来。
We usually observe cars scrambling in <u>groups of three or four</u> at the bus stop. That may block buses from approaching it. (October 13, 2010)

Figure 3. Various artifact contexts created from the same sets of toys by Colin

Table 2. Cross tab of settings where artifacts were created vs. cognitive process types

Settings where artifacts were created	Type-1	Type-2	Type-3	Not sure	Total
During "Activity 1" lessons (small-group co-creation)	8	0	2	2	12
Within the school, not during Activity 1	2	0	3	7	12
At individual students' home	44	10	65	3	122
Other locations	7	29	40	6	82
Total	61	39	110	18	228

Note. Colin's artifacts; n = 228.

As a student who used to dislike Chinese, it was amazing that he had been so motivated to create such a huge amount of artifacts. Over time, his artifacts were getting more enriched and substantial. On August 12, 2010, for example, he set the class record of writing a 600-word paragraph describing his experience in attending the National Day Parade, with 17 photos incorporated in the artifact (Type-3 process). Whereas he could have re-used the photos to create multiple but relatively simple one-sentence, one-photo artifacts, he went for the tedious route.

Table 3 presents pre- and post-intervention measurements (as compared to the class means) as evidences of his considerable improvement in the language. We acknowledge that we are uncertain whether his improvement can be solely attributed to our "Move, Idioms!" intervention. However, we did observe his more enriched contents and the increase and more accurate use of idioms and other vocabularies in his in-class compositions.

Table 3. Pre- and post-intervention results of Colin vs. class means in Chinese Language

		Colin's result	Class mean
"Move, Idioms!" instruments (full scores = 50)	Pre-test	32.0	35.7
	Post-test	43.0	42.7
Year-end school exam (Chinese composition) (full scores = 40)	Previous year	14.0	28.1
	Current year (after intervention)	32.0	30.6
Year-end school exam (full Chinese paper) (full scores = 100)	Previous year	75.5	78.6
	Current year (after intervention)	89.5	81.4

Case Study 2: Jane's experiences of artifact creations in informal settings

Jane came from a predominantly Mandarin-speaking family comprising parents and an 8-year-old younger sister. She was competent in the use of Chinese Language within her class but slightly above average in the entire Primary 5 level in the school. However, she perceived herself to be more fluent in English and preferred to use the language (pre-interview with Jane, January 21, 2010). Jane's mother who attended the meet-the-parents session responded to our call for working with her child in artifact co-creations. Often, it was the mother who proactively gave Jane opportunistic ideas and urged her to carry on. The mother argued that such a collaborative way of learning was effective in further improving Jane's Chinese Language competency and would like to encourage other parents to do the same (interview with Jane's mother, November 15, 2010).

With her mother's support, Jane was very motivated in carrying out Activity 2 and took pride of the artifacts that she created alone or with her family. Furthermore, her younger sister was far more cooperative than Colin's elder sister in modeling for her photo taking (and loved to participate in idea brainstorming), perhaps being younger and showy. In the process, her sister had also learned many Chinese idioms.

(4a) 我有一把<u>五颜六色</u>的雨伞。 I have a <u>colorful</u> umbrella. (July 20, 2010)	(4b) 本来想和朋友在这里玩耍可是，当我看到这些预告时，我<u>闷闷不乐</u>，<u>一言不发</u>地走开。这里不能踢球，随手丢垃圾，流滑板和停脚踏车。 I wanted to play with my friends here. However, when I saw the sign, I was <u>depressed</u> and walked away <u>speechless</u>. Soccer game, littering, skating and cycling are prohibited here. (July 20, 2010)	(4c) 游客们都<u>千里迢迢</u>来观赏新加坡的摩观景轮。他们一边观赏<u>一望无际</u>的美景，一边对新加坡的美景<u>赞不绝口</u>。 Tourists come from <u>far off distances</u> to visit Singapore Flyer. They were watching the <u>vast stretch </u>of beautiful scenery *while* (and) <u>raving about</u> it. (Aug 9, 2010)

Figure 4. Three artifacts created by Jane (pseudonym)

Figure 4 illustrates three examples of Jane's artifacts. Figure 3a and 3b were inspired by the same real-life context – Jane carrying an umbrella. However, she created two different artifact contexts (i.e., LGC) out of it. Her process in creating these artifacts is shown below (post-interview with Jane, November 9, 2010),

1. Her mother fetched her after school. On their way home, she thought she could make a sentence pertaining to her colorful (idiom: 五颜六色) umbrella. She passed her mother her smartphone to take a photo of her back, carrying the umbrella. [Type-2]
2. She checked the photo on her smartphone, and associated it with two other potential idioms: 闷闷不乐 (depressed) and 一言不发 (speechless). [Type-3]
3. She decided to make another sentence by improvising a different context to explain why she looked depressed and speechless in the photo. She noticed the sign (see the first two photos from the left in Figure 4(b)) on the wall at the void deck of a residential apartment nearby. She came out with the idea of not being able to play with her friends due to the prohibitions.
4. The mother-daughter duo carried on their way home. Her mother advised her to take another photo to further depict that "she left the place speechless." She took a photo of the empty corridor right outside their apartment (a different apartment block from they took the photos of the sign) for that purpose.
5. Upon returning home, she made the sentence in Figure 4(a) with the umbrella photo. She then ordered the four photos taken for the second context and made the three sentences in Figure 4(b).

Whilst Jane was essentially autonomous in creating artifacts in Figures 4(a) and 4(b) with her mother's just-in-time, peripheral support, Figure 4(c) is a typical example of the mother-daughter co-creation activities that occurred during the generation processes of many other artifacts. The cognitive process is described below,

1. Jane took a snapshot of the Singapore Flyer, a touristic attraction, with her smartphone on a highway when her family was on their way to visit the Open Day of *Istana*, the office of the President of Singapore. She took many other photos in Istana.
2. Upon returning home, her mother urged her to check the photos in the smartphone. She wrote a few paragraphs and sentences with the photos taken in Istana. When they encountered this snapshot, her mother proposed a sentence opener, "Tourists come from far off distances （千里迢迢）...." [Type-3]
3. Jane wrote, "Tourists come from far off distances to visit Singapore Flyer." Her mother then reminded her that she had just learned the conjunction "一边 xx 一边 yy" ("(doing) xx while (doing) yy") in the previous "Activity 1" session and that could be utilized to extend her write-up. [Type-3]
4. She thought of incorporating two idioms to "xx" and "yy" respectively in the sentence structure of "xx while yy". She wrote, "They were watching the vast stretch (一望无际) of beautiful scenery while (and) raving about (赞不绝口) it." [Type-3]

Jane usually worked alone or worked with her mother in co-creating artifacts. However, there were also times where she had also worked with her sister, with or without her mother's presence. Jane's mother informed us that she had often brought Jane to explore various local places of interest (more frequently than in the past), mainly for carrying out Activity 2. Even though the smartphone used in such an activity can be replaced by a digital camera and paper and pen, Jane's mother preferred Jane to use the phone, as she quipped, "Jane would be lazy to use paper and pen to write." (interview with Jane's mother, November 15, 2010)

Table 4 shows the overall statistics of Jane's artifacts. Jane was certainly more outgoing than Colin as the number of artifacts that she created at "other locations" (157) doubled the sum of those she created in the school and at home (4+8+62=74). The amount of her Type-3 artifacts (130) had also exceeded the sum of her Type-1 and Type-2 artifacts (63+38=101). We tracked her monthly posting statistics and discovered that her artifact creation activities in informal settings had shifted from predominantly Type 1 to predominantly Type-3, plus a healthy amount of Type-2 artifacts created at "other locations". This is because she had gradually been venturing into creating more complex artifacts, i.e., taking a set of photos with a coherent artifact context, and then sitting down, taking her time to compose and extend a paragraph that utilized multiple idioms, often with her mother's participations (e.g., Figure 4(c)).

Table 4. Cross tab of settings where artifacts were created vs. cognitive process of artifact creation

Settings where artifacts were created	Type-1	Type-2	Type-3	Not sure	Total
During "Activity 1" lessons (small-group co-creation)	3	0	1	0	4
Within the school, not during Activity 1	2	3	3	0	8
At individual students' home	47	5	10	0	62
Other locations	11	30	116	0	157
Total	63	38	130	0	231

Note. Jane's artifacts; n = 231.

Table 5 reveals the pre- and post-intervention results of Jane as indicators of her improvement in Chinese Language.

Table 5. Pre- and post-intervention results of Jane vs. class means in Chinese Language

		Jane's result	Class mean
"Move, Idioms!" instruments (full scores = 50)	Pre-test	35.0	35.7
	Post-test	49.0	42.7
Year-end school exam (Chinese composition) (full scores = 40)	Previous year	30.0	28.1
	Current year (after intervention)	36.0	30.6
Year-end school exam (full Chinese paper) (full scores = 100)	Previous year	81.5	78.6
	Current year (after intervention)	86.3	81.4

Discussion

In this section, we will rise above our learning design and research findings to foreground the following aspects,
- To advance the mobile learning field's understanding in the roles that the mobile technology and the mobile learning model would play in seamless learning
- The study's implications on authentic, productive language learning
- To investigate how the notion of LGC is crystallized in the seamless learning processes, especially in the informal learning settings, with or without parental involvement

The roles of mobile technology in seamless learning

Looi, Wong and Song (in press) foregrounded two main characteristics of mobile learning, namely, (a) mobility: Learning no longer happens in a fixed physical place, but occurs in environments that move with the learners; (b) personalization: Learning is more personalized in a continually reconstructed contexts. The new focus is laid on

LGC that could occur in any physical or virtual space, with individual learners having greater control over what and how they learn (Sharples, Taylor, & Vavoula, 2007). In the context of our study, what we have strived to achieve is to facilitate the students in enacting holistic, seamless learning experiences that are rooted in such notions, with the exploitation of both the mobile affordances of mobility and personalization.

What roles did the technology play in "Move, Idioms!"? At first glance, the smartphones seemed to be used in a minimalist way – for photo taking, sentence making and artifact uploading. However, it was our learning design that helped the students in maximizing their learning by exploiting the affordances of mobile learning—mobility and personalization. The instant playback feature of the built-in camera enabled one to check a photo immediately after shooting, and decided whether a retake was needed to make sure her idea was correctly executed and the idiom association was appropriate. In some rare cases, checking the playback might even instantly trigger new ideas (e.g., Figure 3a and Figure 3b).

Through our analysis of student artifacts and the post-interviews, we have also noticed that many students often browsed through and tidied up their photo albums on their smartphones that contained photos taken across locations and time. That prompted some of them to create new artifacts arisen from those "older" photos, or even picking and mixing several photos to create more artifacts—Figure 2a is a similar case, except that the first photo was taken with another camera. In these cases, the students had transformed their smartphones from a productive tool to a cognitive tool. We consider this a potentially new characteristic of seamless learning, on top of the ten major characteristics/dimensions of seamless learning that Wong and Looi (2011) have expounded—the choices and the seamless synthesis of suitable learning resources that a learner picked up (and perhaps all stored in her personal mobile device as a "learning hub" (Wong, 2012)) along her on-going learning journey to mediate the latest learning task.

The implications on authentic, productive language learning

Building on our findings in the previous DBR cycle of study, we further investigated and reflected upon the characteristics of the three types of cognitive processes in artifact creations, which we summarize in Table 6.

Table 6. Comparison between three types of cognitive processes in artifact creations

Type-1	Type-2	Type-3
Assignment-like artifact creation process with relatively prescribed artifact contexts to identify	Immediate, opportunistic, spontaneous idiom-to-context association	Spontaneous photo taking; delayed idiom-to-context association
Good for form-meaning connection in vocabulary learning	Good for context-meaning connection (i.e., use of vocabulary) in vocabulary learning	Good for context-meaning connection in vocabulary learning and extension of the artifact context
Mostly taking place in the school or at home	Mostly taking place at "other locations"	Mostly taking place at home or at "other locations"

We consider the classification and statistical analysis of the students' artifacts in the three types as a potentially effective technique in evaluating the students' learning outcomes in the "Move, Idioms!" intervention. Based on our analysis, the application of the Type-2 creation process (and to a lesser extent, the Type-3 process), requires students to genuinely internalize the vocabulary that they have learned—so that they can immediately react to their daily encounters and retrieve the right vocabulary to describe the situations. Therefore, the amount of (correct) Type-2 artifacts created by the students may serve as an indicator of students' deep learning.

While we favor Type-2 artifacts, we do not discriminate two other types of artifacts. The creation of Type-1 artifacts may serve as a strategy for the students' deep learning of individual idioms in order to achieve internalization. Our concern is on how to elevate those students who stick to creating Type-1 artifacts most of the time (e.g., 15 out of 34 students in our study created more Type-1 artifacts than the sum of Type-2 and Type-3 artifacts) to create more Type-2 and Type-3 artifacts for a more balanced vocabulary development.

As stated before, we observed that being more "outgoing" (visiting "other locations") is a natural strategy to boost the creation of Type-2 and Type-3 artifacts. However, as our target students are at their tender ages, we need to respect some parents' stance of forbidding their children from bringing the smartphones out of home. An alternative strategy is to enact more classroom activities (i.e., Activity 1) that aim for building Type-2 skills among the students. Examples are flashing context-rich photos generated by their peers and invite them to brainstorm for as many relevant idioms as possible, and small-group artifact co-creation activities that are restricted to generating Type-2 artifacts. Students will then be encouraged to bring over the skills to their personal artifact creation activities at home.

Informal learning settings and learner generated contexts

Contexts, especially the Learner Generated Contexts, are the core of our analysis on the students' learning processes and artifacts in this paper. The role of authentic contexts in most of the existing MALL studies has been restricted to scoping learners' language learning processes through technology-mediated (in particular, context-aware technology) pushing of *in-situ*, "context-appropriate" content and scaffolds (Kukulska-Hulme & Wible, 2008), i.e., to position learners merely as the behaviorist consumer of externally facilitated contexts. Examples of such studies are reported in Chen and Li (2010), Ogata, Akamatsu and Yano (2004), and Sandberg, Maris and de Geus (2011). Instead, our study emphasizes LGC as a means to stimulate language-mediated constructivist, active meaning making and reflections on their real-life experiences. With proper enactment of such learning designs, we argue that our novel positioning in language learning will result in a greater level of language internalization.

Furthermore, we have also foregrounded the value of family members, especially parental involvements in their children's mobilized learning and learner context generation in informal settings. In our study, the parents' roles had gone beyond monitoring learning progresses or pushing for drill-and-practice, but motivating and supporting their children's learning which had been blended into their family life. The discourses between Jane and her mother exemplify how family-based socio-constructivist learning may effectively inspire children to push their boundary in carrying out their learning tasks.

Conversely, even without substantial involvement of his family members as what Jane had been enjoying, Colin turned his home into his personal learning and creative playground where he could appropriate suitable physical or digital resources to mediate his artifact creation. With the notion of LGC in mind, we found that what informal learning settings could offer to such a less structured learning activity (i.e., requiring greater spontaneity [mobility] and wit [personalization]) is virtually limitless.

In this regard, we re-conceptualize the nature of "seamless learning environment" from an individual learner's perspective by adapting Barron's (2006) definition of learning ecology (see the Literature Review section) as "the combination of physical or virtual (living) spaces that a person is situated or encounters in his/her daily life that provides opportunities for learning." We remove the wording "contexts found in …" from the original definition in recognizing the potential for LGC from the resources found in each living space; and to carry out a learning activity can be viewed as the act of generating a learning context. The opportunities for learning are always there. It is up to an individual who has established the habit of mind and competencies of seamless learning to identify and appropriate such opportunities to advance her learning.

Conclusion

We have unpacked the students' artifact creation processes in the seamless language learning experience of "Move, Idioms!", particularly those taking place in informal settings. Through the qualitative and statistical investigation of students' cognitive processes in artifact creations, we identified some patterns of such processes and gained better understanding in how physical settings, parents and the technology had played their parts in mediating such learning tasks. Indeed, there were isolated expositions or studies on these three aspects of learning. However, none of the studies had synthetically investigated the interplay of these three elements within the context of seamless learning in 1:1, 24x7 settings, i.e., how the notion of seamless learning and our *explicit* seamless learning design had brought these elements together to construct a learning environment that is conducive for greater learner autonomy in facilitating LGC.

The significance of the reported study is two folded. First of all, it prompted us to re-conceptualize the nature of seamless learning from an individual student's perspective, i.e., students' self-generation of learning contexts within and across their living spaces. Students should ultimately become life-long autonomous learners who are able to decide when, where and how to learn with self-identified resources within their learning spaces. This salient learning design principle of "Move, Idioms!" marks a major departure from most of the prior mobile learning studies which tended to confine the learners to predefined learning goals and resources within externally imposed, relatively static learning contexts. We argue that our design that stresses diversity (in terms of self-generated contexts and artifacts) and personalization of learning—are the keys to achieve this. That leads to the second significant issue of the study—it sheds light on how we shall refine our learning experience design for the next DBR cycle to foster a more holistic, seamless learning habit and experience among the students. Examples are placing greater emphasis in Type-2 and Type-3 artifact creations during Activity 1 lessons, and introducing measures to motivate more parents' deeper involvements in their children's Activity 2 (and even Activity 3) tasks—so that they will become the children's co-creators of their learning contexts. In short, we hope to contribute to the literature of mobile seamless learning by putting forward the importance of explicit design for seamless learning processes that leverage virtually limitless learning opportunities that informal settings and family member involvements may offer to learners, with the support of mobile technologies; and what it takes for the learners to be able to identify and seize such potential opportunities to enhance their learning.

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Correcting Misconceptions on Electronics: Effects of a simulation-based learning environment backed by a conceptual change model

Yu-Lung Chen[1], Pei-Rong Pan[1], Yao-Ting Sung[2] and Kuo-En Chang[1*]

[1]Graduate Institute of Information and Computer Education, National Taiwan Normal University // [2]Department of Educational Psychology and Counseling, National Taiwan Normal University, No. 162, Sec. 1, Ho-Ping East Rd., Taipei, Taiwan, R.O.C. // ylchen@ice.ntnu.edu.tw // 695080192@ntnu.edu.tw // sungtc@ntnu.edu.tw // kchang@ntnu.edu.tw

[*]Corresponding author

ABSTRACT
Computer simulation has significant potential as a supplementary tool for effective conceptual-change learning based on the integration of technology and appropriate instructional strategies. This study elucidates misconceptions in learning on diodes and constructs a conceptual-change learning system that incorporates prediction-observation-explanation (POE) and simulation-based learning strategies to explore the effects on correcting misconceptions and improving learning performance. Thirty-four sophomore students majoring in engineering participated in the experiments. The empirical results indicate that the system significantly corrects participants' misconceptions on diodes and improves learning performance. This study shows that conceptual-change instructions could correct misconceptions effectively by constructing scenarios that conflict with existing knowledge structures. The results also show that misconceptions on diode models and semiconductor characteristics could be corrected in more than 80% of cases. Conversely, difficulty in correcting misconceptions correlates with the fundamental definition of voltage, circuit analysis, or the interaction between different diode concepts.

Introduction

Learning electricity-related concepts is often confusing for various levels of learners (Belcher & Olbert, 2003; Reiner, Slotta, Chi, & Resnick, 2000). The difficulty in learning electricity, electronics, and electromagnetism concepts is attributed to their abstract nature, complexity, and microscopic features (Pfundt & Duit, 1991). Some studies show that most difficulties experienced by learners of electricity-related concepts originate from certain abstract concepts that cannot be comprehended or associated with actual circuits (Ronen & Eliahu, 2000). The inability to see currents flowing through circuits in daily life and to comprehend abstract concepts leads to various misconceptions (Sengupta & Wilensky, 2009) related specifically to the understanding of current, voltage, and power consumption (Lee & Law, 2001; Engelhardt & Beichner, 2004; Sencar & Eryilmaz, 2004; Periago & Bohigas, 2005). Moreover, it is difficult to avoid these misconceptions through general instruction (Ronen & Eliahu, 2000; Tytler, 2002; Kikas, 2003; Mutimucuio, 1998).

Conventional instructions do not focus on detecting and correcting learner misconceptions on electricity (Jaakkola, Nurmi, & Lehtinen, 2005; Jaakkola & Nurmi, 2004; Liégeois & Mullet, 2002). The process of correcting learner misconceptions depends on not only the delivery of new knowledge but also the gradual integration of new concepts related to learners' existing conceptual structures (Vosniadou, 2002). New instructional strategies must be developed to assist learners in actively constructing and adapting their knowledge (de Jong & Van Joolingen, 1998). Posner, Strike, Hewson, and Gertzog (1982) stated that conceptual change develops through cognitive conflict and comprises four conditions: (1) dissatisfaction with existing concepts, (2) intelligibility of new concepts, (3) plausibility of new concepts, and (4) the ability of new concepts to solve existing problems and provide methods for future investigations. The conceptual-change learning environment may incorporate these four conditions by, at first, creating scenarios of conceptual conflict that guide learners to discover their dissatisfaction with existing concepts. Moreover, learning environment needs to manifest plausible and fruitful concept features and implement an effective instructional strategy for learners to comprehend new concepts. This study identifies three key elements for constructing a conceptual-change learning environment according to the four conceptual-change conditions: (1) an appropriate learning environment to manifest plausible and fruitful concept features, (2) an effective instructional

strategy that assists learners to comprehend conceptual implications, and (3) construction of conceptual conflict scenarios for the adaptation and reconstruction of existing knowledge structures.

Simulation-based learning environments are appropriate for manifesting plausible and fruitful concept features. Previous studies have shown that a computer simulation conceptual learning environment that supports activities of observation and reflection helps facilitate the learning of abstract concepts (Chen, Hong, Sung, & Chang, 2011; Mzoughi, Foley, Herring, Morris, & Wyser, 2005; Dori, Barak, & Adir, 2003; Papaevripidou, Hadjiagapiou, & Constantinou, 2005). Computer simulations provide learners with real-time data related to a dynamic phenomenon and information on how certain parameters change synchronously to facilitate higher-level thinking (de Jong & van Joolingen, 1998; Ronen & Eliahu, 2000). Ronen and Eliahu (2000) suggested that simulation could assist in explaining an actual phenomenon by linking it with the implications of a conceptual model. This has led to the frequent use of computer simulations in virtual experimental environments for electricity-related curricula and experimental computer simulation learning (Bradbeer, 1999; Zacharia, 2007; Jimenez-Leube, Almendra, Gonzalez, & Sanz-Maudes, 2001; Donzellini & Ponta, 2004), as well as assisting elementary and high school students to understand electricity-related concepts (Jaakkola & Nurmi, 2008; Kukkonen, Martikainen, & Keinonen, 2009). Additionally, computer simulations can help learners understand complex abstract scientific concepts and modify learners' understanding of electric circuit concepts (Forinash & Wisman, 2005). Colella (2000) argues that computer simulation environments allow learners to observe and investigate specific models of new concepts, and to modify existing incorrect concepts.

Computer-simulated visualizations can allow learners to observe and comprehend abstract and complex concepts (Chang, Chen, Lin, & Sung, 2008; de Jong & Van Joolingen, 1998; Colaso, Kamal, Saraiya, North, McCrickard, & Shaffer, 2002). Ainsworth (2006) also argues that visualization can improve learning performance and assist learners to attain a higher cognitive level. Gordin and Pea (1995) described the prospects for visualization in education to facilitate the learning of difficult, abstract, and complicated concepts based on the usage of discrimination modes and observation processes of the human visual system. Kelly and Jones (2007) also revealed that visualization has excellent potential for learning abstract and obscure scientific concepts because of its ability to activate learner imagination for microscopic scientific phenomena and the development of corresponding concepts. Accordingly, visualization could be an effective instructional strategy for assisting learners to comprehend conceptual electronic implications. However, visualization will probably have educational value only if learners are highly motivated to perform conceptual investigations during a learning activity (Naps et al., 2003). Therefore, effective conceptual-change visualized learning environments must integrate the application of technology and an appropriate instructional strategy to motivate conceptual investigation.

Previous pedagogic studies on conceptual change investigated several instructional strategies that emphasize conflict situations between new concepts and existing knowledge structures, such as anomaly, Socratic dialogue, and prediction-observation-explanation (POE) strategies. The anomaly strategy uses unexpected events for students to produce conceptual conflict (Chinn & Brewer, 1993), whereas Socratic dialogue employs conversation that encourages learners to recall existing concepts and then guides the learner to recognize inconsistencies in their deduction process (Chang, Lin, & Chen, 1998; Chang, Wang, Dai, & Sung, 1999; Chang, Sung, Wang, & Dai, 2003; Vosniadou & Brewer, 1987). Both methods emphasize the learner-perceived conceptual conflict under an instructor's intentional direction, although passive learning activities do not necessarily empower active learner investigations (Eryilmaz, 2002; Liégeois, Chasseigne, Papin, & Mullet, 2003). Conversely, the POE strategy facilitates the reorganization of knowledge structures by exposing learners to cognitive conflict through inconsistencies between existing knowledge structures and the new concepts (White & Gunstone, 1992). The experience is a sequence of prediction, observation, and explanation activities that scaffold self-explanation in conceptual learning. The scaffolding mechanisms that prompt for self-explanation might present the greatest benefits in producing deep learning by removing misconceptions (Chi, 1996; Chi, Bassok, Lewis, Reimann, & Glaser, 1989). The POE strategy constructs a scenario of conceptual conflict for adaptation and reorganization of knowledge structures by engaging a learner to observe, comprehend, and then self-explain a new concept within an interactive learning environment.

This study incorporates the POE strategy into a computer simulation learning environment to develop a conceptual-change learning system based on the difficulties of learning electricity-related concepts and the key elements of conceptual-change learning. A computer simulation environment based on the POE strategy for developing scenarios of conceptual conflict allows learners to observe and investigate electricity-related concepts, and helps

them develop new concepts to facilitate conceptual change. System development and the efficacies of correcting misconceptions and learning performance on diodes are also investigated.

Misconceptions in learning about diodes

The concepts of the diode investigated in this study comprised some conceptual contents such as "semiconductor concept of a diode", "feature of diode bias", "simplified model of a diode", and "basic circuit of a diode." The high probability of misconceptions about diodes being experienced by students who learn basic semiconductor and circuit concepts makes it important to understand these misconceptions.

In this study we have investigated the misconceptions about diodes and related concepts by reviewing the literature (Lee & Law, 2001; Engelhardt & Beichner, 2004; Sencar & Eryilmaz, 2004; Periago & Bohigas, 2005; Küçüközer & Kocakülah, 2007) and conducting a diagnostic test. The 40 questions in the diagnostic test provided by researchers and two subject-matter experts were used to collect information on misconceptions about diodes. First of all, 64 sophomores (who had previously studied diodes) were asked to answer these questions. Their answers were then analyzed to summarize all possible misconceptions held by these students. Table 1 summarizes these results, indicating that there were 7 misconceptions about "semiconductor concept of a diode," 4 misconceptions about "feature of diode bias," 7 misconceptions about "simplified model of a diode," and 10 misconceptions about "basic circuit of a diode."

Table 1. Probable misconceptions of a student who learns about diodes

Conceptual Content	Misconception Designation	Misconception
Semiconductor Concept of a Diode	M1	Confusion about the diode symbol.
	M2	Holes are the majority carriers of an N-type semiconductor.
	M3	The depletion region narrows when reverse bias is applied to a diode.
	M4	A diode's depletion region is caused by minority carriers in the P- and N-type semiconductors.
	M5	Confusion about the drift and diffusion of carriers.
	M6	No current flows through a non-conducting diode when forward or reverse bias is applied.
	M7	Reverse saturation current is affected only by temperature.
Feature of Diode Bias	M8	A diode conducts with no resistance when forward bias is applied.
	M9	Confusion about the status of a diode when forward or reverse bias is applied.
	M10	Confusion about the status of a zener diode when forward or reverse bias is applied.
	M11	A zener diode will irreversible breakdown whenever a reverse bias is applied.
Simplified Model of a Diode	M12	Disregarding internal resistance in the linear model.
	M13	No current in the parallel resistance when a diode is conducting.
	M14	Disregarding barrier voltage in the linear model.
	M15	Disregarding barrier voltage in the constant-voltage-drop model.
	M16	The barrier voltage and internal resistance are included in the constant-voltage-drop model of a diode.
	M17	The internal resistance is included in the ideal diode model.
	M18	The barrier voltage is included in the ideal diode model.
Basic Circuit of a Diode	M19	Incorrect definition of the average output voltage of a rectifier.
	M20	Incorrect definition of the RMS (root mean square) output voltage of a rectifier.
	M21	Only the positive half-cycle input passes through a bridge rectifier.
	M22	The output waveform of a full-wave rectifier is identical to the input waveform.
	M23	Only the positive half-cycle input passes through a full-wave rectifier.
	M24	Both the positive and negative half-cycle inputs pass through a half-wave rectifier (both as positive output waveforms).

M25	The output current passing through an element in a circuit is less than the input current.
M26	Confusion about concepts of basic series-parallel circuits.
M27	The current passing through a zener diode is equal to the current passing through a load resistance.
M28	No current passes through a load resistance when the breakdown voltage is applied to a zener diode.

Twenty-one of the 28 misconceptions about the concepts of a diode listed in Table 1 are related to semiconductor characteristics, bias types, elementary models, and applicable circuits. Four of the remaining seven misconceptions are attributable to incorrect analyses of basic electric current, voltage, and circuit behavior (i.e., "The output current passing through an element in a circuit is less than the input current", "Incorrect definition of the average output voltage of a rectifier", "Incorrect definition of the RMS (root mean square) output voltage of a rectifier", and "Confusion about concepts of basic series-parallel circuits"), while the last three are ascribed to the interaction between fundamental concepts of current (or voltage) and diode (i.e., "No current in parallel resistances when a diode is conducting", "The current passing through a zener diode is equal to the current passing through a load resistance", and "No current passes a through a load resistance when the breakdown voltage is applied to a zener diode"). It can be seen that past misconceptions directly affect not only the learning of relevant concepts but also result in further misconceptions as well as learning issues due to interactions.

Conceptual-change learning activity

The conceptual-change activities in this system are designed to create conceptual conflict scenarios and support conceptual change through the three POE strategy stages. The activities in these three stages are described in subsections below.

Prediction

All misconceptions are listed by the system in which a learner is able to click on the corresponding buttons to enter a page for the prediction phase of the conceptual-change scenario. The system provides a learner with one question that focuses on the given misconception, and that is the first stage to guide learners to discover their dissatisfaction with existing concepts. During a prediction activity, the question and the corresponding possible answers are provided by the system. For example, the question for M4 was "How is a diode's depletion region produced?", and the two possible answers are "Majority carriers in the P- and N-type semiconductors produce a diode's depletion region" and "Minority carriers in the P- and N-type semiconductors produce a diode's depletion region." In the prediction phase of the POE conceptual-change strategy, a learner needs to answer the question and is encouraged to deliberate any critical point affecting misconceptions about the observation activities.

Observation

The objective in the observation phase is to allow a learner to visualize abstract concepts by means of visualization of a computer simulation. As shown in Fig. 1, how minority carriers or majority carriers are generated in P- and N-type semiconductors is illustrated in the system's demonstration along with narration. In general, the generation of majority carriers rather than minority carriers is emphasized by most instruction despite both carriers simultaneously existing in P- and N-type semiconductors. To ensure that the minority electron-hole pair is substantially understood by a learner, how both majority and minority carriers are generated is displayed visually by our system. A learner can click on "Next" on the screen to go to a follow-up learning activity after comprehending how minority and majority carriers are generated by repeated observation and deliberation.
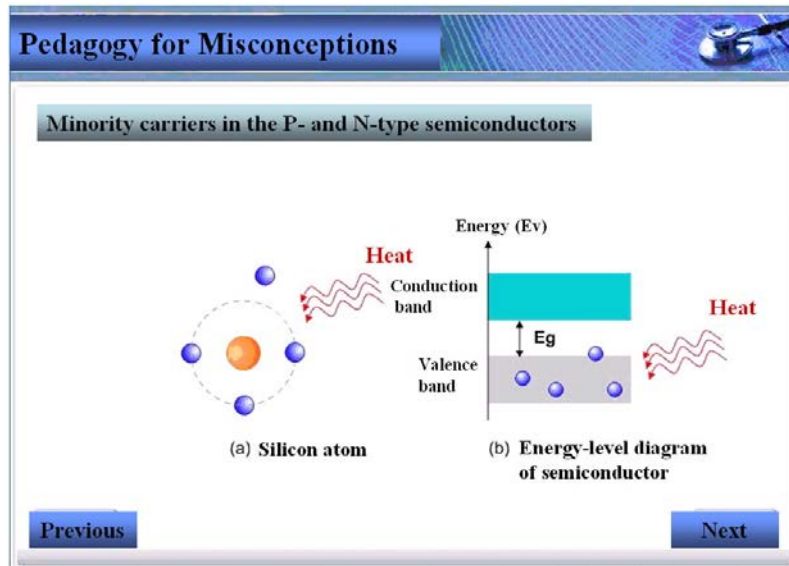
Figure 1. Visualization of how minority carriers are generated

While a learner is becoming familiar with the concept of minority and majority carriers, the process of how the depletion region is produced is illustrated in the system's demonstration. A P-N junction instantaneously produces a depletion region as follows:

1. Electrons (majority carriers) around the P-N junction diffuse to the P-type semiconductor and combine with holes around the junction (Fig. 2).
2. Atoms with five and three valence electrons around the junction form positive ions (due to one electron being lost) and negative ions (due to one electron being captured or one hole being lost), respectively.
3. An ionic layer or a so-called depletion region containing a large number of positive and negative ions develops around the P-N junction.
4. The electric field around the junction developed by positive and negative ions inside the depletion region acts against the diffusion of carriers (electrons and holes) so that an equilibrium is reached.

A learner who has a result consistent with his/her previous concept during the observation phase will draw a verified conclusion, while a learner who has a result that conflicts with his/her previous concept should click on "Back" or "Next" in order to comprehend the conflict concept through repeated observation and deliberation.
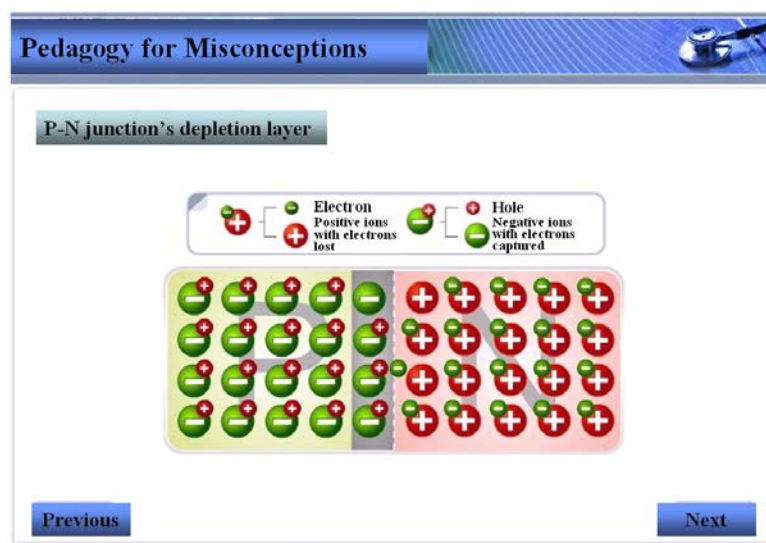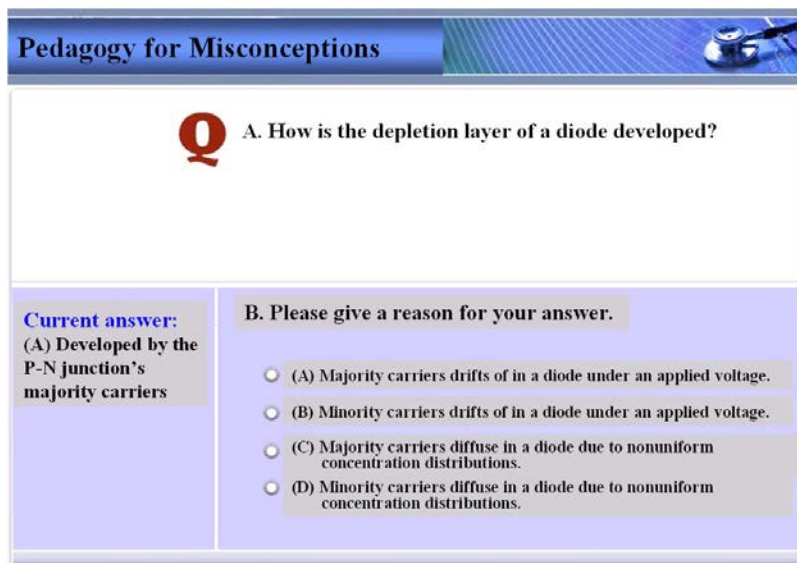
Figure 2. Schematic of how electrons and holes combine around a P-N junction

Explanation

After the observation activities, the explanation phase provides the opportunity for the learner to review and deliberate the rationality of the previous inference for the question "How is the depletion region of a diode developed?" The question and the learner's previous answer are displayed on the screen again. If the learner's misconception has been corrected in the observation phase, the correct answer would be generated. In addition, the learner needs to select the corresponding reason for the answer he/she has chosen in order to verify that the concept has been learned rather than guessed (Fig. 3). If the learner can draw correct conclusions based on the results of observation, he/she is allowed to conduct other misconception-correcting activities as needed; otherwise the learner will return to the observation phase and again review how the depletion region is produced. This procedure corrects his/her incorrect concepts in a step-by-step manner in order to resolve conceptual conflicts.

Figure 3. Reasons for an answer given in the explanation phase

Experiments

This study seeks to verify the system efficacy in correcting misconceptions and improving the learning performance. The learners in the experimental group used the proposed system to perform POE conceptual-change activities, whereas those in the control group performed general Web-based learning activities by reading didactic text and graphical materials. The primary purpose of the adopted quantitative experimental design is to compare the posttest differences between the two groups. Descriptive statistical analysis also measures the effectiveness and efficiency of learning processes beyond the test score to further elucidate any distinction between groups.

Subjects

Thirty-four sophomore students from two classes majoring in engineering (mean age of 19 years) were randomly distributed into the experimental group (17 students) and the control group (17 students). All participants had been learning electronics during their freshman year and possessed conceptual knowledge on diodes.

Experimental design

This study adopts a randomized pretest/posttest experimental design. The independent variable is the group (experimental and control group), whereas the dependent variables are the posttest scores and quantity of misconceptions on diodes. Except the POE visualization and simulation system that was used only in the

experimental group all the other learning materials and the instructor were the same for both groups to avoid experimental errors caused by the use of different instructional methods and learning materials. Analysis of covariance (ANCOVA) was performed using participant's pretest scores as a covariance in case random assignment did not equalize the pre-experimental knowledge between the two groups (Begg, 1990; Mohr, 1995; Sung, Chang, Hou, & Chen, 2010). The pretest scores were used to eliminate the influence of prior knowledge of diodes on the learning results (Fraenkel & Wallen, 2003; Shadish, Cook, & Campbell, 2002).

The treatment of experimental and control groups is summarized in Table 2. Thirty-four students were randomly assigned into the experimental group or the control group during the experiment. In both the experimental and control groups, participants received their own misconception list after the pretest. As expected from the treatment model, participants in the experimental group clicked on the corresponding button of one of the misconceptions in the list to enter a POE learning object; meanwhile, participants in the control group entered didactic learning material by clicking on the corresponding button of one of the misconceptions in the list. After entering a POE learning object, participants in the experimental group answered the question focusing on the given misconception, and visualized abstract concepts by a computer simulation. Following the observation activities, participants reviewed and deliberated on the rationality of the previous inference of the question and selected the corresponding reason for the chosen answer. Meanwhile, participants in the control group read the didactic learning material focusing on the given misconception. Students used the mouse to click or drag the scroll bar to read graphics and the corresponding description on the related concept of the given misconception.

Table 2. Treatment of experimental and control groups

Procedure	Period (minute)	Experimental group	Control group
Pretest	50	Conducting a pretest and receiving his/her own misconception list.	Conducting a pretest and receiving his/her own misconception list.
Instruction about using the learning tools	20	Receiving instruction about using the conceptual change learning system.	Receiving instruction about using the web-based didactic learning environment.
Learning activity	60	Conducting prediction (answer the question on the given misconception), observation (visualize abstract concepts by means of a computer simulation), and explanation (review the rationality of the previous inference and select the corresponding reason for the answer) activities for given misconceptions.	Conducting learning activities with the didactic learning material focusing on the given misconceptions. Participants can use the mouse to click or drag scroll bar to read graphics and the corresponding description about related concept of given misconceptions.
Posttest	50	Conducting a posttest.	Conducting a posttest.

The objective of such an experimental design is to compare the active learning and passive learning environment in correcting misconceptions on electronic concepts. The conceptual change strategy was used in the learning environment as a type of scaffold to help learners grasp electronic concepts. This study proposed the conceptual change scenario to move passive learning to active learning and to find better approaches of engaging students in the learning process for correcting misconceptions. To maintain equal conditions in the two groups, the learning time of participants in the experimental and control groups was equal. We also maintained different presentation forms for the content of each didactic learning material and each POE learning object of given misconceptions, but retained the same content on all related concepts.

Tools

The experimental tools used in the study (the misconception diagnosis test and the conceptual-change learning system) are described below.

Misconception diagnosis test

The diagnosis test which was used in both the pre- and posttests, is based on the procedure of the two-tier diagnosis test provided by Treagust (1988). The test comprises 28 questions in the diagnosis, with each question having two tiers: Tier 1 involves evaluating a learner's learning achievement for any concept, and Tier 2 understands the reason for a learner's answer in Tier 1. To establish expert validity, the questions were submitted to two senior electronics teachers for review and correction. The subjects in the pilot test were 30 juniors who had taken electronics at some stage and were engineering majors, for whom we obtained reliability (KR20) of .732, indicating good internal consistency of this test.

Conceptual-change learning system

The POE system development consists of three primary steps: (1) collecting information on misconceptions on diodes by the two-tier diagnostic test (misconceptions on diodes are described in Section 2); (2) designing the questions, corresponding reasons for answers, and a script of each simulation object according to each misconception with corresponding prediction, observation, and explanation learning scenarios (conceptual change learning activities are described in Section 3); and (3) developing simulation objects with corresponding scenarios and misconceptions using ASP.net and Flash development tools.

There are 28 learning objects corresponding to the 28 misconceptions on diodes in the POE system (Fig. 4). Each learning object consists of a question relating to the corresponding misconception, answers, and the reasons for each answer (each question has two or three alternative answers, each answer has two or three alternative explanations), and visual learning material that facilitates the learning of abstract concepts. Survey data of possible misconceptions held by students discussed in Section 2 form the basis of questions as well as their possible answers and explanations. The visual learning materials were categorized into four groups: (1) semiconductor concept of a diode, (2) features of diode bias, (3) simplified model of a diode, and (4) basic circuit of a diode. The visual learning materials for "semiconductor concept of a diode" and "features of diode bias" groups assist learners in comprehending abstract and complex concepts by demonstrating characteristics of P- and N-type semiconductors and P-N junctions. The remaining groups assist learners in observing the changing waveform of voltage and electric currents in the diode circuits. Narrations accompany visual demonstrations to support all visual learning materials. Learners can choose to pause or repeat the material at their own discretion throughout the process.
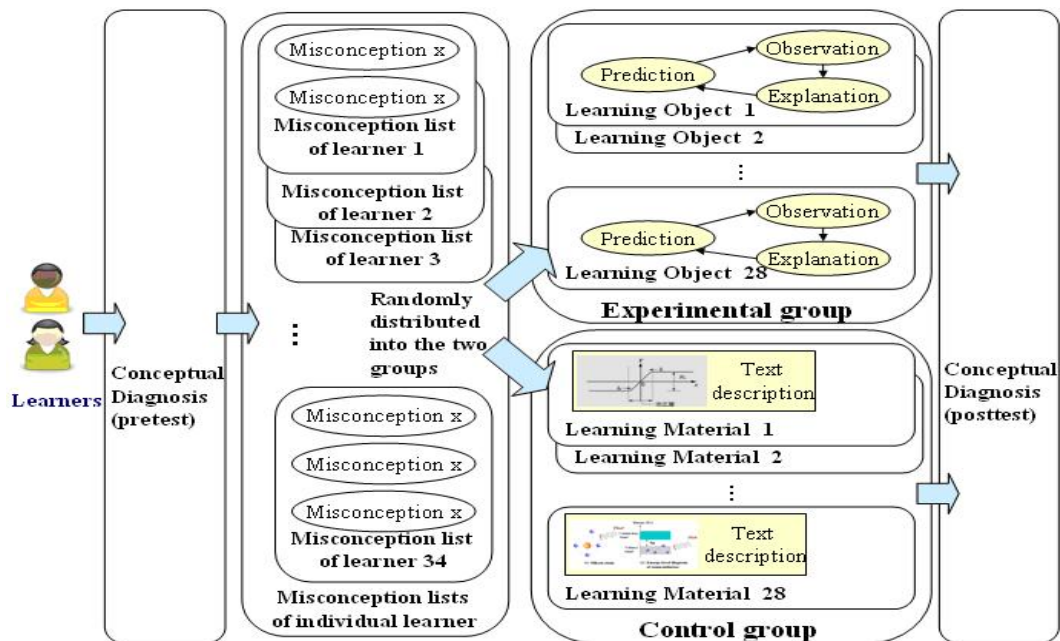
Figure 4. Experiment procedures

Procedures

All subjects in both groups (1) took the 50-minute pretest, (2) received 20 minutes of instruction about using the experimental tools, (3) performed the 1-hour learning activity, and (4) then took the 50-minute posttest. Learners underwent a pretest prior to commencement of the experiment, and misconception lists of each learner were reported at the end of the pretest. The learners were randomly distributed into the experimental group or the control group after the pretest, and received an adaptive POE learning object (experimental group) or hypertext learning material (control group) based on individual learner misconceptions (Fig. 4). Learners in the experimental groups worked with the conceptual-change learning system individually. Participants were encouraged to explore the given misconceptions on diode circuits by conducting the prediction, observation, and explanation activities in a conceptual-change learning context with simulation-based learning material. When conducting the learning activities, participants used the mouse to click or drag components to observe changes, or revised the original prediction based on the concepts discovered in the learning system to construct a final explanation. Contrasted to experimental groups, learners in the control group worked with hypertext learning material individually. Participants were also encouraged to explore the given misconceptions on diode circuits by reading the hypertext learning material. A posttest was applied after the experiments were completed.

Results

Learning performance

This study used ANCOVA in the pretest/posttest experimental design to evaluate and compare the learning performances between the two groups (Kirk, 1995). Significant posttest differences were analyzed after eliminating the influence of prior knowledge on learning performances. The pre- and posttest scores in the two groups are summarized in Table 3.

Table 3. Pre- and posttest scores [mean and standard deviation (SD) values] in the two groups

Group	N	Pretest		Posttest		Adjusted mean
		Mean	SD	Mean	SD	
Experimental	17	8.71	3.58	14.12	5.94	14.00
Control	17	8.53	3.28	11.24	5.72	11.35

Tests of the homogeneity of the regression coefficient revealed that interaction F between the independent variables and the covariate was .952 ($p =.337$), which confirms the hypothesis of homogeneity of the regression coefficient.

The pretest scores were used as the covariate to check the significance of differences in changes in the pre- and posttest scores in the experimental and control groups. Table 4 indicates that there were significant differences between the groups ($F = 4.577$, $p = .040$), with the learning performance in the experimental group (adjusted mean = 14.00) being superior to that in the control group (adjusted mean = 11.35).

Table 4. Summary of learning-performance data from ANCOVA

Source of Variation	SS	df	MS	*F*	*p*
Covariate (Pretest Score)	684.400	1	684.400	52.722	<.001
Between Groups	59.417	1	59.417	4.577*	.040
Error	402.423	31	12.981		

Note. *p* < .05.

Efficacy of misconception correction

We used ANCOVA to evaluate and compare the efficacies of misconception correction in the two groups. After eliminating the influence of prior knowledge on the misconceptions of learners, the significance of differences in the posttest of the number of misconceptions about diodes was analyzed. The numbers of misconceptions in the pre- and posttests in the two groups are summarized in Table 5.

Table 5. Numbers of misconceptions in the pre- and posttests in the two groups

Group	N	Pretest		Posttest		Adjusted mean
		Mean	SD	Mean	SD	
Experimental	17	14.71	2.82	6.47	3.94	6.32
Control	17	14.41	3.97	8.59	4.73	8.74

Tests of the homogeneity of the regression coefficient revealed that interaction F between the independent variables and the covariate was .097 ($p = .758$), which confirms the hypothesis of homogeneity of the regression coefficient.

The pretest scores were used as the covariate to check the significance of differences in changes in the numbers of misconceptions in the pre- and posttest scores in the experimental and control groups. Table 6 indicates that there were significant differences between the groups ($F = 6.447$, $p = .016$), with the number of corrected misconceptions being higher in the experimental group than in the control group.

The data in Table 5 indicate that the mean number of misconceptions reduced by 8.24 in the experimental group and by 5.82 in the control group, which demonstrates that the efficacy of misconception correction was significantly higher for the conceptual-change learning system than for the general web-based learning environment.

Table 6. Summary of misconception-correction data from ANCOVA

Variance Source	SS	df	MS	F	p
Covariate (Pretest Score) Score)	406.830	1	406.830	53.097	.000
Between Groups	49.399	1	49.399	6.447*	.016
Error	237.523	31	7.662		

Note. *$p < .05$.

Analysis of misconception correction

To further characterize the efficacy of the system in correcting any misconceptions and investigate the detailed reasons for the findings, we analyzed pre- and posttest misconceptions of the experimental group. The misconceptions could be categorized into two groups: (1) those that were difficult to correct—M20, M27, and M13, with success rates of 7%, 14%, and 29%, respectively; and (2) those that were effectively corrected—M1, M6, M12, M10, M4, M2, and M14, with success rates of 100%, 100%, 100%, 90%, 89%, 83%, and 83%, respectively.

The three misconceptions that were difficult to correct were attributable to misinterpretation of the basic definition of voltage (M20) and fundamental electricity concepts affect follow-up learning of new conceptions about diodes (M13 and M27). On the other hand, the seven misconceptions that could be effectively corrected were categorized as being associated with (1) the diode symbol, elementary model of a diode, and functioning of applicable circuits of a diode (M1, M10, M12, and M14); and (2) abstract semiconductor characteristics (M2, M4, and M6). The reasons for the success rate differing with the type of misconception correction are discussed in detail in Section 6.

Learning process

The learning performance and process recorded in the learning system were analyzed to further elucidate any distinctions between the learning processes of individual learners. Three aspects of the learning performance and process were analyzed:
1. Correction rate of misconceptions: The mean ratio of misconceptions corrected by each subject (the number of corrected misconceptions after learning divided by the number of misconceptions before learning) was 58% in the experimental group and 43% in the control group.

2. Learning effectiveness: A strong positive correlation existed between the mean learning time and the mean ratio of misconceptions corrected in the experimental group (Pearson's correlation coefficient r=.641, p=.006), but there was no significant correlation in the control group (r = −.060, p = .819). This indicates that the ratio of

misconceptions corrected by a learner who spent more time in learning was proportionally high in the experimental group, whereas the learning time spent in the control group had no effect on the efficacy of misconception correction.

3. Learning sequence: The learning sequence of the four subjects in the experimental and control group are listed in Table 7. For misconception correction, learners E1 (experimental group) and C1 (control group) had high success rates, whereas learners E2 (experimental group) and C2 (control group) had low success rates. Based on the learning sequence findings, regardless of the success rates in misconception correction, the control group read the same learning material twice or even three times more (on average, the control group is 1.94 times per learning material, experimental group is 1.1 times per learning object). This required more time for the control group participants to correct the same misconception. The mean learning time spent on a single misconception was 119 s in the experimental group and 218 s in the control group.

Table 7. List of the learning sequence of four learners

subject ID	success rate of correction	learning sequence	mean learning time (second)
E1 (experimental group)	83%	Start> learning object A(226 s)> learning object B(232 s)> learning object C(122 s)> review learning object C(96 s)> learning object D(173 s)> learning object E(368 s)> learning object F(161 s)	230
C1 (control group)	67%	Start> learning material A(200 s)> review learning material A (86 s)> learning material B(241 s)> review learning material B (142 s)> learning material C(260 s)> learning material D (240 s)> review learning material D (186 s)> learning material E (185 s)> review learning material E (161 s)> review learning material E (31 s)> learning material F (269 s)> review learning material F (59 s)	343
E2 (experimental group)	20%	Start> learning object A(57 s)> learning object B(81 s)> learning object C(111 s)> learning object D(196 s)> learning object E(116 s)	112
C2 (control group)	20%	Start> learning material A(212 s)> review learning material A (17 s)> learning material B(356 s)> learning material C(165 s)> review learning material C (102 s)> learning material D (217 s)> review learning material D (74 s)> learning material E (280 s)	285

Discussion

Different approaches addressing the pedagogical challenges of simulation-based learning have recently been implemented and examined. The results indicate that the effectiveness of simulation-based learning is reduced, if learning context becomes a stepwise procedure rather than an autonomous activity (Chang, Chen, Lin, & Sung, 2008; Njoo & de Jong, 1993; Quinn & Alessi, 1994). Studies also show that learning performance is higher when learning environments enhance the manipulation mechanism in learning activities (Chen, Hong, Sung, & Chang, 2011; Naps et al., 2003). However, the question remains as to whether simulation environments that emphasize mental manipulation would enhance learning performance without hands-on manipulation. This study attempts to implement a suitable strategy that scaffolds self-explanation to increase the opportunities for learners' mental manipulation through a sequence of POE activities in a simulation-based learning environment. Moreover, different from the previous studies, this research adopted the deeper consideration in the correcting misconceptions on diodes.

The results show that the efficacy of participants' learning on diodes with the POE conceptual-change strategy was significantly greater than participants using general Web-based learning. Previous research has shown the learning efficacy and positive learning effects that visualization and computer simulation provide (Colaso, Kamal, Saraiya, North, McCrickard, & Shaffer, 2002; Jensen, Self, Rhymer, Wood, & Bowe, 2002; Luo, Stravers, & Duffin, 2005; Naps et al., 2003). Visualization through computer simulation allows learners to observe and learn abstract scientific concepts (de Jong & Van Joolingen, 1998; Colaso, Kamal, Saraiya, North, McCrickard, & Shaffer, 2002), and the interaction with multiple external representations facilitates learning at a higher cognitive

level (Ainsworth, 2006). The abstract, complex, and microscopic nature of fundamental electricity and follow-up electronics concepts can be incomprehensible to learners and might present barriers to learning (Pfundt & Duit, 1991; Ronen & Eliahu, 2000). Accordingly, a simulation-based visualized learning environment that resolves these difficulties will improve learning performance. This study investigated the differences in learning performances between a conceptual-change learning system and general Web-based learning environment and also examined differences in learning effectiveness. The results indicate that the conceptual-change learning system can improve learning performance, learning effectiveness, and correct misconceptions.

Our results for the efficacy of correcting misconceptions about diodes revealed that the system with the integrated POE strategy was significantly better than the general web-based learning. In previous studies related to applications of conceptual-change instructions, changing a learner's concept driven by constructing the scenario of a new concept conflicting with the existing knowledge structure could correct the misconceptions (Chinn & Brewer, 1993; Vosniadou & Brewer, 1987; White & Gunstone, 1992). In our study, a learner who confronted any inconsistency between a predicted result and observed phenomenon was easily able to resolve a conflict that could not be explained by his/her own concept, and he/she was inclined to change his/her existing concept for any new concept learned (Liew & Treagust, 1998; Gunstone & Champagne, 1990).

To strengthen the efficacy of correction, we further analyzed those misconceptions that were difficult to correct (with success rates less than 30%). It is notable that such misconceptions (i.e., M20, M27, and M13) were correlated with the fundamental definition of voltage, circuit analysis, or the interaction between different concepts of a diode. Accordingly, the interaction between a misconception about fundamentals of electricity and a new concept about a diode can generate the new misconception. The learner's misconception about a mathematical model (or definition) or fundamental circuit analysis is still not clarified in a visualization environment. On the other hand, those misconceptions that were effectively corrected (with success rates greater than 80%) could be categorized as being related to the diode symbol or confusion about simplified model of a diode (i.e., M1, M10, M12, and M14) or to abstract semiconductor characteristics (i.e., M2, M4, and M6). In this regard, the use of visualization and demonstration produced a highly effective correction of misconceptions about the diode model, and semiconductor characteristics since they were categorized (Kelly & Jones, 2007).

From our analyses and findings, the effect of this conceptual-change learning system with the integrated POE strategy on the correction of misconceptions was better for abstract element models, and semiconductor characteristics than for some mathematical models (or definitions) and circuit analysis. For the purpose of instruction, we now consider four conditions necessary for conceptual change as argued by Posner et al. (Kelly & Jones, 2007) in the simulation-based conceptual-change learning system:

1. Dissatisfaction: A learner's dissatisfaction with existing concepts is substantially triggered by cognitive conflict constructed in the POE conceptual-change learning strategy.
2. Intelligible: A new concept displayed by a visualized computer simulation is intelligible to a learner.
3. Plausible: The rationality of a concept defined by some mathematical models is difficult to represent in a visualized observation process owing to the process of deducing and exhibiting a mathematical model not being similar to changes in a scientific phenomenon.
4. Fruitful: Fundamental misconceptions about circuit analysis that have been present for a long time might not be correctable by repeated observation and reflection alone. Therefore, it is necessary to provide a more fruitful learning environment that incorporates visualization, manipulation, and exploration contexts into the learning mechanism.

Having summarized the literature on the application of visualization to education, Sanger, Brecheisen, and Hynek (2001) stated that students' misconceptions could be substantially alleviated by representing the microscopic world using the visualization of a computer simulation; however, the visualization did not appear to satisfy the learning requirements for all kinds of learning content. This indicates that the improvement in learning performance varies with the learning content, which is consistent with the experimental results obtained in the present study. Therefore, correcting misconceptions about mathematical models and fundamental circuit analysis requires manipulative models and scientific exploration functions in the learning environment. Among all possible factors affecting the efficacy of learning performance revealed by previous studies, the common recommendation is to employ an appropriate learning strategy and promote interaction with learners for more active manipulation in addition to observation and reflection (Colaso, Kamal, Saraiya, North, McCrickard, & Shaffer, 2002; Korhonen & Malmi, 2000; Naps et al., 2003; Tversky, Morrison, & Betrancourt, 2002). Furthermore, some previous studies found that using a scientific

exploration environment constructed by computer simulation allows learners to manipulate parameters and observe the resulting changes in a given concept, which not only helps learners to comprehend abstract and complexity concepts, but also helps them to construct a concrete model of new concepts, and finally to correct existing misconceptions about fundamental circuit analysis (Colella, 2000; Forinash & Wisman, 2005).

Conclusions

This study analyzed and classified misconceptions that learners can have about diodes. The results revealed both existing fundamental electricity concepts and follow-up electronics concepts, and further explored the possible difficulties confronted by a learner. The results could provide important reference data for improving the instruction of electronics and the learning performance of diodes and relevant topics.

The POE conceptual-change strategy was incorporated into the visualized learning environment of computer simulation, and empirical research revealed that by interacting with this system, learners can correct their misconceptions about diodes and substantially reinforces the learning effectiveness of online learning.

The results of this study also indicate that misconception corrections in definitions of mathematical models and fundamental circuit analysis need to be improved. Therefore, the functions of this conceptual-change learning system should be expanded, such as by providing more parameter manipulation of abstract models and a scientific exploration context, and employing mechanisms that promote interaction between a learner and the system. Besides that, we will enhance the system by providing more than three possible answers and more than three possible explanations in each question to avoid guessing by the learners.

Future studies should focus on the following issues: (1) verify the ability of the system to correct misconceptions about fundamental circuit analysis and relevant mathematical models; and (2) conduct empirical studies comparing various functions of learning environment for conceptual change.

Acknowledgements

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Timely Diagnostic Feedback for Database Concept Learning

Jian-Wei Lin[1]*, Yuan-Cheng Lai[2] and Yuh-Shy Chuang[1]
[1]Chien Hsin University, Taiwan // [2]National Taiwan University of Science and Technology, Taiwan //
jwlin@uch.edu.tw // laiyc@cs.ntust.edu.tw // yschuang@uch.edu.tw
*Corresponding author

ABSTRACT

To efficiently learn database concepts, this work adopts association rules to provide diagnostic feedback for drawing an Entity-Relationship Diagram (ERD). Using association rules and Asynchronous JavaScript and XML (AJAX) techniques, this work implements a novel Web-based Timely Diagnosis System (WTDS), which provides timely diagnostic feedback whenever a learner encounters hurdles when learning database concepts. The WTDS provides crucial hints that help students rectify their misconceptions at each step to prevent prospective mistakes. To identify the learning effects of various feedback types, this work compares the proposed WTDS with systems providing other feedback types. The evaluation results demonstrate that all systems enhance learning achievement significantly. However, learning achievement of the class using the WTDS was significantly better than that of other classes, and the learning achievements of all cluster levels in the class using the WTDS were enhanced significantly. Finally, questionnaires and interviews were used to acquire student attitudes about the proposed system.

Introduction

Feedback provides learners with opportunities to adjust and develop their cognitive strategies and to rectify misconceptions during training (Azevedo & Bernard, 1995). Maughan et al. (2001) noted that e-learning feedback provides the information required to identify needed improvements. Scholars thus deem feedback as an essential e-learning component that facilitates student learning (Wang, 2008). Additionally, feedback received during a learning process can assist learners in reflecting on their learning and improve their motivation (Marriott, 2009). However, most early e-learning systems only offer short statements, such as "correct" or "incorrect," or update a score as feedback for student input, thereby limiting communication with learners. Therefore, e-learning systems that provide feedback to address student problems during a learning process have become popular. Diagnostic feedback allows learners to receive useful hints, which may facilitate the identification of a learner's misconceptions, provide crucial clues to rectify misconceptions, or offer remedial materials for learning (Chen et al., 2007; Lee et al., 2009).

Studies related to feedback timing (e.g., timely and delayed feedback) have obtained conflicting outcomes for the effects of feedback on learning (Anderson et al., 2001; Corbalan et al., 2010; Corbett & Anderson, 2001; Schroth, 1992). Although researchers for decades have examined the effects of timely feedback and delayed feedback on learning, study results for feedback timing have always been controversial (Mory, 2004). However, timely feedback has typically proven to have better effects than delayed feedback for a well-structured problem, which is a logic-, story-, and rule-based problem with predefined steps and exact solutions (Laxman, 2010). Timely feedback is mainly based on the theory proposed by Jonassen (1997), which claims that timely feedback is important in informing learners where their problem-solving processes went wrong and in providing coaching at an appropriate time.

Currently, most works related to well-structured problems provide diagnostic feedback only after a learner finishes a problem. However, this delayed feedback may hinder acquisition of the information needed during a problem-solving process (Dempsey et al., 1993; Kulik & Kulik, 1988). Thus, timely diagnostic feedback is promising to help learners enhance their learning achievements.

This work investigates the influence of timely diagnostic feedback on learning the "Database Concept," which belongs to the type of well-structured problems. To provide timely diagnostic feedback, this work first extracts a learner's database concept, an Entity-relationship Diagram (ERD) (Chen, 1976), into a two-dimensional matrix. This matrix and the correct matrix are compared to obtain the misconceptions of learners. Based on these misconceptions,

association rules (Han & Kamber, 2001) are adopted to model learner behavioral patterns. Analyzing learner misconceptions can provide suitable hints and discover prospective misconceptions.

Using the proposed approach, this work realistically develops a novel Web-based Timely Diagnosis System (WTDS) to diagnose learning obstacles and to further provide crucial and adaptive hints in real time during a problem-solving process. This work also describes how to use the Asynchronous JavaScript and XML (AJAX) technique (Paulson, 2005) and association rules to achieve timely diagnostic feedback. An evaluation is conducted to assess the effectiveness of the proposed WTDS. Finally, questionnaires and interviews are used to acquire student attitudes toward the proposed WTDS.

Background and literature review

Entity-relationship diagram

The Entity-Relationship Model is a data modeling method in the database concept that produces a conceptual schema or semantic data model of a relational database. Diagrams created by this process are called Entity-Relationship Diagrams (ERD) (Chen, 1976). An ERD is a critical tool in designing a database schema, helping users to achieve enhanced understanding of the database schema by displaying the structure in a graphical format (Elmasri & Navathe, 2006).

An ERD includes several essential concepts, such as entity, attribute, relationship, and the cardinality ratio of relationships, found in the detailed reference of Elmasri and Navathe (2006). Figure 1 is an example of the ERD for an enterprise. The typical steps of establishing an ERD are outlined as follows:
1. Creating entities: In accordance with the applied field, precisely picking up the entities (e.g., Employee and Project).
2. Determining relationship and the cardinality of the relationships: identifying the relationships between entities. Further denoting a cardinality of "many" can be done by writing "N" or "M" next to the entity while denoting a cardinality of "one" by writing "1" next to the entity.
3. Identifying attributes: Drawing the corresponding attributes for each entity and relationship if necessary.
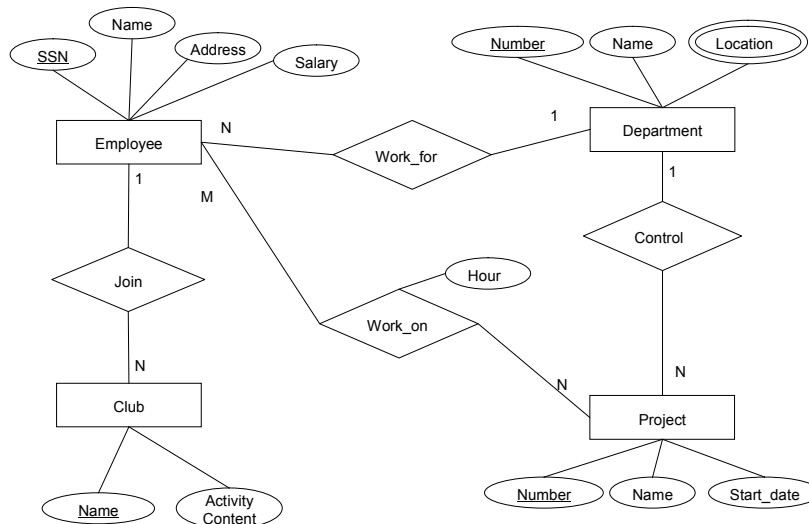4. Executing refinement:

Figure 1. ERD for database Enterprise

Accordingly, drawing an ERD evidently belongs to the well-structured problem because it is a logic-, story-, and rule-based problem with predefined steps and exact solutions.

The related works

Feedback should be more than simple results (e.g., correct or incorrect) or correct answers. In addition to appraising the correctness of a learner's solution, informing students where their problem-solving process went wrong and providing coaching from that point onward are also important (Jonassen, 1997). An effective coaching method, "diagnostic feedback," has been proven to contribute to learning achievement. These diagnosis systems basically use diagnostic algorithms to discover individual misconceptions based on their incorrect responses to test problems and provide the corresponding remedy materials when necessary (Chen et al., 2007; Heh et al., 2008; Huang et al., 2008; Lee et al., 2009).

On the other hand, timely feedback is defined as feedback that occurs immediately after a student has completed a step. Delayed feedback, relative to timely feedback, is defined as a feedback that only occurs after the student has completed the task or test (Shute, 2008). Researchers have examined the effects of feedback timing (timely versus delayed) on learning for decades, but still have conflicting arguments of the effects on learning outcome. Some literatures assert the superiority of delayed feedback (e.g., Schroth, 1992), whereas others affirm the superiority of timely over delayed feedback in verbal materials, procedural skills, some motor skills, programming, and mathematics (Anderson et al., 2001; Corbalan et al., 2010; Corbett & Anderson, 2001; Wang, 2008). Thus, the study of feedback timing has always been muddied (Mory, 2004), and this may relate to the subject, applied field, and test form (e.g., single or multiple choices, or text-based) (Lewis & Anderson, 1985).

Although feedback differs for different subjects and different test forms, most published works adopted diagnostic and delay feedback to address well-structured problems. That is, the feedback offers the information about weak concepts of a learner and provides remedy materials (or adaptive hints) only after he/she completes a well-structured problem. For example, Chen et al. (2007) used association rules to design a multiple-choice diagnosis system for elementary school students learning mathematics. Heh et al. (2008) developed a multiple-choice assessment system for learning database concepts at a university. Huang et al. (2008) developed a text-based assessment system for university students learning a programming language. Lee et al. (2009) also used association rule based on the Apriori algorithm (Agrawal & Srikant, 1994) to design a text-based diagnosis system for senior high school students learning a programming language. However, these works only investigated the effects of providing delayed diagnostic feedback on learning.

For a well-structured problem requiring rule-using, predefined steps, and logical solutions, timely feedback is seemingly better than delayed feedback because an error made in one step during the problem-solving procedure carries over to the following steps and consequently to the final solution (Corbalan et al., 2010). In other words, if a student has a misconception on one-step, the subsequent steps and even the result could be wrong because this mistake can propagate over the entire problem-solving process. To prevent such carry-over effects, Mory (2004) suggested addressing this by detecting mistakes and providing timely feedback to that mistake during the problem-solving process. Wang (2010) used timely feedback to develop a multiple-choice web-based assessment system for natural science at an elementary; timely hints are provided whenever a student chooses an incorrect option during a problem-solving process. However, the provision is non-diagnostic feedback which is delivered in a pre-determined sequence, starting from "general hints" and gradually moving toward "specific hints." Such non-diagnostic feedback may not uncover individual misconception and further unable to provide adaptive assistances.

Notably, most above works focus on either diagnostic feedback or timely feedback. In other words, using timely diagnostic feedback for well-structured problem is relatively scant. Effective learning requires suitable feedback and how to generate suitable feedback in different fields is a key problem. Timely diagnostic feedback which provides adaptive assistances whenever a learner encounters hurdles during problem-solving process seems promising for address a well-structured problem. However, few studies have investigated the effects of both timely and diagnostic feedback for a well-structured problem. This work investigates these effects in detail.

Constructivist principles followed by the WTDS

According to constructivist theory, learning is a leaner-centered activity and a learner actively constructs meaningful knowledge with his/her own experiences. Figueira-Sampaio (2009) had elaborated the best educational principles proposed by constructivist theory. Four principles among them the WTDS follows are: "timely useful feedback,"

"learner independence," "learners are engaged in solving real-world problems," and "active learning." The following describes the details.

1. Timely useful feedback: The WTDS uses timely diagnostic feedback as "timely useful feedback."
2. Learner independence: The WTDS immerses learners into a context that presents a problem to be solved, encouraging them to individually practice, explore, and develop independent thinking ability.
3. Learners are engaged in solving real-world problems: the WTDS can provide diverse real-world ERD problems (as shown in Table 3) for learner practice by slightly modifying its parameters.
4. Active learning: Instead of exploring alone, learners should be provided with supporting and coaching (Ng'ambi & Johnston, 2006). The support of timely diagnostic feedback can decrease learner frustration and improve learner motivation, enabling learners to become more active in learning (Marriott, 2009).

The follows will discuss how the WTDS achieve these principles in practice.

Proposed approach

This research adopts timely diagnostic feedback to aid ERD learning with systematic hints once learners encounter learning barriers during the diagram-drawing process.

Overview

The kernel module is based on association rules to mine interesting associative or correlative relationships among a set of data items (Han & Kamber, 2001). Extensive information must be available for mining before the diagnosis process. Thus, preliminary tests must be conducted to acquire a model of learner behavioral patterns. These patterns can be deemed a set of data items for mining. By applying the Apriori algorithm, frequent itemsets can be found for association rules. In our case, a frequent itemset means that if a student makes a mistake on an item of an itemset, he or she is very likely to make the mistake on other items of the same itemset. This is because when a learner has a misconception on an item, it is very likely that the learner not only fully misunderstand the item, but also other related items (Lee et al., 2009).

This study then generates association rules from these frequent itemsets and further calculates the confidence (probability) for each association rule, which explicitly reveals the probability of making mistakes on related items once a mistake is made on an item. These frequent itemsets can be regarded as learning blockades. Providing adequate corresponding hints in a timely manner can therefore be useful to conquer these learning blockades.

Detailed steps

The diagnosis feedback is generated by executing the following steps.

Step1: Presetting the correct ERD by an instructor

The first step is for an instructor to draw the correct ERD. To facilitate computing, the graphic information is converted into numeric data in a two-dimensional matrix, $R_{correct}$. The translated formula is as follows:

$$R_{correct} = [R_{ij}]_{k \times k}$$ --- (1)

where $\begin{cases} R_{ij} = R_{ji} = 0; & \text{if } E_i \text{ and } E_j \text{ have no relationship} \\ R_{ij} = R_{ji} = 1; & \text{if } E_i \text{ and } E_j \text{ are one-to-one relationship} \\ R_{ij} = N \text{ and } R_{ji} = 1; & \text{if } E_i \text{ and } E_j \text{ are one-to-many relationship} \\ R_{ij} = M \text{ and } R_{ji} = N; & \text{if } E_i \text{ and } E_j \text{ are many-to-many relationship} \end{cases}$

where k is the number of entities. Taking Fig. 2 as an example, suppose that the left part is the correct ERD by an instructor. After the translation process, the resulting matrix is shown in the right part of Fig. 2.
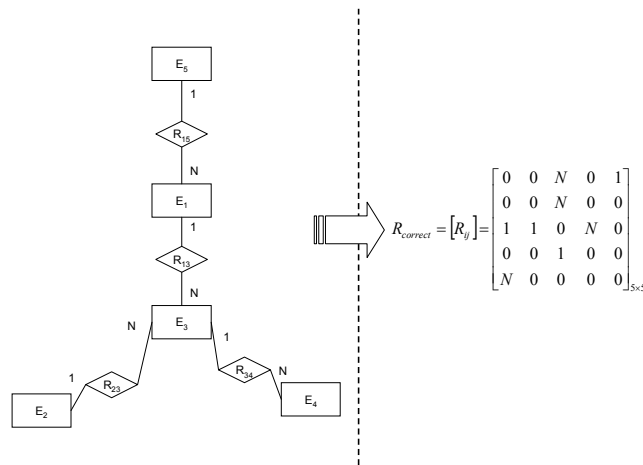
Figure 2. Translating the correct ERD answer to a matrix

Step2: Comparing the ERD results of all testees with the correct ERD

The next step acquires the answering pattern of a testee. After a testee finishes his or her ERD, the corresponding matrix R_{test} is obtained through Formula (1). The mistakes the testee makes can be identified by comparing R_{test} with $R_{correct}$. For example, assume the test result of a testee is shown in the left part of Fig. 3. After comparing R_{test} with $R_{correct}$, we can identify these mistakes: two wrong relationships R_{12} and R_{23}. By repeatedly comparing the test results of a number of testees, we can obtain the mistake patterns for all testees, for example, Table 1. The table is deemed as a transaction database D (i.e., training data) for mining mistake patterns. For a clearer explanation, the example in Table 1 with the mistake list of nine testees is used to explain the complete diagnosis procedure. The procedures are the same when the number of testees exceeds nine.
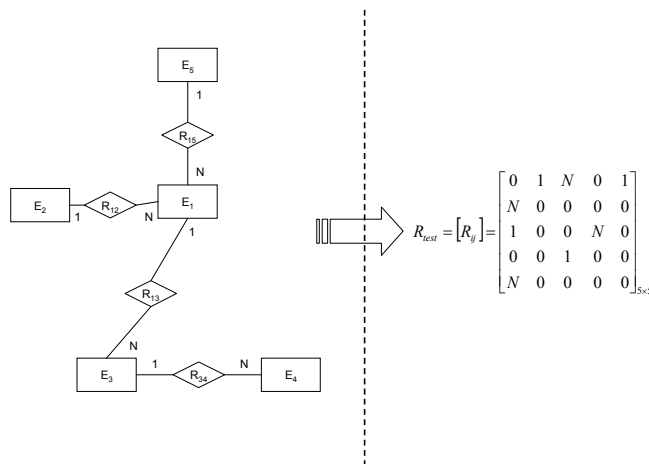
Figure 3. Translating the ERD of a testee into a matrix

Table 1. Transaction database consisting of the test results of nine tesetees

Transaction ID	List of Wrong Items (Relationships)
T_1	R_{12}, R_{13}, R_{23}
T_2	R_{13}, R_{15}
T_3	R_{13}, R_{14}
T_4	R_{12}, R_{13} ,R_{15}
T_5	R_{12}, R_{14}
T_6	R_{13}, R_{14}
T_7	R_{12}, R_{14}

| T_8 | R_{12}, R_{13}, R_{14}, R_{23} |
| T_9 | R_{12}, R_{13}, R_{14} |

Step3: Using the Apriori algorithm to find frequent itemsets and then generating association rules.

Figure 4 shows the pseudo-code of the Apriori algorithm. The Apriori_gen (L_k) function, which aims at generating candidates for C_{k+1}, mainly contains two steps: Join Step and Prune Step. Join Step uses $L_k \times L_k$ to generate a candidate, C_{k+1}, which consists of $\binom{|L_K|}{2}$ itemsets. Prune Step is applied to prune an itemset in C_{k+1}, which has an infrequent subset (e.g., the itemset has one subset, which is not in L_k). Readers interested in this algorithm can refer to Agrawal & Srikant (1994) for further details.

C_k: Candidate itemset of size k
L_k: Frequent itemset of size k

L_1= {Frequent items};
For (k = 1; L_k != ϕ ; k++)
{
   C_{k+1}= candidates generated from L_k ; //Apriori_gen(L_k);
   For each transaction t in database D
   {
      Counting each candidate in C_{k+1} that are contained in t ;
      L_{k+1}= candidates in C_{k+1} with min_support ;
   }
}

Figure 4. Pseudo code of the Apriori algorithm

Figure 5 illustrates a procedural example of how to use the Apriori algorithm to generate frequent itemsets using the transaction database D (i.e., Table. 1), where the minimum support count is set as 2. The final two frequent itemsets: {{R_{12}, R_{13}, R_{14}}, {R_{12}, R_{13}, R_{23}}} are generated, as shown in L_3. These resulting frequent itemsets can be deemed learning blockades for students. Therefore, we can foresee that according to first frequent itemset {R_{12}, R_{13}, R_{14}}, if making a mistake on R_{14}, a student is very likely to also make mistakes on R_{12} and R_{13}.
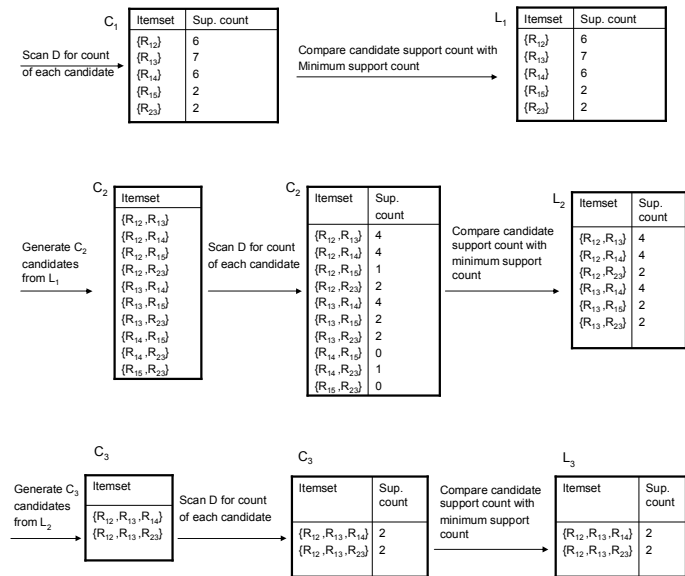
Figure 5. Using the Apriori algorithm to find frequent itemsets

Once the frequent itemsets have been found, it is straightforward to generate strong association rules from them, where strong association rules satisfy both minimum support and minimum confidence (Han & Kamber, 2001). For $\{R_{12}, R_{13}, R_{23}\}$, the resulting association rules accompanying their confidence are shown in Table 2, each listed with its confidence. For $\{R_{12}, R_{13}, R_{14}\}$, the generation of association rules is the same as $\{R_{12}, R_{13}, R_{23}\}$. If we set the minimum confidence threshold to 50%, then the output rules are these association rules with confidence >= 50%.

The space of frequent itemsets can be analyzed as follows. Since no meaning exists for R_{ii} (*i.e.*, elements are located on the diagonal of a matrix), only $k \times (k-1)/2$ items exist. Let m be $k \times (k-1)/2$. Since the minimum number of items of a frequent itemset is 2, the number of itemsets in this case is first counted. The possible number of frequent itemsets is C_2^m when the number of items within a frequent itemset is 2. Similarly, the possible number of frequent itemsets is C_m^m when the number of items within a frequent itemset is m. Thus, the size of the space is

$$C_2^m + C_3^m + \text{L } C_m^m = 2^m - 1 - m$$

Table 2. Association rules for the frequent itemset $\{R_{12}, R_{13}, R_{23}\}$

Association Rules	Confidence
$\{R_{12}, R_{13}\} \Rightarrow \{R_{23}\}$	2/4 = 50%
$\{R_{12}, R_{23}\} \Rightarrow \{R_{13}\}$	2/2 = 100%
$\{R_{13}, R_{23}\} \Rightarrow \{R_{12}\}$	2/2 = 100%
$\{R_{12}\} \Rightarrow \{R_{13}, R_{23}\}$	2/6 = 33%
$\{R_{13}\} \Rightarrow \{R_{12}, R_{23}\}$	2/7 = 29%
$\{R_{23}\} \Rightarrow \{R_{12}, R_{13}\}$	2/2 = 100%

S*tep4: Inputting the hints of learning blockades for diagnostic feedback*

Once frequent itemsets (i.e., learning blockades) are identified, the instructor is able to input the corresponding hints for each frequent itemset to provide suitable feedback for prospective students. In this manner, the instructor needs to input only the hints for major learning blockades, thereby saving effort in inputting unimportant hints.

During student practice, the system can respond to the corresponding hint once a mistake is made. Based on the results of the frequent itemsets and association rules, the related hints and their occurrence probability of related mistakes are automatically generated to prevent students from making subsequent mistakes. For example, if a student commits an error on R_{23} (e.g., marking the wrong cardinality ratio of the relationship or drawing a meaningless relationship), the system not only returns the hint of R_{23}, but also the hints of R_{12} and R_{13} and the probability of committing such an error, which is 100%.

Web-based timely diagnosis system

Using the proposed approach, we implemented a realistic system, the Web-based Timely Diagnosis System (WTDS). Visual Studio .NET 2008 was chosen as the developmental tool for implementing the entire system because it fully supports the required techniques: HTML, JavaScript, ASP.NET, and AJAX.

Architecture of WTDS

In a traditional web application, a user request causes a response from a web server. For example, a server returns a new page with desired information when a user presses a submit button. Thus, when drawing an ERD, the common scenario is that a student submits the result only after finishing the ERD, and then receives feedback from the web server, or delayed feedback. The typical software model of delayed feedback is presented in the left part of Fig. 6. The verification module indicates whether the provided answer is either "correct" or "incorrect" instead of hints or references. Thus, the module is easy to design because it only compares a finished ERD work with the correct ERD and simply checks whether the two ERD matrixes (i.e., Figs. 2 and 3) are the same.

To provide timely feedback, the new technology AJAX is presented for creating more efficient and interactive web applications that handle users' requests instantly. AJAX applications do not require installing a browser plug-in, such as Java Applet and Microsoft ActiveX, but work directly with most popular browsers, allowing immediate updating of partial content on a web page when a user performs an action.

When drawing an ERD, the process flows of timely feedback are as follows: Whenever a user executes a drawing step on a browser, this action triggers the local AJAX engine for submitting the request to the web server. The web application then processes this request and returns the results. After receiving the results, the browser's partial page is updated according to the returned results. This processing flow is employed iteratively if the browser operates continuously. This AJAX feature that enables the result to return right after a student has completed a step can be used for timely feedback. The software model of the timely diagnosis feedback is shown in the right part of Fig. 6. The Diagnostic module is designed according to the descriptions of the proposed approach in the previous section.
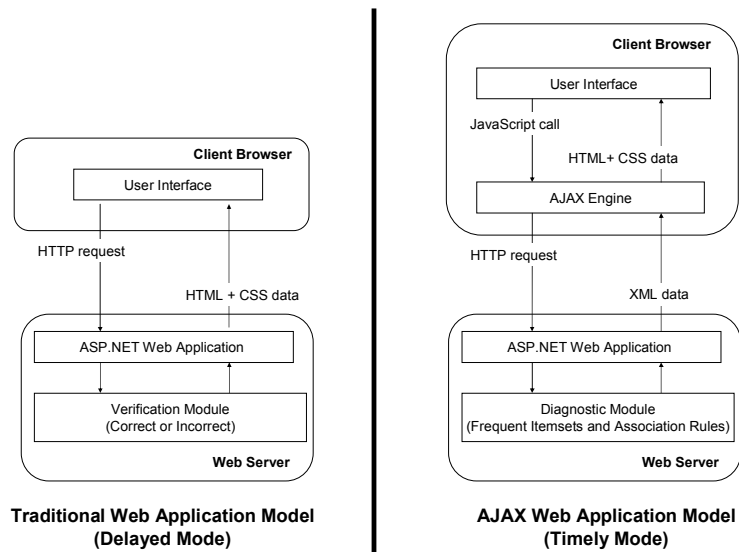
Figure 6. Different software models for timely and delayed mode

Operation procedure and demonstrations

The operation procedure of WTDS is divided into two phases, shown in Fig. 7.
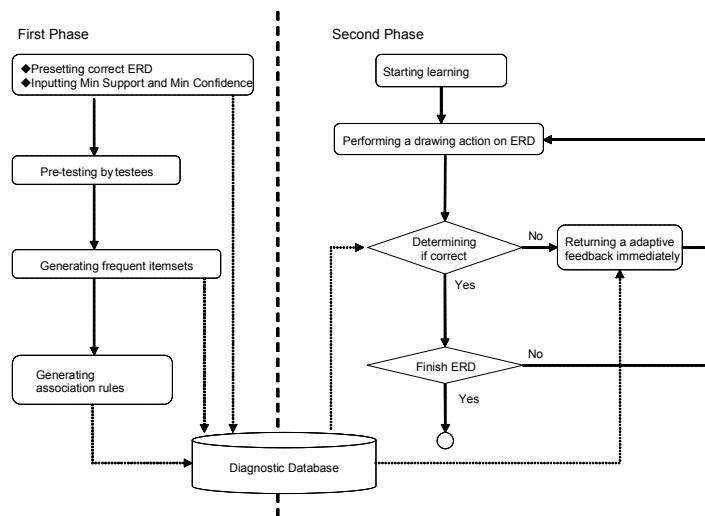
Figure 7. Operation stage of the IAFA system

The first phase generates a diagnostic database, which consists of the correct ERD answer, frequent itemsets, and association rules. An instructor first draws correct ERDs using the management interface of the system. The values of minimum support and minimum confidence must be settled for generating frequent itemsets and association rules, after which several testees are involved in simultaneous pretesting. Following the pretest, the system automatically generates frequent itemsets and association rules and then imports them into the database. An instructor can input hints for each frequent itemset in the management interface, as shown in Fig. 8. These hints do not contain information about correct answers; that is, they only provide clues crucial to rectifying a learner's misconceptions about entities and relationships. These hints scaffold students to actively reflect and fix faulty concepts whenever they make mistakes during a problem-solving process.

R13	An Employer has many orders
R12	A Customer has no relationship wit
R23	A Customer may have many Order
R13	An Employer has many orders
R12	as no relationship with a Employee
R14	' has no relationship with a Product

Upload Hints

Figure 8. Inputting hints

In the second phase, students begin their learning process. When a student performs a drawing on ERD, the system determines if this step is correct. If incorrect, the WTDS returns diagnostic feedback immediately to inform the student. The procedure repeats iteratively until the working ERD is finished correctly.

Figure 9 illustrates the user interface for students to practice their ERDs. The functions include selecting and laying out entities, building relationships and cardinality ratio, adding attributes, setting strokes, and setting font and line colors. After laying out entities in their proper place, a student is able to build relationships between entities and their cardinality ratio. If the built relationship is incorrect, the diagnostic feedback appears immediately below. For example, as shown in Figure 9, once the student builds an incorrect relationship between Employee and Product, the feedback displays the following information: 1) Frequent Itemsets: There are R_{13}, R_{12}, and R_{14}. 2) Major and likely errors and related hints: Because a major mistake is made on R_{14}, there is a greater likelihood to make mistakes on R_{13} and R_{12}. Meanwhile, the hints for R_{13}, R_{12}, and R_{14} are also provided. 3) The confidence (e.g., probability) of making errors on R12 and R13 is also shown for reference.

Figure 9. User interface

Evaluation

The experimental course, called "Data Processing and Application," primarily teaches database concepts.

To enable students to practice diverse ERD models, five different ERD models were established based on the proposed system, including School, Sales, Publisher, Enterprise, and Hotel, as shown in Table 3. Thirty-six students were asked to join the pretest so that each ERD model has its own transaction database D to generate corresponding frequent itemsets and association rules. The Apriori algorithm was used where the minimum support count and confidence were set as 2 and 50%, respectively.

Table 3 depicts the results. The second column shows the number of frequent itemsets (denoted as NFI), whereas the third column shows the number of association rules (denoted as NAR). Our observation indicated that more entities may contribute to more NFI, resulting in more NAR.

Table 3. Results of data mining of different ERD models

ERD Model (Entities)	NFI	NAR
Enterprise (Department, Project, Employee, Club)	3	8
Sales (Orders, Sales, Product, Customer)	4	10
Publisher (Book, Publisher, Author, Member)	5	13
School (Department, Teacher, Course, Student, Classroom)	5	12
Hotel (Hotel, Location, Rooms, Cost, Manage, Facilities)	6	14

Objectives

To identify whether timely diagnostic feedback can effectively enhance learning achievement, this evaluation compared WTDS with two common feedback type systems, namely WDDS (Web-based Delayed Diagnosis System) and WVS (Web-based Verification System). In WDDS, diagnostic feedback is returned only after a student solves a problem completely. On the other hand, WVS only shows whether the learner's answers are correct after he/she solves a problem completely.

To conduct the evaluation, the latter two systems must be developed. Based on the developed WTDS, it is relatively easy to build these systems because they are much simpler than the WTDS for the used software techniques and modules. The building of these systems requires only slight modifications in the inner software structure of WTDS. Modifying GUI to equip these systems with the same GUI is unnecessary. For building WDDS, the only modification is removing the AJAX function from WTDS. For building WVS, other than removing AJAX functions, replacing the diagnostic module with the verification module is required. The software model of WVS is illustrated in the left part of Fig. 6.

This study was administered to three classes: the first class consisted of 52 students using WTDS; the second class consisted of 49 students using WDDS; and the third class consisted of 51 students using WVS. The students in the three classes are the first time to take the course of "Data Processing and Application" for learning their database concepts. This evaluation addressed the following issues: (1) analyzing the learning behavior and achievements among these three classes; and (2) analyzing the learning achievements within the WTDS class.

Research tools and procedure

This study adopted a quasi-experimental design method requiring four weeks. In the first week, all classes took the pretest and were familiarized with their designated system. In the following two weeks, all classes received traditional database instruction in traditional classrooms from the same teacher based on the same learning material. During these two weeks, all students used the designated system to practice in school or at home. In the fourth week, all classes took the posttest. In the meantime, questionnaires were administered to the WTDS class to elicit student attitudes toward the proposed system.

To assure pretest validity and reliability, the content of the pretest was reviewed by 2 experts, and then conducted by 26 students. Inappropriate questions were removed according to the corresponding difficulty and discrimination levels, resulting in 16 multiple-choice questions and Cronbach's α being 0.86 in total. To ensure posttest validity and reliability, the content of the posttest was also similarly handled to that of the pretest, resulting in 19 multiple-choice questions and a total Cronbach's α value of 0.82.

The first part of Table 4 shows the descriptive statistics of the pretest results. Moreover, One-way ANOVA was further conducted to verify possible significant difference in the background knowledge of students in the three classes. The results revealed no significant difference in the average scores of the background knowledge between these three classes ($F = 0.120, p > .05$).

Results and discussions

To analyze the preference tendency of participants, all systems recorded participant activities as logged data, including login time, source IP, and staying period (the time a visitor spends on the system). SPSS Ver.12 was used to conduct statistical analysis.

Comparison among the three classes

Table 4 also shows the descriptive statistics and paired-samples t test of the mean scores and standard deviations of achievement on the pretest and posttest. For each class, the mean in the posttest was significantly higher than that in the pretest, meaning that all three systems can enhance students' learning achievement significantly.

Table 4. Descriptive statistics and paired-samples *t* test of the pretest and posttest for different classes

Group	N	Pre-test		Post-test		t value
		Mean	SD	Mean	SD	
Class 1 (WTDS)	52	30.48	6.46	80.19	14.59	-32.39*
Class 2 (WDDS)	49	29.96	7.12	73.51	15.76	-27.14*
Class 3 (WVS)	51	29.01.	6.86	68.69	16.91	-21.32*

Note. *The mean difference is significant at the .05 level.

Analysis of Covariance (ANCOVA) was further used to compare learning achievement among these classes. The analysis regarded the experimental treatment as the independent variable, posttest scores were seen as dependent variables, and pretest scores were taken as the covariate. Before analyzing covariance, homogeneity of regression coefficients was tested to examine whether homogeneity existed in the intra-group (test of the homogeneity of intra-group regression coefficients). SPSS analysis demonstrated that the F value of the regression coefficients was 2.68 ($p > .05$) for the hypothesis of homogeneity to be accepted. Thus, covariance analysis was further conducted.

Posttest scores were adjusted by removing the influence of the pretest from the scores on the posttest. Table 5 shows that learning achievement among these classes is significant ($F = 12.40, p < .05$), indicating a great difference in achievement among these classes in learning ERD. The Least Significant Difference (LSD) was used to compare these classes, as shown in Table 5.

1. Students in Class 1 (using WTDS) perform significantly better than those in Class 2 (using WDDS) and Class 3 (using WVS). Timely diagnostic feedback provides more effective learning than the rest. WTDS immediately provides diagnostic hints for students when they make mistakes and helps in solving problems. Thus, students can revise their thoughts through the guidance of timely feedback and in turn improve their ERD problem-solving ability.

2. Students in Class 1 and Class 2 have better performance than those in Class 3. This may be because Class 3 only provides the "correct or incorrect" answer in the final solution, resulting in insufficient information for handling learning barriers, limiting students' problem-solving ability, and encouraging rote memorization.

Table 5. One-way ANCOVA on the scores of the post-test

Variable	Class	Mean[a]	SD	F	Post Hoc[b]
Pre-test				164.64*	N/A
Type of System	Class 1	79.61	1.48	12.40*	Class 1> Class 2* ; Class 1> Class 3*
	Class 2	73.82	1.53		Class 2> Class 3*
	Class 3	69.01	1.51		

Note. * The mean difference is significant at the .05 level. [a] Covariates appearing in the model are evaluated at the following values: Pretest = 30.14. [b] Adjustment for multiple comparisons: LSD (equivalent to no adjustments).

Total retention time of each student in the three classes was also computed, which means the total time students spend on their designated system during the evaluation period. This value is calculated by accumulating staying time of every login. Table 6 shows that WTDS has the longest total retention time, although the result does not reach a level of significance ($F = 0.59$; $p > .05$). This may be because students in each class felt the designated system could help their learning irrespective of the feedback type the system provided, causing total retention time among these classes to have no significance.

Table 6. One-way ANOVA on total retention time

Class	Total Retention Time (Minutes)		SD	F	P
	Mean				
Class 1	33.68		16.21	0.59	0.62
Class 2	29.32		17.24		
Class 3	30.57		15.96		

Comparison within the WTDS class

Under normal distribution, the most suitable ratios for high-level cluster (HC), medium-level cluster (MC), and low-level cluster (LC) are 27%, 46%, and 27% (Kelley, 1939), respectively. Hence, the WTDS class was further divided into three clusters according to their pretest scores (Liu et al., 2010). Students with scores in the top 27% were allocated to HC, and those with scores in the bottom 27% were allocated to LC, and the rest belonged to MC.

Table 7 shows the descriptive statistics and paired-sample *t* test for the three clusters. For each cluster, the mean score in the posttest is significantly higher than that in the pretest, meaning that all clusters benefit by the proposed WTDS.

To investigate whether there is significant difference among the three clusters in learning achievement, ANCOVA was further used. SPSS analysis demonstrated that the F value of the regression coefficients was 3.05 ($p > .05$) for the hypothesis of homogeneity to be accepted, and ANCOVA was then conducted. The result showed that the learning effectiveness among three clusters is not significant ($F = 0.41$, $p > .05$), indicating no significant difference in learning achievement between the three clusters. Timely diagnostic feedback can be deemed the problem-solving scaffold with a temporary framework to support learning. Regardless of the cluster, WTDS supports all learners in their "zone of proximal development" to perform complex tasks, such as problem solving, without the help of which they may be unable to perform (Jonassen, 1997). However, this result may contradict Liu et al. (2010), who found that the learning strategy of computer-assisted concept mapping had greater benefit for LC than for HC. This contradiction may result from differences of the applied field and applied techniques.

Table 7. Descriptive statistics and paired-sample *t* test of the pretest and posttest for different clusters

Cluster	N	Pre-test		Post-test		t value
		Mean	SD	Mean	SD	
LC	14	22.50	2.51	68.57	13.74	-12.77*
MC	24	30.42	2.59	78.71	11.95	-21.41*
HC	14	38.57	2.60	94.36	5.32	-42.05*

Note. * The mean difference is significant at the .05 level.

Questionnaire and interviews

To understand student satisfaction on relevance to their concern, a questionnaire with a Likert scale ranging from 5 (*strongly agree*) to 1 (*strongly disagree*) was provided to the WTDS class. This questionnaire was based on the study by Su et al. (2010), and further modified to elicit student attitudes toward WTDS. Among 52 students in the WTDS class, 46 valid questionnaires were collected and used for data analysis. After completion of the questionnaire survey, 7 students were selected for short interviews for eliciting their perceptions.

Table 8. Questionnaire result

No	Question	M	SD
1.	Did the WTDS provide suitable user interfaces and stability?	4.11	0.73
2.	Did you experience overall satisfaction toward the WTDS?	4.10	0.89
3.	Did the WTDS aid you in learning ERD?	4.35	0.81
4.	Did the WTDS reduce your frustration in solving ERD problems?	4.25	1.01
5.	Did the WTDS increase your confidence in solving ERD problems?	3.86	0.96
6.	Did the WTDS stimulate you to spend more time on it?	3.96	0.91

The questionnaire results, shown in Table 8, reveal that most of the evaluated aspects received positive feedback. Most students indicated that they were satisfied with WTDS and agreed that it is a stable and convenient online system. The results of questions 3 and 4 show that most students also agree that the WTDS is a practical auxiliary tool that can reduce student frustration when solving an ERD problem. For example, an interviewee stated: "*I am a novice and it is helpful for me when encountering a hurdle. Too many hurdles will certainly decrease my willingness to learn. The WTDS guides me to solve the problem step by step, sustaining me to continue until finishing the work.*" This is because when the learner gradually overcomes each sub-problem, the possibility of solving the whole problem increases.

The results from questions 5 and 6 show that the system moderately stimulates students to spend more time on it. Five of 7 interviewees stated that they had practiced at home. As one interviewee stated, *"I spent much time on the system, especially before the day of the exam because it provides sufficient examples to practice."* Another interviewee commented, "*I used to practice on paper and seldom on a computer screen. But I am interested in the WTDS. This is because when I have a misconception and make a mistake on one step, the system can respond with useful hints so that I can untangle the misconception immediately and remember not to make the same mistakes in subsequent solving processes.*" These responses may support the perspective of Mory (2004), who states that during initial practice, feedback should be provided for each step of the problem-solving procedure, allowing learners to verify immediately the correctness of a solution step.

Conclusions

This work investigates the influence of timely diagnostic feedback on database concept learning. This work first adopts the Apriori algorithm to find frequent itemsets and then generates association rules for drawing an ERD. Once frequent itemsets are identified, an instructor inputs the corresponding hints for each frequent itemset to provide suitable feedback to students. This work implements the WTDS using association rules and AJAX techniques to promote student efficiency in learning ERD. Providing timely diagnostic feedback gives students the necessary guidelines and directions when encountering hurdles during a problem-solving process.

An evaluation was conducted to compare the WTDS with the WDDS and the WVS. Evaluation results reveal that all systems have significant influences on ERD learning. The class using the WTDS had better achievement than those using the WDDS and WVS, even though total retention time for the three classes was insignificant. In the class using the WTDS, learning achievement of each cluster was enhanced significantly. Questionnaire results show that most students were satisfied with the WTDS and agreed that it can aid and stimulate student learning and decrease frustration when solving ERD problems.

This work has the following limitations. First, the proposed methodology for providing timely diagnostic feedback should be suitable for learning other similar data models, such as a data flowchart, state diagram, and concept map. However, whether this methodology is suited to all well-structured problems, and even to ill-structured problems,

remains unclear. Second, the proposed WTDS assumes that whenever a student makes a mistake, that student will correct the mistake instantly according to feedback. However, if a student neglects feedback and does not correct the mistake, mistakes can accumulate. Because feedback does not contain any information about remedial sequencing, a student's remedial path to correct accumulated mistakes is heuristic. In the future, we will investigate the effect of remedial sequencing rules and attempt to identify optimal rules.

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Pre-service Teachers' Perceptions on Development of Their IMD Competencies through TPACK-based Activities

Hatice Sancar Tokmak[1*], Tugba Yanpar Yelken[2] and Gamze Yavuz Konokman[2]

[1]Computer Education and Instructional Technology Department // [2]Educational Sciences Department Mersin University, Yenisehir Campus, B Blok No 15, 33343, Turkey // haticesancarr@gmail.com // tyanpar@gmail.com // gyavuzkonokman@gmail.com

[*]Corresponding author

ABSTRACT

The current study investigated perceived development of pre-service teachers in their Instructional Material Design (IMD) competencies through the course *Instructional Technology and Material Design,* which is based on a technological, pedagogical, and content knowledge (TPACK) framework. A total of 22 Elementary Education pre-service teachers participated in the study. Five activities based on TPACK were designed by the instructors to provide students with specific teaching experience. Action research methodology was followed during the study, and each activity was part of the cycle of design. Data were collected through a questionnaire on pre-service teachers' IMD competencies, their journals, assignments, open-ended questionnaires, teaching practice forms, observations, and software evaluation forms. The study revealed that pre-service teachers gained essential competencies in instructional material design. Moreover, the results showed that they experienced incorporating TPACK into their future teaching practices.

Keywords

TPACK, Instructional material design competencies, Action research, Pre-service teachers

Introduction

One framework used to explain and describe teachers' knowledge and skills related to technology integration is Technological, Pedagogical, Content Knowledge, collectively referred to as TPACK (Mishra & Koehler, 2006; Niess, et al., 2009). Technological tools are often used as educational aids in primary and secondary education (Polly, Mims, Shepherd, & Inan, 2009); the technology means "the systematic application of scientific and other organized knowledge to practical tasks" (Galbraith, 1967, p. 12 as cited in Earle, 2002). Mishra and Kohler (2006) list some of technologies used in traditional classrooms as textbooks, overhead projectors, typewriters, and charts of the periodic table. According to Yanpar-Yelken (2011), every tool that can be used for educational purposes can be defined as technology, including 3D materials, board markers, and textbooks. Digital technology refers to multiple formats, including information that can be evaluated and integrated using computers (Pool, 1997).

Teachers must have the ability to use these tools effectively in order to facilitate learning processes (Clements, 2002). Polly et al. (2010) emphasize that teachers need to understand (a) the relationship between technology and content, including how technology can be used for the learning of specific content; (b) the relationship between technology and pedagogy, including how specific pedagogies best support the use of technology; and (c) the relationship between content and pedagogy, including how specific pedagogies facilitate the learning of specific content. In other words, teachers need to be knowledgeable about the intersection of technology, pedagogy, and content (Özgün-Koca, Meager, & Edwards, 2010). Nelson, Chistopher, and Mims (2009) state that TPACK-competent teachers exhibit best practices in pedagogy, content, and technology, and organize meaningful, collaborative, and technology-rich learning opportunities for their students. The Ministry of National Education, General Directorate of Teacher Training and Education (2006) has identified a set of Teaching Profession General Competencies, one of which is related to Material Preparation and Development. Specifically, teachers need to be able to develop educational materials that demonstrate content knowledge, utilize pedagogical knowledge, and incorporate technology. To meet the competency levels determined by the Ministry of National Education, teachers need TPACK knowledge. Therefore, pre-service teacher education programs are expected to provide TPACK necessary to apply the model effectively. Finger, Jamieson-Proctor and Albion (2010) advocate this with the words: "Preservice teacher education programs have the responsibility for preparing future teachers who are likely to be teaching their students in a world characterized by ongoing technological changes" (p. 114).

According to Angeli and Valanides (2008), "TPCK development efforts need to invest on socio-cognitive constructivist ideas" (p. 16), since the effort transforming a content domain through technology must firstly target learners' conceptual ecology consisting of their knowledge base. Moreover, Nelson et al. (2009) state that some technologies, such as Web 2.0 tools, are based on construction of knowledge together; teachers with well developed TPACK used these tools to provide learners with experiences in which they were active. This study helped pre-service teachers to gain experience in designing instructional materials and integrating them through the course Instructional Technology and Material Design, which was designed based on TPACK.

Theoretical background of the study

The TPACK framework is designed as an extension of Shulman's Pedagogical Content Knowledge (PCK), which requires an understanding of both pedagogy and content (Shulman, 1986). Mishra and Koehler (2006) and Angeli and Valanides (2008) explain that Shulman's framework has transformed into TPACK, connecting technology to curriculum content and pedagogical approaches. TPACK is defined as "a conceptual framework designed to illustrate the characteristics of teacher knowledge and technology integration in education." (Nelson, Christopher, & Mims, 2009, p. 82).

The TPACK model features interdependent components of teachers' knowledge: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). Shin et al. (2009) define CK as learned or taught knowledge about a subject matter; PK as knowledge about practices and methods of teaching, including classroom management skills, teaching strategies, and evaluation techniques; and TK as knowledge about both standard and more advanced technologies.

The interactions among these bodies of knowledge are represented as pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006). Shin et al. (2009) define PCK as the awareness of best teaching approaches and content arrangement for effective teaching. TCK refers to an understanding of appropriate technology use (Cox, 2008). TPK indicates the application of technology in education without referring to specific content (Cox, 2008). With regard to TPK, Shin et al. (2009) add that teachers equipped with knowledge about technologies use them as pedagogical strategies in their classrooms. TPACK is not defined as a simple combination of three independent domains; instead, content, pedagogy, and technology are interdependent, each one affecting the others (Harris, Mishra, & Koehler, 2007). That is to say, choice of content influences pedagogical methods and technology, while technology affects how content is taught (Mishra, Koehler, & Zhao, 2007). Holmes (2009) emphasizes that teachers need to be able to integrate technology with specific content in meaningful ways in order to teach effectively. Hu and Fyfe (2010) add that the development of TPACK occurs when teachers know how to use computers and are aware of strategies that incorporate ICT tools and enhance student understanding of content.

Research questions of the study

What is the elementary education pre-service teachers' perception about development of their IMD competencies in a TPACK-based course consisting of collaborative projects?
a. How does this perception pertain to technology use?
b. How does it relate in terms of pedagogical knowledge while designing and using Instructional Material?
c. What is their perception in terms of content knowledge on the IMD?
d. What is their perception in terms of technology, pedagogy, content knowledge (TPACK) on the IMD?

Methodology

We practiced action research methodology in the current study. Altrichter, Posch, and Somekh (2005) state that, "Action research starts from practical questions arising from everyday educational work" (p. 5). We, as the instructor and teaching assistants of the Instructional Technology and Material Design course, began by assessing the students' awareness of being a teacher and knowledge of how to integrate technology into their teaching. Gall, Gall, and Borg (2003) emphasize that teachers are also researchers who reflectively investigate their practice through action research.

We changed our course plan as a result of the continuous evaluation of our teaching. According to Avison, Lau, Myers, and Nielsen (1999), in action research studies, practice and research inform each other synergistically and iteratively. We applied the steps outlined by Glanz, who points out that the nature of action research is cyclical, and each cycle consists of several phases: Select a focus, collect data, analyze and interpret data, take action, reflect, continue/modify (as cited in Gall, Gall, & Borg, 2003). In the current study, we planned five activities around these phases of action research design in order to address the research questions. After classroom practice, we improved the design of some activities to enhance our teaching. To do this we followed "Steps of the action research process" offered by Altrichter, Posch, and Somekh (2005): Finding a starting point, clarifying the situation, developing action strategies and putting them into practice, and making teachers' knowledge public.

Sampling

Out of 25 elementary education pre-service teachers who enrolled in the Instructional Technology and Material Design course, 22 participated in the study. Three pre-service teachers did not want to take part in the questionnaires, although they did write and submit journals during the course. We applied two forms of convenience sampling, captive and volunteer, drawing samples from an accessible and willing population (Teddlie & Yu, 2007).

All pre-service teachers were second-year college students enrolled in the night program for elementary education. Half the participants were male, and half were female. Ages ranged from 19 to 25 with an average age of 21. The average GPA was 2.79 out of 4.0. According to the questionnaire results, all participants had taken some of the same educational courses, including: Introduction to Education Sciences, Psychology of Education, and Teaching Techniques and Methods. Except for one female pre-service teacher, all students reported using a computer regularly for between two and 12 years, with an average of six years of use. Moreover, they had also used computers to create Word documents, Excel spreadsheets, and PowerPoint presentations for class work.

Instruments

Instruments were applied as the following:
1. The demographic questionnaire: consisted of ten questions, asking about age, gender, department, program types, class level, GPA, education lessons, computer use, coursework that demanded computer use, and activities conducted using the computer.
2. The Teacher Skills Related with Material Development and Evaluation questionnaire: was developed by the Ministry of National Education (2006) to identify pre-service teachers' perceptions of relevant competencies. It also has ten items. In this questionnaire, the pre-service teachers were asked to rate their perceived current levels of competency for ten items on a five-point Likert-type scale (1 = Not Competent, 2 = Slightly Competent, 3 = Competent, 4 = Very Competent, 5 = Extremely Competent).
3. The IT questionnaire: consisted of six diagrams that showed competencies about IT. The meaning of figures in the questionnaire represented individuals' perceptions of their competencies in technology and their ability to integrate them into teaching. It was applied at the beginning and at the end of the course.
4. An open-ended message design activity questionnaire: had four questions to learn students' opinions about the Message Design activity. The questions were about: what the pre-service teacher took into account while communicating both synchronously and asynchronously; whether there was a change in terms of procedure while communicating on the internet and face-to face; what difficulties they met during communicating on the internet and face-to face; and what they gained from this activity.
5. Open-ended journal entry questionnaires: after each activity asked pre-service teachers to describe four components as skills acquired, difficulties faced, strategies used to tackle those difficulties, and group members' labors.
6. A Teaching Practice Evaluation Form: was applied after the 3D and PowerPoint design activities. The form consisted of four parts: personal, classroom management, content presentation, and teaching methods applied and goals. It was developed by the facilitators of the course.
7. The Software Evaluation Checklist. This checklist was developed by Heinich, Molenda, Russell, and Smaldino (2002) and has three main parts: software description, rating, and open-ended questions. Software description includes title, serial title, keywords, format, source, date, cost, length, subject area, intended audience, brief

description, objectives, and entry capabilities required. The rating section has 12 points for evaluation. The third part included open-ended questions about strong points, weak points and recommended actions for the course.

8. Four-part, open-ended questionnaire was conducted to learn about pre-service teachers perceptions on skills acquired, difficulties faced, strategies used to tackle those difficulties, and group members' labors.

All the instruments were applied to define whether a change occurred in pre-service teachers' perception about their IMD competencies. The IT questionnaire was applied at the beginning and end of the course to see whether the pre-service teachers thought that their relationship with IT changed during the course. Moreover, journals applied after each activity aimed to learn which competencies they gained. Table 1 shows a timeline of the instruments conducted as related to planned activities.

Table 1. Activities planned and instruments correlated to research questions

Date	Instruments and Activities
22nd February 2011	Introduction to Course Demographic Questionnaire The Teacher Skills Related to Material Development and Evaluation Questionnaire
Beginning of the Course (1st March 2011)	Questionnaire about IT

During the Course (1st March-31st May 2011)	Activity 1: Instructional Message Design
	    Open-Ended Activity Design Questionnaire
	    Open-Ended Journal Entry Questionnaire
	Activity 2: 3D Material Design and Teaching Practice
	    Open-Ended Journal Entry Questionnaire
	    Teaching Practice Evaluation Form
	Activity 3: PPT Design and Teaching Practice
	    Open-Ended Journal Entry Questionnaire
	    Teaching Practice Evaluation Form
	Activity 4: Software Evaluation
	    Open-Ended Journal Entry Questionnaire
	    Software Evaluation Checklist
	Activity 5: Instructional Web Site Development
	    Open-Ended Journal Entry Questionnaire

End of the Course (9th of June 2011)	Open-Ended Questionnaire Questionnaire about IT

Procedure

The procedure of the study was drawn from the stages of the action research process described by Altrichter, Posch, and Somekh (2005). As seen in Figure 1, the first step of the procedure was finding a starting point. To that end, the Teacher Skills Related to Material Development and Evaluation questionnaire was applied at the beginning of the course. The results showed that the students lacked technology integration knowledge. In the second step of the procedure, clarifying the situation, we met with pre-service teachers to discuss the results of the questionnaire and their impressions about the class. As the instructors and teaching assistants, we defined activities under the scope of the third step, developing action strategies and putting them into practice, and then applied these activities during the course. However, since the aim was to develop their IMD competencies with regard to technological, pedagogical, and content knowledge, each activity was revised according to students' comments after completion. At this step, pre-service teachers were divided into groups of five since we also wanted them to learn about each other with respect to social constructivism (Yanpar-Yelken, 2011). For the fourth step, making teachers' knowledge public, we wrote the current article for publication. The procedure of the study continued during the Instructional Technology and Material Design comprising of 12 four-hour sessions.

| A. Finding a Starting Point |
| *The students lacked teaching experience and had not used technology for teaching purposes.* |

| B. Clarifying the Situation |
| *The instructor and teaching assistants defined the purposes: evoking students' awareness of "being a teacher" and improving teaching practices.* |

| C. Developing Action Strategies and Putting Them into Practice |
| *The instructor and teaching assistants defined five activities and divided students into groups of five.* |

| D. Making Teachers' Knowledge Public |
| *The instructor and teaching assistants shared their knowledge of the current study.* |

Figure 1. Steps of the action research process (Altrichter, Posch, and Somekh, 2005)

Activities designed based on TPACK

Using the TPACK framework, five activities were designed in a course entitled Instructional Technology and Material Design to develop the Elementary Education pre-service teachers' IMD and integration competencies. Five activities related with TPACK knowledge as follows:

PCK+TK: The first activity was an in-class activity about message design. Five event examples, one for each group, were prepared to show importance of message design in teacher-student interaction. These event examples were assigned to each group and the groups was asked to write a scenario and perform it based on these scenarios. Within the groups, one of the pre-service teachers performed as teacher while others performed as students (PCK). Moreover, the pre-service teachers discussed the scenario that was created by each group at the end of the lesson. Then, all the pre-service teachers continued discussing the components of message design (source, message, channel, and receiver) both synchronously (e.g., MSN, Skype, Gtalk) and asynchronously (e.g., Gmail, Hotmail, Yahoo) on the internet (TK).

TPACK: The second activity included 3D material design and in-class teaching with the material designed. The groups were asked to choose a subject matter from the national curriculum of primary schools. They prepared 3D materials to teach the selected subject matters by thinking how to teach it. Then, they taught the chosen subject matters by integrating 3D materials in class (TPACK).

TPACK: The third activity was PPT design and in-class teaching with designed material. The groups selected a subject matter from national curriculum of primary schools and prepared PPT to teach the chosen subject matters. Then, they taught the selected subjects by integrating PPT in class (TPACK).

TCK: For the fourth activity, the groups were instructed to evaluate educational software designed for primary school students using Heinich et al. (2002) Software Evaluation Checklist. Then, they were instructed to search educational software for teaching subject matters, evaluate and present them in class. During the presentation, the group members were asked to mention their scores as a result of Heinich et al. (2002)'s Software Evaluation Checklist by explaining why they gave these scores. Moreover, they were directed to mention their suggestions for improvement of the designs of software.

TPACK: The fifth, last, activity was web site construction on subject matters they selected from the primary school curriculum. In class, web-design principles were discussed, and a web tool was introduced to the pre-service teachers, who had very little experience with web site development. Then, the groups prepared the Web sites and published them to teach a subject online. The groups presented their web sites and other groups made suggestions for improvement. The groups also continued discussing each others' products.

All the above activities were designed in order to provide pre-service teachers with experiences and knowledge on material design by focusing what they would teach and how they would teach. The pre-service teachers designed 3D materials, PPTs and web sites in addition to selecting and evaluating educational software by focusing on design principles. All these activities related to material design competencies and directly addressed the research question.

Data analysis

The analysis of the data gathered through the demographic questionnaire, the Software Evaluation checklist (Heinich et al., 2002), the Teaching Practice Evaluation Form, and the open-ended questionnaire about change were descriptive in nature. Thus, we analyzed these data using descriptive statistics. Two researchers coded the journals and observation notes by organizing categories of significant statements through themes, as described by Ayres, Kavanaugh, and Knafl (2003). Then, we gathered a list of themes found in the data and correlated them under the constructs social constructivist course design. According to Miles and Huberman's (1994) formula, interview intercoder reliability on the merged themes was 92 percent.

Validity issues

The data collected in the current study were also qualitative in nature. We used the following strategies suggested by Creswell (1998) to validate the study results:
- Peer debriefing: We discussed the process of the study with colleagues before, during, and after data collection.
- Triangulation: We triangulated methods by collecting data through journals, assignments, open-ended questionnaires, teaching practice forms, observations, and software evaluation forms.
- External audits: We asked for experts' comments on the techniques used in the research study. Moreover, all the developed instruments were verified by an expert before application
- Members check: All data were analyzed by two researchers and verified by an expert.

Results

Action research step 1: Finding a starting point

This step began with the results of the Teacher Competencies Related to Material Development and Evaluation questionnaire prepared by the Ministry of National Education (2006). The competencies described in the questionnaire aligned with TPACK. Items 1, 5, 6, 7, and 8 were about pre-service teachers' content knowledge (CK); items 2, 4, and 10 were about pedagogical knowledge (PK); and items 3 and 9 were about technological knowledge (TK). Most pre-service teachers defined their skill levels as "Slightly Competent," as seen in Table 2.

Table 2. Results of the teacher skills with frequencies of students' answers

Item No and TPACK	Perceptions about Competencies Related to Material Development and Evaluation	(1) Not Competent	(2)Slightly Competent	(3)Competent	(4)Very Competent	(5)Extremely Competent
1.(CK)*	To prepare worksheets	4	14	2	0	0
2.(PK)	To take into account individual differences while designing or selecting instructional materials	3	10	8	1	0
3.(TK)	To use the computer or other technologies while designing instructional materials	3	18	1	0	0
4.(PK)	To take into account students' opinions while designing materials during instruction	3	15	4	0	0
5.(CK)	To take into account usability and cost effectiveness while designing instructional materials	6	11	4	1	0
6.(CK)	To design instructional material appropriate to content	6	11	4	1	0
7.(CK)	To benefit from environmental resources	4	14	3	1	0
8.(CK)	To take into account how the design of instructional material allows content presentation	4	14	4	0	0
9.(TK)	To access concepts related to teaching-learning by using technology and evaluate them in terms of accuracy and appropriateness	4	16	2	0	0
10.(PK)	To contribute to the improvement of students' creativity and aesthetical understanding by giving them the opportunity to design materials	3	15	3	1	0

Note. * Two students did not answer the first question.

The instructor also asked pre-service teachers about Instructional Technology (IT), technology integration in instruction, and their expectations about the course. Two teaching assistants observed these conversations, recording their observations. Three codes emerged as a result of analysis of these notes: misconceptions about IT, lack of knowledge about technology integration, and more practice. Similar, the pre-service teachers thought IT just meant technology, not a tool that can be used in teaching. They stated they did not know how to integrate technology, and they needed practice to learn.

Action research step 2: Clarifying the situation and IT questionnaire results

While discussing the results, the instructor and teaching assistants identified their main purpose as improving pre-service teachers' IMD competencies by planning TPACK-based activities. Moreover, since the pre-service teachers did not know how to integrate technology in instruction, they were placed in groups of five in order to learn from each other. The instructor and teaching assistants incorporated a social constructivist approach to make pre-service teachers experience instructional material design via group learning. Also, they decided to have pre-service teachers present their products or teach using their products both in class and on the internet to provide across group learning.

A questionnaire focusing on Instructional Technology and student relationships about Instructional Technology and Material Design was conducted at the beginning of the course (Appendix A). The students stated that the figures in the questionnaire accurately showed the person's competencies in combining technology, pedagogy, and content.

In the questionnaire at the beginning of the course, 11 pre-service teachers selected Figure 1, which showed no relationship between IT and the person, while seven selected Figure 2, which indicated a slight relationship between IT and the person. Two pre-service teachers claimed a relationship with IT in the middle by selecting Figure 3, while one selected Figure 4 (a bit above the middle) and one selected Figure 5, which showed the relationship between the person and IT as very close.

Action research step 3: Developing action strategies and putting them into practice

Message design activity (all sub-research questions)

The open-ended journals of the groups showed that these pre-service teachers understood key components of designing messages to dialog with students. Moreover, the groups emphasized that they learned to take into account students' individual differences, ages, and genders during message design. During the activity, students stated that they also learned specific teaching and classroom management strategies with regard to the events. All groups claimed that watching and criticizing other groups' dramatizations made them think about different situations that a teacher may face. Because of this activity, they saw deficiencies in their strategies and identified alternatives as suggested by other groups (RQ1d).

The groups completed an open-ended activity design questionnaire that included questions about their communication experience via e-mail and chat programs. The themes that emerged as a result of the students' answers were (a) being a model for students in an online environment, (b) message design according to students' ages and skill levels, (RQ1b) (c) presenting important points with highlights, (RQ1c) (d) considering the quality of technological infrastructure, (RQ1a) and (e) understanding the benefits of communication with students outside class. The pre-service teachers stated that they tried to be a positive model while utilizing both asynchronous and synchronous communication tools. According to them, good grammar and avoiding jargon or abbreviations was important while communicating with students. Moreover, they stated that based on students' age and class level, appropriate font size could highlight important points. The groups acknowledged that a teacher should assess technical infrastructure quality and the channel of the message. According to them, if a teacher communicates with students synchronously, they must be aware of video and sound quality and bandwidth availability.

Lastly, pre-service teachers stated that the activity demonstrated the benefits of communicating with students outside the classroom. They indicated that they intend to use both asynchronous and synchronous communication tools to contact students.

3D material design and teaching practice activity (all sub-research questions)

The groups' journals and teaching plans, the Teaching Practice Evaluation form, and created materials were analyzed to measure pre-service teachers' teaching competencies. The open-ended journal entries presented several themes: material design principles appropriate to student level (RQ1b); appropriateness of content, color, and font (RQ1c); cost effectiveness; enhancing students' participation and improving creativity (RQ1b); difficulty using 3D materials during practice (RQ1d); classroom management problems (RQ1d); and the importance of having alternatives and sharing knowledge via technology (RQ1a). The open-ended journals also showed that the pre-service teachers took into account the relationship between content and student level during material development. They explained that they tried to use appropriate colors, font size, and pictures, and they started to think about the cost of materials. The pre-service teachers emphasized that they tried to include games, puzzles, and matching to make students more active. Except for one group, the pre-service teachers did not find themselves successful during practice. The Teaching Practice Evaluation Form showed that three groups gave themselves a C (69-74 out of 100), while one group gave themselves a B (75-89) and the other an A (90-100). During the teaching practice, they had difficulty using the materials effectively because of classroom management problems and students' unexpected questions or

behaviors. They became aware that they lacked alternative methods for handling unexpected situations. The Teaching Practice Evaluation Forms also indicated low self-determined grades for classroom management.

Additionally, the instructor wanted pre-service teachers to share their instructional materials via blogs and YouTube. The groups indicated that as people saw and commented on their materials on the internet, they realized that sharing knowledge through technology helped other teachers enhance their practices, as well (RQ1a). Analysis showed that colors, font types, and picture use were very similar in two groups' materials. The lesson plans showed that groups tried to design materials to keep students active (RQ1d); however, the journals and Teaching Practice Evaluation Form showed that they could not apply their plans effectively. Figure 2 shows one of the groups' 3D material, which was designed to teach the phases of the moon through experiments.

Figure 2. 3D material designed by one of the groups to teach the phases of the Moon

PPT design and teaching practice (all sub-research questions)

The results of the demographics questionnaire that was applied at the beginning of the course showed that the pre-service teachers had mostly used PPT for presentation purposes rather than teaching purposes. For that reason, the instructor and teaching assistants wanted the groups to teach a subject from the national curriculum. For this activity, groups' journals, teaching practice evaluation form, lesson plans, group PPTs, and observation notes were analyzed. According to the analysis, the following themes emerged: ways to provide for student participation (RQ1b); difficulty in teaching with PPT (RQ1d); problems related to classroom management; PPT design that used contrast colors, appropriate font size, and animations and pictures but eliminated excessive use of elements (RQ1c); and content that highlighted strategies and presented concise information. The groups' journal analysis showed that they struggled to make their students active during the lesson (RQ1d): three groups used worksheets, the fourth used gaming, and the last used a puzzle (RQ1a). According to the groups' journals, although they saw improvement with respect to their classroom management, they did not find themselves successful at making students active. According to them, it was very difficult to teach using PPT presentations in a constructivist curriculum. All the groups first presented the content, and then tried to make students active through gaming, puzzles, and worksheets. On the Self Evaluation Forms, the groups rated themselves highly on classroom management but lower on teaching strategies such as providing for students' participation, asking questions, assessing learning during instruction, and material use. One group gave themselves an A; the others gave themselves Bs. Another issue the groups mentioned in the journals was PPT design issues. While they attempted to give concise information without excessive elements, they also wanted to include pictures and animations in their presentation to attract students' attention. In addition, during the PPT preparation, they paid attention to the contrast between background and text colors.

Software evaluation and presentation (sub-research questions 1.a and 1.d)

The groups' journals, the Software Evaluation Checklist developed by Heinich et al. (2002), and instructional software were analyzed to determine the following themes: learning about instructional software concepts (RQ1a),

being aware of the importance of selecting software (RQ1a); being aware of the criteria to select software (RQ1a), and thinking about how to integrate software in teaching practices (RQ1d).

According to the groups' journals, this activity taught them about instructional software concepts. Before this activity, they had the misconception that all computer materials were software or, for example, videos on the internet. During this activity, pre-service teachers became aware of options from CDs, the internet, and bookstores. They also emphasized that while selecting the instructional software, they also had to consider its integration capabilities. According to the groups' journals, they did not experience any difficulties during the software selection process because they worked together. Except for one group, which selected software that taught chess, the groups selected software for mathematics education. The Software Evaluation Checklists showed that the groups generally tended to grade each criterion as high. Observations supported this result, as groups were very pleased with the software they selected. However, the groups' journals showed that after the presentations, the pre-service teachers had learned several main points about educational software selection.

Web-based Instruction(all sub-research questions)

The groups' journals and websites were analyzed to learn their opinions about web-based instruction activity and its contribution to their profession. The following themes emerged: the new experience teaching on the web (RQ1d), lack of knowledge with regard to designing a website (RQ1a), not knowing how to broadcast on the internet (RQ1a), not knowing how to make students active (RQ1b), tackling problems posed by group members, and the need to add communication tools (RQ1a).

The group journals showed that preparing web-based instruction was a new experience for them. They had difficulty designing websites, although the instructor showed them how and prepared a small sample website during class. They also had difficulty publishing their websites, despite course instruction. The pre-service teachers struggled to make students active during web-based instruction, partly due to the lack of communication tools for teacher-student interaction. The pre-service teachers stated that they learned many things from their group members during this activity. They emphasized that if they had not been working as a group, they would not have been able to design the web-based instruction successfully. The analysis of the websites showed that the groups focused on activities such as puzzles, game site links, and tongue twisters. In their journals, the groups complained about their lack of competency developing games and simulations. The websites were designed according to principles that indicated construct colors for background and texts (RQ1c).The categorization of the content and simplicity of the language used were appropriate for elementary school students (RQ1b). The only aspect that the groups omitted from the material design principles involved usability. Four groups' websites did not initially provide a menu that allowed students to navigate freely. Based on instructor direction, they later added menu structures to their sites.

Open-ended and IT questionnaires results (research question 1 in general)

At the end of the course, the groups were wanted to share their opinions about their experiences through their journals. After analysis, five themes emerged: learning through experiences, gaining a different point of view about teaching, learning instructional material design, benefits of technology integration in instruction, and enjoyment of 3D material design.

The pre-service teachers expressed satisfaction from learning course content through the activities, which expanded their perspectives about teaching and technology integration. They gained awareness of the importance of knowing content well, capturing students' attention, and making instruction entertaining by encouraging students' participation and using technology. Moreover, they stated that awareness of technology was not enough; teachers need to know how to use it during instruction for maximum effectiveness. The groups listed the benefits of technology integration to instruction as making knowledge concrete for students and making instruction entertaining and motivating. All groups stated that they liked designing and teaching with the 3D materials the most.

The IT questionnaire applied at the end of the course indicated that pre-service teachers saw their relationships with IT grow closer during the course. Twelve students selected Figure 4, with an IT relationship a bit above the middle,

while seven described their relationship with IT as very close (Figure 5). Three of them chose Figure 6 at the end of the course, representing that the person was fully integrated with IT.

Discussion and conclusion

Under the scope of the course, we designed activities based on TPACK to develop elementary education pre-service teachers' IMD competencies. The aims were to make them use TPACK during instruction consistent with teacher competencies described by the Ministry of National Education (2006).

With regard to the research question, the IT questionnaire was given to the pre-service teachers in order to understand their perceptions on the relationship between them and IT. The results showed that most pre-service teachers selected Figure 1 (n = 11) and Figure 2 (n = 7). Also, according to the IT questionnaire, the pre-service teachers perceived they had a closer relationship with IT at the end of the semester. Twelve of them selected Figure 4, while 7 selected Figure 5 and Figure 6 (n = 3). The results of the journals that pre-service teachers wrote after the each activity supported to this finding. The groups' analysis journal results after the message design activity showed that pre-service teachers learned how to design messages to dialog with students by taking into consideration the students' individual differences including age and gender. The open-ended activity design questionnaire that the groups completed after their communication experience, via e-mail and chat programs, showed that the pre-service teachers realized the importance of discussing the subject matter outside the classroom, thanks to the technology. For the 3D and PPT design activity, pre-service teachers learned to create materials by considering the design principles such as appropriateness to level, content, font use, cost effectiveness, usability, student participation, and student creativity. As regards the fourth activity, they learned how to select educational software according to relevant criteria and integrate educational software in instruction. With regard to the fifth activity, they perceived that they learned how to design web-based instruction, although they experienced some difficulties since they had not done it before. Parallel to the results, Doering, Veletsianos, Scharber, and Miller (2009) found that the in-service teacher gained a considerable movement within TPACK domains through TPACK-based course experiences.

One of the results of the current study was that the pre-service teachers started to think as teachers and also, talked about the benefits of their learning into their future teaching. Similarly, Özgün-Koca et al. (2010) found in their study that the mathematics pre- service teachers' TPACK development was closely related to a shift in identity from *learners of mathematics* to *teachers of mathematics*." (p. 10). Moreover, they were confident about incorporating technology into their future teaching (Özgün-Koca et al., 2010).

The journals and observation notes showed that pre-service teachers learned from their group members. The comments made by peers during presentations and teaching practice activities made them aware of many concepts of teaching, one of the promises of social constructivism mentioned by Airasian and Walsh (1997). Jang found in the study, that peer coaching enhanced both the teachers' TPACK and technology integration skills (as cited in Jang, 2008). Jang (2008) stated that teachers can tackle the difficulties of applying a new technology more easily if they work together instead of alone. In the current study, pre-service teachers stated that they had difficulties while designing Web based instruction but could tackle these difficulties thanks to working with a group.

Moreover, the results showed that the pre-service teachers' perception of IT was changed. At the beginning of the course, IT, to them, meant technology; they did not think about its instructional implications or know how to integrate it into teaching. The journals showed that pre-service teachers thought that their competencies using technology, pedagogy, and content for teaching purposes were enhanced through experiences. These results were consistent with the study of Bos (2011) who found that using TPACK framework helped teachers become aware of the value in teachers integration of meaningful technology in instructional units. Chai, Koh and Tsai (2010) also found pre-service teachers' TPACK perceptions before and after attending TPACK-based ICT course design significantly different with moderately large effect sizes.

In sum, according to the study results, TPACK offers many benefits for preparing teachers to incorporate technology in the classroom. However, to apply it successfully, researchers should continue to investigate and present TPACK-based course design examples, especially those applied in K-12 schools.

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APPENDIX A
Pre- and Post Questionnaire

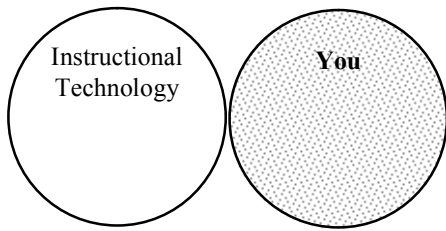The graphics below are representing the relationship between you and Instructional Technology. Using a symbol, please note where you believe you would currently align yourself.
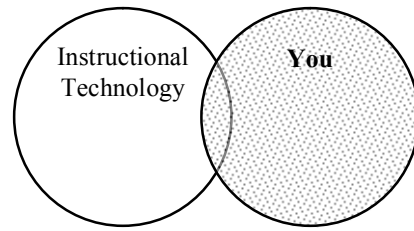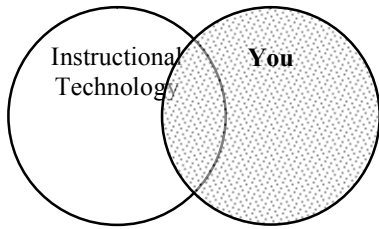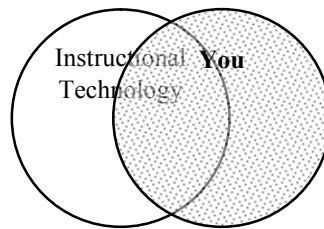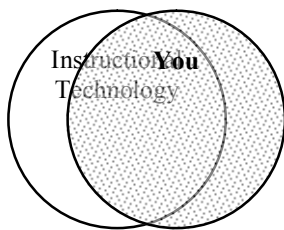
Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

How Benefits and Challenges of Personal Response System Impact Students' Continuance Intention? A Taiwanese Context

C. Rosa Yeh[1] and Yu-Hui Tao[2*]

[1]Graduate Institute of International Human Resource Development, National Taiwan Normal University, 162, Sec. 1, Ho-Ping E. Rd., Taipei, Taiwan, R.O.C. // [2]Department of Information Management, National University of Kaohsiung,700 Kaohsiung University Road, Nan-Tzu District, Kaohsiung, Taiwan, R.O.C. // rosayeh@ntnu.edu.tw // ytao@nuk.edu.tw
*Corresponding author

ABSTRACT
To address four issues observed from the latest Personal Response System (PRS) review by Kay and LeSage (2009), this paper investigates, through a systematic research, how the derived benefits and challenges of PRS affect the satisfaction and continuance intention of college students in Taiwan. The empirical study samples representative college students enrolled in three universities from each of the Northern, Central, Southern, and Eastern geographical regions in Taiwan. The results based on 406 valid returned questionnaires and partial least square analysis confirm that classroom environment and learning benefits have positive effects, whereas technology- and student-based challenges have negative effects on student satisfaction, thus influencing their intention to continue using PRS. In contrast, assessment benefits and teacher-based challenges do not have significant influences on student satisfaction. The present research contributes to literature by empirically testing PRS benefits and challenges derived from previous works, validating only the aspects that influence student satisfaction and, consequently, their behavioral intention to continue using PRS. The implications and suggestions derived from this rigorous research are highly relevant in practice. The findings enable a set of general design strategies for successful PRS implementations, providing the empirical basis for conducting future in-depth PRS research.

Introduction

The Personal Response System (PRS) (Griff, & Matter, 2008), also known as the audience response system (Bunz, 2005) or student response system (Bunce, VandenPlas, & Havanki, 2006), is a voting system (Draper, & Brown, 2004) that allows teachers to initiate a multiple-choice question exam using a computer and then displaying it on screen for the class; the students, in turn, anonymously respond to the questions through clickers. PRS allows the teacher to collect and summarize the answers in a statistical format on screen. This allows teachers to quickly assess student feedback and immediately make the necessary teaching adjustments to achieve better student learning effects. PRS has been studied extensively since a new generation of infrared PRS became available in 1999 and subsequently used after 2003 (Abrahamson, 2006).

The latest PRS review published by Kay and LeSage (2009) covers research studies from 2000 to 2007, including several earlier review papers by Judson and Sawada (2002), Fies and Marshall (2006), Simpson and Oliver (2007), and Caldwell (2007). These PRS review papers have provided rich meta-analyses of PRS literature derived through a qualitative approach, facilitating the further understanding and development of current practices of PRS in schools. Although a quantitative meta-analysis review remains the ideal method, this is not a feasible option due to the lack of empirical PRS studies in literature. Nevertheless, the abovementioned qualitative review papers agree on the considerable benefits and potential challenges of using PRS as well as its future research opportunities. Based on these, an empirical research that can validate the findings of previous studies is feasible and advantageous.

Four related PRS issues are included in the review conducted by Kay and LeSage (2009). First, specific benefits and challenges are good factors derived from the qualitative literature analysis, but these may need empirical studies to confirm the impact of the use of PRS. Second, while Kay and LeSage (2009) identify technology-based challenges in their research, few PRS studies actually involve technology-related theories in discussing ways by which to establish PRS usage in classrooms. The quantitative technology acceptance model (TAM) meta-analysis presented by King

and He (2006) revealed that technology is a potential moderating factor that can influence several model relationships. TAM is a popular technology-related theory, which proposes perceived usefulness and perceived ease of use as the two core influences of the actual use of a technology through the mediating effect of intention to use. Bhattacherjee (2001) tested the expectation confirmation theory (ECT), another technology-based theory used to predict usage. ECT compares the users' experiences and expectations and examines the effect of confirmation/disconfirmation on continuance usage. Third, Kay and LeSage (2009) suggested the expansion of PRS use in social science subjects and K-12 classrooms. For the interest of the current research, it is more favorable to obtain generalized research results by expanding the samples from a small class or single university to a larger regional or country-wide scope. Finally, Kay and LeSage (2009) studied listed systematic research with reliability and validity analyses as the first direction in relation to further studies in this research area. A rigorous research method for empirical studies is needed to achieve the goal of a systematic research with quantitative reliability and validity analyses.

To address the four issues, a path model on PRS usage is formulated, after which a rigorous empirical study is conducted, with practical relevance on PRS perceptions using college students in Taiwan as representative sample. The comprehensive procedure of structural equation modeling (SEM) for validating the measurement model and the model fitting (Gefen et al., 2000) helps achieve the objective of a systematic research with reliability and validity analyses that most PRS studies lacked. Moreover, Section 2 also presents a critical literature analysis of the review of Kay and LeSage (2009), four earlier PRS review articles, and a brief but critical review of technology-related theories. These reviews provide the context in formulating the proposed research model and in designing the empirical test as discussed in Section 3. Detailed data analysis and discussion are presented in Sections 4 and 5, respectively, followed by the presentation of conclusions in Section 6.

Background information

PRS reviews in literature

Recent studies provide adequate evidence on the positive perception of students on the use of PRS in higher education. Judson and Sawada (2002) provided the earliest summary of PRS use with 33 references from 1960 to 2000, and concluded that the pedagogical practices of the instructor, and not the technology itself, which affects student comprehension when using PRS. In contrast, Fies and Marshall (2006) reviewed the methods employed to assess PRS, including pedagogical constructs in the traditional and modern PRS systems with 21 references from 1996 to 2005. They concluded the need for concerted research efforts that can rigorously explore conditions of use across diverse settings and pedagogies. From a rigorous research perspective, Kay and LeSage (2009) commented that their selected peer-reviewed references are somewhat lacking and dated because the majority of their references included works published after 2003, prior to the established use of PRS.

Simpson and Oliver (2007) provided a summary of the pedagogical and organizational implications of PRS adoption, with corresponding perceptions of staff and students. In particular, they compared the PRS practice before and after 2000 and up to 2006 with 39 references. They concluded that both the practice and the research on PRS have matured, with a focus on the development of models seeking abstract and sharing practices. Meanwhile, Caldwell (2007) reviewed 25 peer-reviewed articles that identified the primary users of PRS, articulated the rationale for using PRS, as well as explored and questioned the strategies used by PRS. She concluded that PRS is a valuable tool for introducing and monitoring peer learning methods in the large lecture classroom. She also summarized the best practices for teachers adopting the system in terms of planning, attendance, communication with students, peer learning, grades and anxiety, preventing wasted time and frustration, writing effective questions, and other survival tips. However, Caldwell (2007) and Simpson and Oliver (2007) did not address sufficiently the impact of PRS on student learning (Kay & LeSage, 2009).

Therefore, Kay and LeSage (2009) argued that a more comprehensive review of PRS literature is needed in order to present a more current and representative summary of benefits, challenges, key problems, and future directions of PRS use. Their review is based on a very comprehensive review process of 67 papers. However, a statistical meta-analysis is not feasible because only 10 studies provided formal statistics.

The benefits of PRS are grouped into three categories: classroom environment, learning, and assessment benefits. Classroom environment benefits include attendance, attention, anonymity, participation, and engagement. Learning benefits include interaction, discussion, contingent teaching, learning performance, and quality of learning. Assessment benefits include feedback, and formative and comparative assessments.

The challenges of PRS are grouped into three categories: technology-, teacher-, and student-based challenges. Technology-based challenges include non-functional remote control devices and PRS. Student feedback, coverage, and question formulation are examples of teacher-based challenges. Student-based challenges include acceptability of new methods, discussion, effort, summative assessment, attendance for grades, identification of students, and negative feedback.

Key problems encountered by the current PRS research include the lack of systematic research methodology, bias toward using the anecdotal, qualitative data, excessive focus on attitudes as opposed to learning and cognitive processes, and inconclusive samples derived from limited education settings. The four research directions identified for future PRS research include (1) the need to determine why specific benefits and challenges influence the use of PRS; (2) the need for an in-depth research that analyzes the impact of specific types of questions on the creation of a student-centered learning experience; (3) the need for knowledge-rich learning that builds a classroom community that, in turn, facilitates the expansion of PRS to include social sciences subject areas and K-12 classrooms; and (4) the need for more research on the individual differences in the use of PRS, focusing on gender, year level, age, and learning style.

There are more research studies published after 2009 than those uncovered by Kay and LeSage. However, none of these new studies presented either a review or a meta-analysis of PRS. The majority focused on the teaching effects (Bradford, 2010) in domains such as science (Hoyt et al., 2011) and medicine (Stoddard & Piquette, 2011). Thus, the above summarized review results are still relevant and should be subjected to further evaluation.

Related technology-based theories and models

In technology-related theories, usage is typically the ultimate dependent variable, despite the various terms used to refer to it. For example, this is manifested as "adoption" in TAM-related theories and the unified theory of acceptance and use of technology (Venkatesh et al., 2003), "continuance usage" in ECT, and "success" which generally implies adoption or infusion in diffusion of innovation theory (Rogers, 1995). These information system (IS) theories are all applied in research at the individual level analysis. Usage can also be manifested at the organizational level analysis, such as "adoption" in technology, organization, and environment framework (Tornatzky & Fleischer, 1990).

In ECT, the ultimate goal is to determine the impact on usage continuance intention as mediated by satisfaction. In contrast, the IS success model (DeLone & McLean, 2003) identifies the parallel relationship between satisfaction and usage with regards their common antecedents. Therefore, satisfaction is closely related to usage as either an influencing or a mutually influencing factor.

The antecedent of satisfaction in technology-based theories may include confirmation/disconfirmation between expectation and actual perceptions of the targeted technology in ECT; it can also be quality of system, information, and service in IS success model (DeLone, & McLean, 2003). In addition, Wixom and Toad (2005) proposed a theoretical integration of user satisfaction and technology acceptance by linking the beliefs and attitudes from the object-based perspective of IS success model and the behavioral perspective of TAM.

Research methods

Based on the research questions and knowledge obtained from the review of previous literature, a description of the research model and hypotheses are provided in Section 3.1. This is followed by Section 3.2, which presents the description of the design of the empirical study.

Model and hypothesis development

Satisfaction is used to measure technology-based applications in education research. For example, So and Brush (2008) found high collaborative learning affects satisfaction, whereas Wu et al. (2010) concluded that performance expectation and learning climate affects satisfaction in blended e-learning systems. DeBourgh's (2003) research on an e-Learning nursing course found good pedagogy to be an influential factor affecting students' perceived satisfaction, whereas Tao et al. (2009) found that learning performance and playfulness affect user satisfaction in business simulation games. For PRS, Carnaghan and Webb (2007) empirically investigated the casual effect of PRS on learning outcome and satisfaction in accounting education; in comparison, nearly all PRS studies were descriptive and reported high levels of student satisfaction (Judson, & Sawada, 2002).

In the conclusions on benefits and challenges made by Kay and LeSage (2009), they inferred that benefits should have positive influences, whereas the challenges should have negative influences on student satisfaction. Thus, the current study presents its hypotheses on the influence of the benefits and challenges of PRS on user satisfaction below.
H_1 PRS benefits have positive effects on satisfaction.
H_{1-1}. Classroom environment benefits have positive effects on satisfaction.
H_{1-2}. Learning benefits have positive effects on satisfaction.
H_{1-3}. Assessment environment benefits have positive effects on student satisfaction.
H_2 PRS challenges have negative effects on satisfaction.
H_{2-1}. Technology-based challenges have negative effects on satisfaction.
H_{2-2}. Teacher-based challenges have negative effects on satisfaction.
H_{2-3}. Student-based challenges have negative effects on satisfaction.

DeLone and McLean (1992) reviewed the existing definitions of IS success and their corresponding measures, and classified them into six major categories, in which user satisfaction and use are mutually influenced. In their revised IS success model (2003), the relationship between user satisfaction and use has been refined into the following: User satisfaction influences intention to use, while use influences user satisfaction. Therefore, satisfaction is deemed closely related to usage as either an influencing or a mutually influencing factor.

Extending the use to continuance usage, Bhattacherjee (2001) provided evidence for extending ECT in IS domain, such that satisfaction significantly influences intention to continuance usage. The application of ECT can also be found in educational settings, such as business simulation games (Tao et al., 2009) and e-learning systems (Hernandez et al., 2011). Hence, the hypothesis below is proposed.
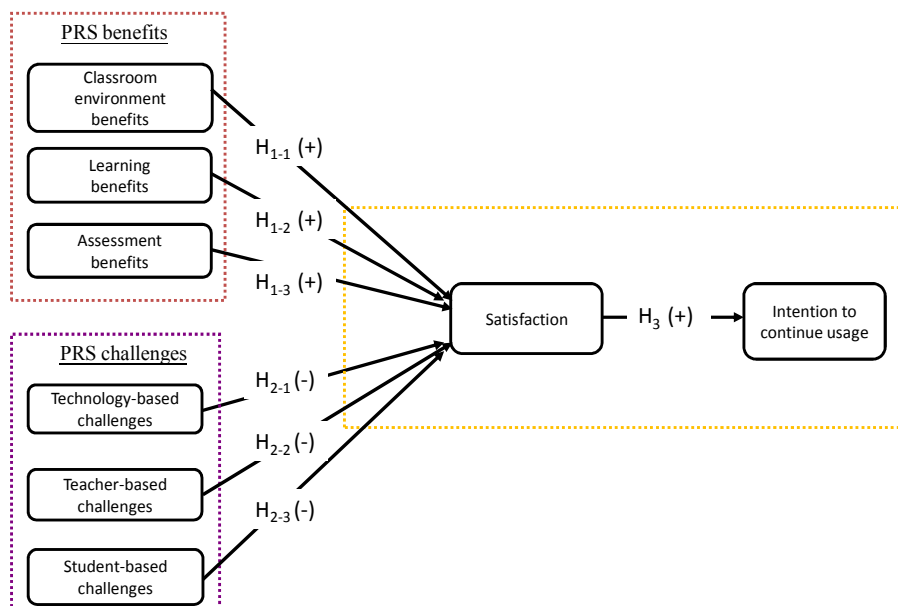H_3. Student satisfaction has positive effects on the intention to continue usage.

Figure 1. The proposed integrated model

The integrated research model shown in Figure 1 is formulated to explore a general and simple IS model format for the investigation of the impact of PRS benefits and challenges on usage continuance intention, which is mediated by satisfaction.

Research design

Section 3.1 addresses the first two issues and this section addresses the remaining two issues. Regarding the third issue, the objective of this study is to obtain results that are representative of the 164 higher educational institutions of Taiwan. Therefore, the target population comprises college students who have used PRS systems in their classes. The Taiwan research population loci are divided into the Northern, Central, and Southern regions. Several studies added the Eastern geographical regions as well. To ensure that all of the Taiwanese regions are well represented, the sample populations were selected from three universities in each of the four regions. The sampling approach was employed to identify the teachers in each university who were willing to assist in the distribution of the questionnaires to students in PRS classes.

The student questionnaire had four sections. The first section consisted of items that collected data to measure PRS benefits. The second section collected data on PRS challenges. Both sections were based on the 13 benefits and 12 challenges summarized by Kay and LeSage (2009). However, there were only two items on the technology-based challenges. Moreover, one of the items on "bringing" the remote control devices, was not applicable to most situations in Taiwan. For this reason, alternative items were added to replace the inapplicable question. New items were also created to complete the total number of questions in this variable to three. The third section collected data on satisfaction and the intention to continue usage based on Bhattacherjee (2001), with minor modifications to reflect the targeted PRS technology and the specific setting for future PRS classes addressed in the current study. Four questions on satisfaction and four questions on the intention to continue usage were included. The last section collected data on four personal profile items, including sex (male vs. female), school location (Northern, Central, Southern, or Eastern), and class performance (top 25 %, top 50 %, top 75 %, or bottom 25 %). The Appendix provides the detailed listing of questionnaire items and corresponding sources. Students were asked to respond to each questionnaire item of the first three sections using a 7-point Likert scale, with 1 representing "extremely disagree" and 7 representing "extremely agree."

To address the last issue, a systematic research with reliability and validity analyses was conducted. The analytical method used for the descriptive statistics was SPSS. Partial least square (PLS)-based SEM was used on the path model to assess the impacts of PRS benefits or challenges on satisfaction and continuance intention.

Analysis

Sample profile

A total of 406 valid questionnaires were returned. The descriptive statistics for the five profile variables are shown in Table 1. Female students account for twice the percentage of male students, which may be attributed to the classes selected for data collection. Except for the schools located in the South, which account for almost 50% of the samples, students from the three other locations have a fairly even gender distribution. The main reason for the greater number of responses from the Southern region is the more enthusiastic response we received from volunteer teachers from this area in terms of monitoring and collecting the questionnaires from their students, compared with those of teachers from the three other regions. Given that the teachers were recruited through a consistent approach, it is reasonable to retain the full data for the following analyses.

Approximately 5% of the students considered themselves to be at the bottom 25% of the overall class performance, whereas the majority evaluated themselves as part of the upper 25% to 50%. The participation of college students was representative of the range from freshman to senior, with greater than 10% participation from each year level. Only a small percentage (3.2%) of graduate students participated in this investigation.

<div align="center">Table 1. Student profile</div>

Gender:	Male	131(32.3%)	Female	263(64.8%)
Location:	North	56 (13.8%)	Central	80 (19.7%)
	South	201 (49.5%)	East	59 (14.5%)
Expected class performance:	Top 25%	72 (17.7%)	Top 50%	223 (54.9)
	Top 75%	77 (19%)	Bottom 25%	20 (4.9%)
Year level:	Freshman	87 (21.4%)	Sophomore	155 (38.2%)
	Junior	86 (21.2%)	Senior	48 (11.8%)
	Graduate	13 (3.2%)		

Measurement model validation

Descriptive statistics was used to derive the means and standard deviation (S.D.) of the eight variables in the proposed integrated model. The Smart PLS software for PLS-SEM developed by Ringle et al. (2005) was utilized to analyze the path model. The second column in Table 2 displays the descriptive means and S. D. of all the variables after data screening for the qualified factor loading, composite reliability, and average variance extracted (AVE) values, as a measure of the shared or common variance in a latent variable. In general, the mean scores of the three benefits that exceed 5 on a 7-point Likert scale indicate a relatively positive perception of PRS benefits. Meanwhile, teacher- and student-based challenges that are rated slightly below 4 are expressions of neutral to moderately lower perceptions of PRS challenges. Technology-based challenges that are rated slightly above 4 indicate neutral to moderately higher perceptions of this challenge. Regarding the two outcome variables, namely, satisfaction and continuance usage, both are rated positively because their mean scores are closer to the positive value of 5.0.

The SEM path model analysis includes the measurement model and model fitting. The PLS measurement model includes item reliability (factor loading), composite reliability, and AVE and its square root. After excluding items with factor loadings below 0.7, a minimum hurdle suggested by Fornell and Larcker (1981), the new factor loadings all exceed the value 0.7, as shown in the fourth column. One exception is the IBC3, under the teacher-based challenges, which has a value slightly lower than 0.7; however, this has been retained for evaluating the IBC construct with at least two measurement items in the model. The convergent validity is further examined to determine whether or not the AVE is greater than 0.5 (Fornell, & Larcker, 1981). The sixth column shows that all AVE values are greater than 0.5, thereby indicating good convergent validity.

<div align="center">Table 2. Descriptive statistics and reliability</div>

Variables	Mean/S.D.	Items	Factor loading (>0.7)	Composite reliability (>0.7)	Average variance extracted (AVE) (>0.5)
Technology-based challenges (TBC)	4.13/1.42	TBC1	0.83	0.90	0.75
		TBC2	0.89		
		TBC3	0.88		
Teacher-based challenges (IBC)	3.78/1.08	IBC1	deleted	0.77	0.64
		IBC2	0.95		
		IBC3	0.60		
Student-based challenges (SBC)	3.50/1.37	SBC1	0.74	0.91	0.71
		SBC2	0.75		
		SBC 3	0.80		
		SBC 4	0.82		
		SBC 5	deleted		
		SBC 6	deleted		
		SBC 7	deleted		
Classroom environment benefits (CEB)	5.09/1.03	CEB1	deleted	0.87	0.68
		CEB 2	0.83		
		CEB 3	deleted		
		CEB 4	0.79		
		CEB 5	0.87		
Learning benefits (LB)	5.06/1.02	LB1	0.74	0.89	0.63

		LB2	0.75		
		LB3	0.80		
		LB4	0.82		
		LB5	0.84		
Assessment benefits (AB)	5.33/1.00	AB1	0.89	0.88	0.71
		AB2	0.87		
		AB3	0.76		
Satisfaction (SAT)	4.94/1.20	SQ1	0.94	0.97	0.88
		SQ2	0.95		
		SQ3	0.94		
		SQ4	0.92		
Intention to continue usage (USE)	4.78/1.23	USE1	0.95	0.93	0.88
		USE2	0.93		
		USE3	deleted		

Discriminant validity can be determined by the square root of AVE, which is higher than the correlations with other constructs. In Table 3, the square roots of AVE in the diagonal column are all higher than the construct-pair correlations, indicating adequate discriminant validity in all variables. The evidence suggests that the overall reliability and validity of the data set with seven items deleted are adequate. Table 3 also shows the negative correlations between the three challenge constructs (TBC, IBC, and SBC) and all other constructs, providing initial evidence that those challenges do have negative impacts on satisfaction.

Table 3. Discriminant validity analysis

Constructs	AVE	Correlation of Constructs							
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TBC(1)	.75	.87[a]							
IBC(2)	.64	.40	.80						
SBC(3)	.71	.40	.61	.84					
CEB(4)	.68	-.12	-.08	-.28	.82				
AB(5)	.71	-.15	-.18	-.34	.60	.84			
LB(6)	.63	-.14	-.17	-.34	.71	.74	.79		
SAT(7)	.88	-.28	-.18	-.41	.55	.50	.59	.94	
USE(8)	.88	-.21	-.10	-.37	.50	.44	.52	.81	.94

Note. [a] Each of the diagonal $\sqrt{AVE}$ value is required to exceed the construct AVE value, and other related coefficients of the non-diagonal construct values.

Hypothesis testing results

The results of the hypotheses tests are shown in Table 4. As can be seen, classroom environment and learning benefits are positively related to student satisfaction at 0.01 and 0.001 levels, respectively, whereas the assessment benefits are not. Similarly, from among the three challenges, only technology- and student-based challenges are negatively related to satisfaction at 0.01 level; teacher-based challenges are not significant at all. Satisfaction is positively related to continuance usage intention at 0.001 level. Accordingly, both H_1 and H_2 are partially but strongly supported. Meanwhile, H_3 is fully supported by data that are similar to those reported in numerous ECT research studies.

Table 4. Integrated research model and results

Research hypothesis		t value	Results
H_1	H_{1-1}. Classroom environment benefits have positive effects on satisfaction.	2.70**[a]	Supported
	H1-2. Learning benefits have positive effects on satisfaction.	4.60***[b]	Supported
	H_{1-3}. Assessment benefits have positive effects on student satisfaction.	0.72	Not supported
H_2	H_{2-1}. Technology-based challenges have negative effects on satisfaction.	3.06**	Supported
	H_{2-2}. Teacher-based challenges have negative effects on satisfaction.	1.55	Not supported
	H_{2-3}. Student-based challenges have negative effects on satisfaction.	2.72**	Supported

| H_3 | Student satisfaction has positive effects on the intention to continue usage. | 27.30*** | Supported |

Note. [a] *** Significant at 0.001. [b] ** Significant at 0.01.

The final path model is presented in Figure 2. The R square values are 0.45 and 0.66 for satisfaction and intention to continue usage, respectively. These are high levels according to Cohen (1977), thus indicating a superior explanation power of the research model.
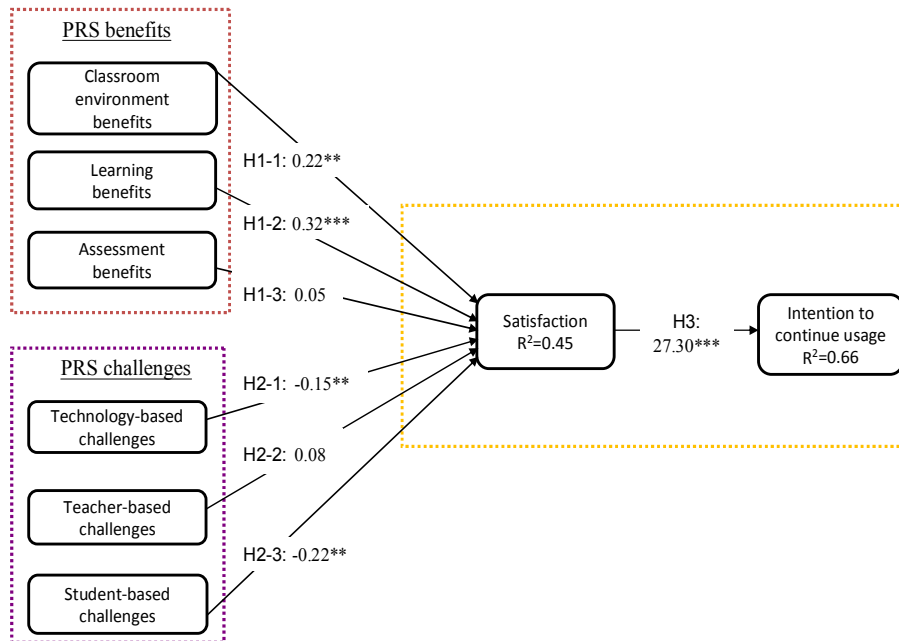
Figure 2. Integrated research model and results

Discussion and implications

Four implications may be derived along with the discussion of the outcomes obtained in Section 4, followed by a suggestion for the higher education institutes in Taiwan facing PRS implementation.

The first implication is that the teachers and school administrators must prioritize their efforts to better manage their PRS implementation by promoting higher student awareness on classroom environment benefits and learning benefits to increase student satisfaction. They can also achieve this by addressing critical issues related to technology- and student-based challenges, thus reducing student dissatisfaction. This implication is based on the hypothesis testing result of the present empirical study, which found that classroom environment benefits (H_{1-1}) and learning benefits (H_{1-2}) have positive influences, whereas technology-based challenges (H_{2-2}) and student-based challenges (H_{2-3}) have negative influences on student satisfaction (see Table 4). These efforts can eventually help enhance the behavioral intention of students in Taiwan to continue to using PRS. Furthermore, classroom environment benefits and learning benefits also received more favorable ratings from the students, with positive mean scores of 5.09 and 5.06 (see Table 2), respectively; this should be emphasized when promoting PRS usage. Table 2 shows that student-based challenges have a mean score of 3.50, indicating fairly low student perceptions on these factors as challenges. Thus, teachers and school administrators may find it easier to overcome such challenges. However, students perceive technology-based challenges to be neutral or moderate with a mean score of 4.13, indicating the need for further investments on the procurement and maintenance of PRS technology.

T**he second implication** is that more research and development efforts on deployment strategies may be needed by the teachers and school administrators of Taiwan to effectively implement PRS assessment that, in turn, fulfills its promises of generating positive benefits to influence student satisfaction toward continuance usage. The rationale behind this implication lies in the two rejected hypotheses related to assessment benefits (H_{1-3}) and teacher-based

challenges (H$_{2-2}$), as shown in Table 4. The descriptive analysis in Table 2 indicates a lower level of student agreement on teacher-based challenges (3.78) and a higher level of agreement on assessment benefits (5.33). The unexpected results deserve more attention and discussion than the supported hypotheses. For the assessment benefits (H$_{1-3}$), the descriptive statistics provided by Tao and Yeh (2009) suggest that the teachers in Taiwan have failed to facilitate PRS at a level that would have allowed the effective use of student feedback. Moreover, the teachers failed to a) utilize the PRS assessment to detect the occasions when students have certain misconceptions and b) initiate appropriate discussions to promote student comprehension. The reason why teachers do not use PRS assessment may be attributed to the fact that students resent PRS quizzes or simulation tests, because these are associated with attendance monitoring and the requirement to accumulate points as evidence of their participation (D'Arcy et al., 2007; Tao & Yeh, 2009). This is also evident from the descriptive statistics obtained, in which Taiwanese students felt strongly about questionnaire items on student-based challenges, such as summative assessment (SBC4) and attendance for grades (SBC5). Hancock (2010) concluded that although synergy exists when formative and summative tests using PRS are combined, the students are sensitive as to how the assessments have been designed by the instructors.

Meanwhile, the insignificant negative influence of the teacher-based challenges (H$_{2-2}$) may be attributed to the inability of students to experience or understand the challenges from the teacher's perspective in relation to the task of responding to student feedback (IBC1) and the process by which the questions have been developed (IBC3). The insignificant negative influence may also be attributed to the fact that the teachers may have failed to make their complaints known or reveal any challenges they experienced in class, such as the issue of limited academic coverage (IBC2). In fact, these challenges have been observed by Tao and Yeh (2009) and d'Inverno et al. (2003). In contrast, it is also reasonable to believe that these challenges may have more impacts on the teachers than on the students. Therefore, student perceptions on this category of challenges may not be as significant compared with their perception in the two other categories.

The third implication lies in the finding that actually presents a good opportunity for teachers and school administrators in Taiwan: the potentially negative impact of teacher-based challenges is not significant from the students' perspective (H$_{2-2}$). Although it would have been better to assess the teacher-based challenges from the teachers' perspective, the students' perceptions present valuable feedback to the teachers, encouraging them to continue implementing PRS in the classroom even if the course content may not be fully covered (IBC2) and PRS questions are too few or not always well designed (IBC3). This is particularly encouraging because the mean score of teacher-based challenges in Table 2 is 3.78, indicating a moderately lower to neutral student perceptions on these teacher-related factors as challenges. Therefore, teachers should not let those teacher-based challenges hinder their use of PRS.

The fourth implication is that more in-depth studies may be needed to explore the differences between Taiwan and Western countries, such as the United States, in teacher-student dynamics in the context of using PRS. This approach may help explain the gap between Western literature and the results of the present study on assessment benefits (H$_{1-3}$) and teacher-based challenges (H$_{2-2}$). The rationale for this implication is that the benefits and challenges derived from literature should all have significant impacts on satisfaction. However, the present empirical study could not prove the assessment benefits and teacher-based challenges, which have been derived from Western studies. The higher mean score of assessment benefits (5.33) among the three benefit variables, and a moderately lower mean score of teacher-based challenges (3.78) further support the need for an investigation that can determine why these are not related to student satisfaction in Taiwanese context.

One feasible and general approach for sustaining the positive benefits and minimizing the impacts of negative challenges is to enhance the PRS service capability of the teachers' resource centers, which can be easily found in the higher education institutes in Taiwan and other colleges worldwide. Currently, very few schools in Taiwan have undertaken full-scale implementations of PRS, and most of these do not provide adequate PRS-related support to their faculty, if they do provide it at all. Regardless of the scale of such implementations, one quick solution, for example, to bridge the assessment benefits-satisfaction gap is to provide teachers with better training and consultation sessions as well as promote PRS benefits through planned student activities. Teachers' resource centers are in the best position to organize these support activities, taking into consideration extant PRS research outcomes and the distribution of this knowledge to individual teachers before PRS is formally used in course delivery.

Conclusions

Addressing four PRS issues observed from the recent review by Kay and LeSage (2009), an empirical study employing a systematic approach (issue 4) which conducted a survey of college students throughout Taiwan (issue 3), the current research validates the influence of the challenges and benefits (issue 1) classified by Kay and LeSage (2009) on PRS continuance usage as mediated by student satisfaction (issue 2). The resulting model (Figure 2) demonstrates that learning and classroom environment benefits have positive influences, whereas technology- and student-based challenges have negative influences on student satisfaction, thus strongly and positively influencing behavioral intention for PRS continuance usage, respectively. These PRS challenges and benefits obtained from the qualitative review of Kay and LeSage (2009) are only partially validated in the Taiwanese context.

The primary research contribution of this study is that it combines research rigor with relevance in practice (Robey & Marcus, 1998). It systematically tested issues on PRS implementations that have been presented by extant non-systematic, but practical research. Based on the empirical results, four implications have been derived, and one general solution is suggested for PRS research and practice. These serve as good references that can help both school administrators and teachers determine resource allocations on PRS implementation and better deploy effective strategies when adopting PRS in classroom teaching and learning, respectively.

Although this research is conducted in Taiwan, a set of universal guidelines can also be derived from the findings, which can be applied by teachers worldwide and help them adopt PRS more successfully in the classroom. First, teachers are advised to familiarize themselves with PRS implementation issues that have been discussed in reputable literature, such as Caldwell (2007) or the PRS book by Duncan (2005). These issues include planning, attendance, communication with and dynamics among students, grades, and other technical tips. Second, instead of a full-blown implementation, gradually scaling up the use of PRS in classroom activities is a better alternative, starting with light, and perhaps, fun activities to overcome student perceptions that PRS usage leads to more confusion and effort. Third, the teacher or the teaching assistant should come earlier before each class to ensure that the PRS and remote devices are functioning properly. Fourth, PRS must be used to check student comprehension of key learning points, while making it clear that the purpose is to clarify misconceptions and modify instructions when necessary, instead of testing the students. Fifth, PRS must be used in group activities to increase the levels of student engagement and peer discussion. Finally, students must be recognized and immediately rewarded when they demonstrate better performance in a learning activity using PRS. These design strategies create the appropriate learning environment as suggested by classroom environment benefits and learning benefits. Doing so can enhance the students' perceived satisfaction, while minimizing the hurdles of technology- and student-based challenges and avoiding negative perceptions of PRS usage at the same time.

Three future research directions can be suggested. First, the resulting model in this research can be made more comprehensive by supplementing the perceptions of the teacher counterparts in future research. Meanwhile, as suggested in the fourth implication above, further research into the differences of student perceptions and behaviors in classrooms between the West and Taiwan may be needed, because several perceptional differences toward PRS usage have been observed. Finally, other in-depth PRS research suggestions from five PRS review papers should also be validated empirically using existing theories.

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Appendix: Questionnaire Items and Sources

CEB - Classroom environment benefits (Kay, & LeSage, 2009)	
	Using PRS enables students go to class more.
	Using PRS enables students to be more focused in class.
	Using PRS enables students to participate anonymously.
	Using PRS enables students to participate with peers more in class to solve problems.
	Using PRS enables students to be more engaged in class.
LB - Learning benefits (Kay, & LeSage, 2009)	
	Using PRS enables students to interact more with peers to discuss ideas.
	Using PRS enables students to actively discuss misconceptions to build knowledge.
	Using PRS enables the instruction to be modified based on feedback from students.
	Using PRS enables the learning performance to increase.
	Using PRS enables qualitative differences in learning.
AB - Assessment benefits (Kay, & LeSage, 2009)	
	Using PRS enables the students and teacher to get regular feedback on understanding..
	Using PRS enables the assessment to be done to improve student understanding and quality of teaching.
	Using PRS enables students to compare their own response to class response.
TBC - Technology-based challenges (Kay, & LeSage, 2009 or this research)	
	The remote or system setup was not ready on time and caused the class delay its progress onsite.
	Remote devices did not function properly.
	The overall system did not function properly.
IBC - Teacher-based challenges (Kay, & LeSage, 2009)	
	I think less experienced teachers cannot adjust to student feedback.
	I think the use of PRS often make the teachers short of time to cover the course content.
	I think designing good PRS questions will cost a lot of teacher's time.
SBC - Student-based challenges (Kay, & LeSage, 2009)	
	Students find it difficult to shift to a new way of learning.
	Discussion leads to confusion or wasting time.
	Too much effort is required by students when using ARSs.
	Using ARS for tests may not be popular with students.
	Students do not like ARS used for monitoring attendance.
	Students want to remain anonymous.
	Students feel bad when receiving negative feedback.
SAT - Satisfaction (Bhattacherjee, 2001)	
	My overall experience of PRS is very satisfied. 。
	My overall experience of PRS is very pleased.
	My overall experience of PRS is very contented.

	My overall experience of PRS is absolutely delighted
USE - Intention to continuance usage (Bhattacherjee, 2001)	
	I want to continue using PRS in future classes rather than discontinue its use.
	My intentions are to continue using PRS rather than any alternative means in future classes.
	If I could, I would like to *dis*continue use of PRS in future classes.

Game-Based Remedial Instruction in Mastery Learning for Upper-Primary School Students

Chun-Hung Lin[1], Eric Zhi-Feng Liu[1*], Yu-Liang Chen[2], Pey-Yan Liou[1], Maiga Chang[3], Cheng-Hong Wu[4] and Shyan-Ming Yuan[5]

[1]Graduate Institute of Learning and Instruction, Center of Teacher Education, Research Center for Science and Technology for Learning, National Central University, Jhongli City, Taoyuan, Taiwan // [2]Department of Information management, Ta Hwa Institute of Technology, Hsinchu County, Taiwan // [3]School of Computing and Information Systems, Athabasca University, Alberta, Canada // [4]Department of Computer Science & Information Engineering, Asia University, Taichung, Taiwan // [5]Department of Computer Science, National Chiao Tung University, Hsinchu, Taiwan // sjohn1202@gmail.com // totem@cc.ncu.edu.tw // imklchen@gmail.com // lioupeyyan@gmail.com // maiga@ms2.hinet.net // smyuan@cs.nctu.edu.tw

[*]Corresponding author

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ABSTRACT

The study examines the effectiveness of using computer games for after-school remedial mastery learning. We incorporated instructional materials related to "area of a circle" into the popular Monopoly game to enhance the performance of sixth-grade students learning mathematics. The program requires that students enter the answers to avoid the shortcomings of multiple-choice questions. Throughout the game, whenever students are unable to answer questions correctly they receive immediate remedial instruction specifically for that question. This study sought to compare the effectiveness of game-based and video-based remedial instruction incorporated with elements of mastery learning. The results demonstrate that (a) both instructional videos and the proposed Monopoly game enhance the learning of mathematical concepts; and (b) the Monopoly game is more effective than instructional videos at leveraging the benefits of mastery learning. The goal of the research was to integrate games and mastery learning into after-school remedial instruction and design a game to practice the steps of mastery learning.

Keywords

Game-based learning, Remedial instruction, Mastery learning, Learning effectiveness

Introduction

The recent application of different multimedia, such as videos (Sedaghat, Mintz, & Wright, 2011) or digital games to the field of education to enhance learning is an important development (Hwang & Wu, 2012; Liu & Lin, 2009; Liu, 2011; Sancho, Moreno-Ger, Fuentes-Fernandez, & Fernandez-Manjon, 2009; Susaeta, Jimenez, Nussbaum, Gajardo, & Andreu et al., 2010). Digital games are a form of entertainment, and therefore an effective tool for motivating students to engage in learning activities (Prensky, 2003). Those studies indicated that games have great potential to motivate students to engage in the learning process than other media. Due to the characteristics, recently, more and more digital games have been applied into diverse disciplines, such as English (Liu & Chu, 2010), mathematics (Chang, Wu, Weng, & Sung, 2012), computer science (Papastergiou, 2009) and so on. Many studies have found that game-based learning is an effective way to enhance students' learning motivation and learning performance (Chuang & Chen, 2009; Virvou, Katsionis, & Manos, 2005). O'Neil, Wainess, and Baker (2005) indicated that the alignment between game design and instructional design has a great impact on the effectiveness of students' learning. Therefore, considering how to design the digital game to fit the need of learning activities is the keystone of game-based learning (Kebritchi & Hirumi, 2008).

In order to close the achievement gaps between high and low achieving students, it is important to consider how to help students with low achievement improve their learning performance. Scholars in the field of educational research have suggested that teachers should pay more and more attention to individual differences when teaching and providing remedial instruction for students with low achievement (Lo, Wang, & Yeh, 2004; Yang, 2010). In order to remedy the shortcoming of traditional teacher-centered instruction that ignores the need of students with low achievement, Bloom (1968) proposed the idea of mastery learning. Mastery learning is an instructional method which allows students to take their time to achieve the learning goals. In mastery learning, the learning content would be broken down into several small learning units, and only the students acquire the prerequisite knowledge or

skills can move to the next learning unit. Some studies have shown that mastery learning can help teachers to diagnose students' weakness, and show positive effect on students' learning attitude (Changeiywo, Wambugu, & Wachanga, 2011) and learning performance (Wambugu & Changeiywo, 2008; Yildiran & Aydin, 2005). However, most of the studies integrated mastery learning in a formal classroom context (LeJeune, 2010; Marshall, 2009), and few studies discussed the effect of mastery learning on students' learning performance in a remedial instruction context. Therefore, in this study, we try to design a monopoly game based on mastery learning for remedial instruction, and further investigate the effect of the game on students' learning performance.

For the structure of the paper, the literature review about the relationship between educational games and remedial instruction as well as the role of mastery learning in remedial instruction was examined first. Following the section of literature review, the specific research questions were proposed. Second, the section of research methods was stated to investigate the effectiveness of the instructional video and the monopoly game on enhancing master learning. Furthermore, the section of game design section was presented to show the details of the learning content of monopoly game and the characteristics of the monopoly game for this study. Fourth, the section of results was shown to answer the research questions. Finally, conclusions and discussion were offered to highlight the contributions and significance of the study.

Literature review

Educational games and remedial instruction

Game-based instruction is an important method of learning. It has been found that games evoke in players the experience of flow and positive emotions (Chiang, Lin, Cheng, & Liu, 2011). A number of studies have found that the application of video games can enhance learning motivation, and learning attitudes (Lin & Liu, 2009; Papastergiou, 2009). Researchers in education have consistently argued that allowing students to study by playing would be a more effective way to improve the quality of education than endeavoring to develop new teaching materials or methods. After personally engaging in various electronic games, Gee (2007) discovered that many of the most inspired electronic toys contain important learning principles. Unlike other forms of media, games are capable of simulating the world as perceived by children, which increase their willingness to be engaged. Game-based learning theory is grounded in the concept that a competitive game environment requires students to actively participate, thereby increasing their desire to learn. Teachers who use educational computer games enhance the imagination of their students. In addition to entertaining students, games can help students to develop thinking skills (Seonju, 2002).

Instructional content expressed in a game format can hold learners' attention, and help to increase their learning motivation (Lin & Liu, 2009). Educational computer games that utilize sound, light, images, and animation can be designed to target students of a particular age. This provides an immersion environment to inspire students through the engagement in a competitive scenario. Due to the characteristics, the concept of game-based learning was applied in different domains, such as mathematics (Ke, 2008), vocabulary learning (Frederick, 2010), civil engineering (Ebner & Holzinger, 2007), and problem-solving ability (Shih, Shih, Shih, Su, & Chuang, 2010). Tüzün, Yılmaz-Soylu, Karakuş, İnal, and Kızılkaya (2009) designed a 3D computer game to teach geography to students in primary school, and the results demonstrated an increased success rate over traditional teaching methods. Papastergiou (2009) demonstrated that senior high-school students using game-based learning methods retained information about computer memory more efficiently than their counterparts who did not use games. Yien, Hung, Hwang, and Lin (2011) designed an educational game for elementary school students in a nutrition course, and they found that game-based learning can enhance students' learning achievement and attitude. Additionally, Liao (2010) analyzed 38 studies to compare the effectiveness of game-based learning and traditional instruction, and found that game-based learning is more effective than traditional instruction in Taiwan.

Although more and more researchers and teachers applied educational games into instruction to assist their students' learning (Charlton, Williams, & McLaughlin, 2005; Holmes, 2011), however, a consensus has yet to be reached regarding the influence of computer games on the cognitive processes involved in learning. To investigate the influence of video games on learning, Chuang and Chen (2009) designed a quasi-experimental study to evaluate the differences between educational games and traditional computer assisted instruction. They found that students receiving game-based instruction showed significant improvement in their ability to recall facts and in their problem-solving skills. Nevertheless, other researchers found no significant improvement in learning, despite the fact that educational games

enhance learning motivation and learning attitude (Ke, 2008; Lin & Liu, 2009). When designing educational games, designers must consider both entertainment and education (Lin & Liu, 2009). Unlike regular computer games, educational games must be based on appropriate instructional theory and integrate suitable teaching strategies to ensure the effectiveness of the games in the promotion of learning.

Mastery learning in remedial instruction

According to mastery learning theory (Bloom, 1981; Carroll, 1963), different students require different durations of study to attain the same degree of mastery. Bloom suggested that despite the use of nontraditional instructional methods, most educators in school settings continue to set fixed amounts of time to complete the educational content and then assess the students according to the degrees of mastery they attain. When applying the concepts of mastery learning to the design of courses, teachers should divide the curriculum into smaller units and set goals for each unit in advance (Anderson, 2000). Students learn the units in a logical sequence and are expected to demonstrate an appropriate degree of mastery (for example, 80%) in each unit before progressing to the next. Students who did not reach the requisite degree of mastery would receive remedial instruction (Davis & Sorrel, 1995). Bloom claimed that mastery learning increases proficiency and encourages positive attitudes and interest in studying (Guskey, 2007). Bloom emphasized that mastery learning is applicable to most school subjects, particularly those with a sequential nature such as science and mathematics (Guskey & Gates, 1986). Master learning has been applied to a wide range of disciplines in primary education, such as physics (Francis, Figl, & Savage, 2009; Wambugu & Changeiywo, 2008), computer science (LeJeune, 2010), and mathematics (Bowen, 2008). Yildiram and Aydin (2005) found that mastery learning significantly enhanced junior high school students' learning in mathematics, beyond what is possible using traditional instruction. Ritchie and Thorkildsen (1994) found that mastery learning helped fifth grade students perform better in mathematics learning.

There are two fundamental issues associated with mastery learning: setting aside time after class to perform remedial instruction and allowing students to study at their own pace. To address the former issue, it is our hope that engaging students in computer games will encourage them to set aside time for remedial instruction. To deal with the latter issue, we created a video game based on the board game, Monopoly, in which the learning content was divided into small units following a logical sequence based on the findings of Lalley and Gentile (2009). Students who are unable to meet a set academic standard (at a given checkpoint) receive remedial instruction for the corresponding unit by watching a remedial instructional video repeatedly until they become proficient in that unit. This arrangement ensures that students are able to progress at their own pace in the proper sequence.

The purpose of the study was to design an educational game based on mastery learning theory for after-school remedial instruction, and examine the effect of game-based remedial instruction on students learning mathematics. Three research questions are listed below:

1. Can the use of an instructional video enhance mastery learning?
2. Can the use of the Monopoly game enhance mastery learning?
3. To what extent do differences in mastery learning appear after employing the Monopoly game and after showing the instructional video?

Methods

According to the previous literature, computer games can increase academic performance if they are used appropriately. In this study, an educational game was used for the experimental group while educational videos were used for the control group. The purpose of the study was to investigate whether both approaches to instruction are able to enhance the effectiveness of mastery learning. In addition, we examined the effectiveness of web-based remedial instruction in enhancing the learning of mathematics by providing a customized Monopoly game and self-produced educational videos.

Participants

Nonrandom cluster sampling was employed to select students from 6 sixth-grade classes. All subjects expressed a desire to participate in remedial instruction. Following completion of a pretest assessment, the participating students

were divided into an experimental group and a control group based on the average scores for male and female students. Each group consisted of 20 males and 13 females for a total of 66 participants; however, during the experiment, four students (two were male and two were female) dropped out. The data for the four students were subsequently excluded, such that only 62 students were analyzed in the study. In the end, the experimental group included 18 males and 12 females (a total of 30 students) and the control group included 20 males and 12 females (a total of 32 students).

Research design

This study focused on the results of remedial instruction administered to students with a prerequisite knowledge of a particular unit of study who however failed to meet the standard scores required for the unit. Therefore, we first administered an assessment test, and students who failed to demonstrate the requisite knowledge were excluded from participation in the study. Participants were then divided into a control group and an experimental group. The students in both groups received the same instruction with the same learning content. Following the lecture, the students were assigned a written assessment, the results of which determined whether they should undergo remedial instruction.

Students in the control group, who failed to reach the desired standard (less than 80 points) according to a formative measure, used headphones and a computer in an e-classroom to watch an online instructional video. When students encountered a problem they could not solve, they could choose to watch a video pertaining to that question category. The students were allowed to watch the video and review the supplementary materials as many times as they wished. At the same time, students who reached the standard (more than 80 points) received extended instruction.

Students in the experimental group who failed to reach the standard according to the same formative measure used headphones and a computer in an e-classroom to play the Monopoly game. When they completed the game, they received extended instruction along with other classmates who reached the standard. The remedial instruction lasted 40 minutes, during which time the students in the experimental group and those in the control group engaged in the Monopoly game or online instructional video, respectively. Following the remedial instruction, a post-test exam, similar to the pre-test exam was conducted to evaluate the learning achievement of the students. The study process is presented in Fig. 1. Finally, a t-test was conducted to determine whether the results from the control and experimental groups showed significant differences. Because the study focused on students requiring remedial instruction, we excluded the data of the students who reached the standard (i.e., more than 80 in the pretest), and analyzed only the data of students who scored less than 80 on the pre-test.
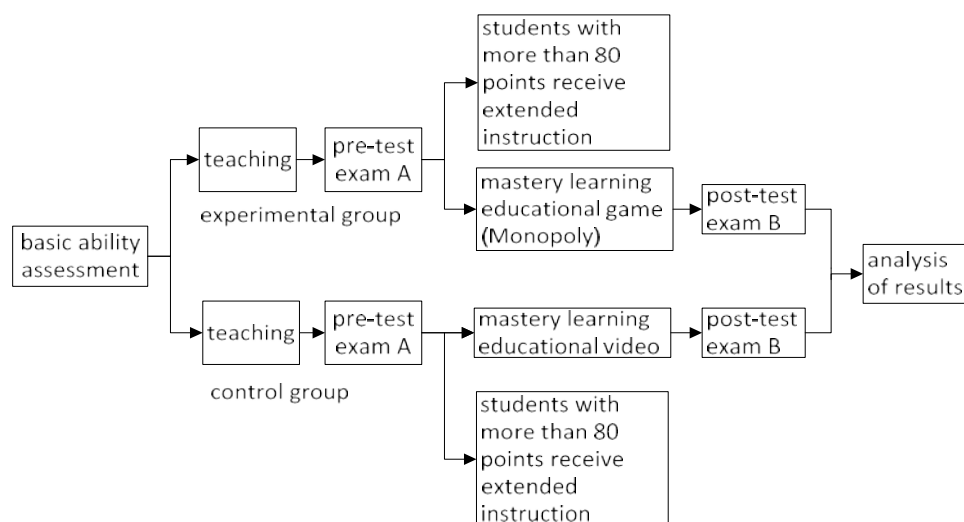
Figure 1. Flow chart of the experimental design

Game design

The goal in designing the proposed game was to optimize the benefits of mastery learning by incorporating this teaching approach within a program provided for after-school remedial instruction. In so doing, we ensured that the study objectives were aligned with the learning objectives of mastery learning. Would it be possible to design a game capable of forcing students to watch an instructional video repeatedly until they achieved mastery in that area? Could such a game motivate participants to play the game until they broke through every obstacle and reached the end of the game, and in so doing achieve mastery of the target content?

Learning content of monopoly game

The main topic of the learning content in this study was the area of a circle. This topic covered five concepts: Estimating a circle, the formula to calculate the area of a circle, sector and central angles, leaf area, and the application of sector area method (Fig. 2).

The remedial instruction was designed as a tree and was assigned to students accordingly. Figure 2 presents the learning tree in which branch A is the estimation of a circle (hereafter designated as A), sub-branch A1 is the area of a leaf (hereafter designated as A1), sub-branch A2 is the area of a circle (hereafter designated as A2), and so on. Following completion of A1 and A2, students proceed to topic A. Because both A1 and A2 each have several groups of questions from which to randomly draw, no other questions are selected from A1 or A2 once the students have completed these categories. Instead, the game selects questions from category A or from categories B, C, D, and E. The students complete the unit on the "area of a circle" when each of the concepts, ABCDE, has been completed.
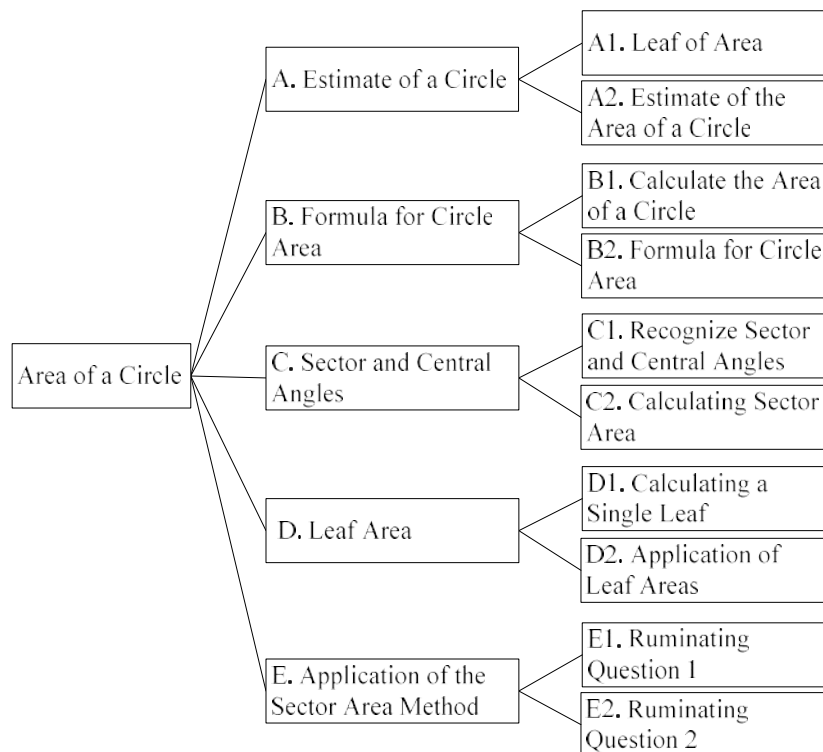
Figure 2. Learning tree for the "area of a circle" unit

Monopoly game

The player rolls dice to determine how students can move forward. Each location on the gameplay map corresponds to a question category. Figure 3 shows the game played by the experimental group. The left side of the game

illustrates the Monopoly gameplay map (virtual board) and the player's avatar. The right side of the game is a panel containing (from top to bottom): (1) the student's ID number, (2) the playing time, (3) game progress, (4) the list of previously studied topics, (5) buttons to roll the dice and control the video player, and (6) a real-time ranking list, which is refreshed every 5 minutes.
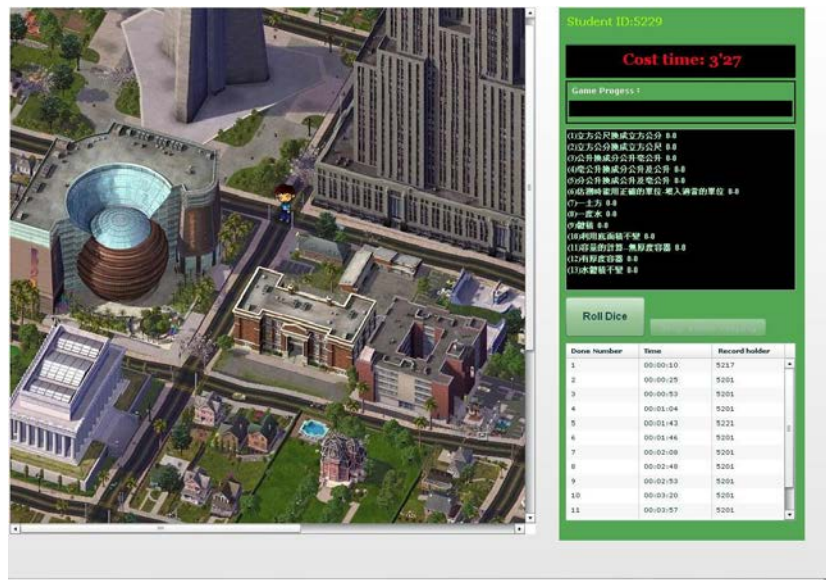
Figure 3. The "Monopoly" game for the experimental group

After clicking on the ROLL DICE button, the avatar moves to a new location corresponding to the number rolled, whereupon a question appears. A sample question is shown in Figure 4. The player must enter the correct answer in the input box located at the bottom of the screen. The category of the question is "measuring the area for different shapes." For example, the shapes formed by the intersections of circles with rectangles, arcs, and lines, as well as irregular shapes such as backyards, the country of Taiwan, and leaves. When the player answers the question correctly, he/she can continue playing the game by clicking the 'Roll Dice' button. The types of questions in the study include multiple-choice and open-ended items, where the students enter a random number in the space provided.
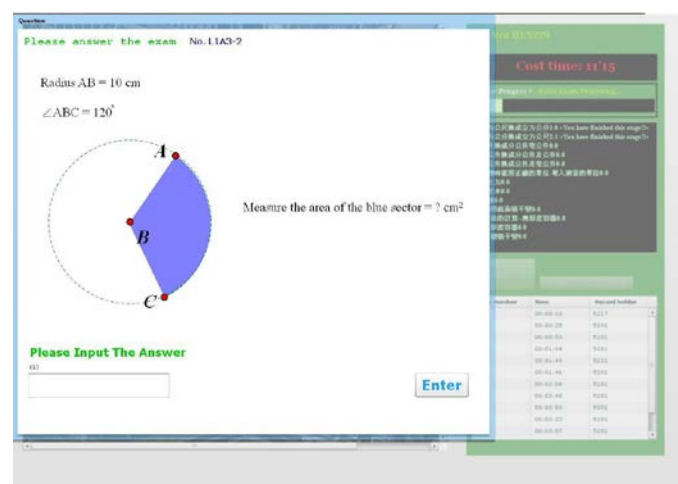
Figure 4. Interface for questions and answering questions

If the player answers the question incorrectly, the game is paused and an instructional video is initiated. The player can control the video playback using three buttons: "Play," "Pause," and "Stop." Manipulating the triangular marker above the three buttons enables the player to watch the video from a specific place (Fig. 5). If the player believes that

he/she can understand the content, they may stop the video at any time by clicking the "Stop Video Playing" button located on the right-hand side and clicking the 'Roll Dice' button to continue playing their game. The videos for students in the experimental group were the same as those used for the control group. In the experimental group, the video appears when the student triggers particular events in the Monopoly game; however, students in the control group can decide when to watch the instructional videos.

Figure 5. Example instructional video

Results

Does the use of instructional video enhance mastery learning?

Table 1 shows that a significant difference was found between the pre-test (M = 59.00, SD = 17.21) and post-test (M = 64.69, SD = 15.74) in the control group (t = -2.06, p < .001). This suggests that the integration of an instructional video based on the concept of mastery learning is beneficial for students learning mathematics.

Table 1. Pretest and posttest results for the control group

	N	M	SD	t
Pretest	32	59.00	17.21	-2.06***
Posttest	32	64.69	15.74	

Note. ***P < .001.

Does the use of the game, monopoly, enhance the success of mastery learning?

As shown in Table 2, following completion of the Monopoly game, the average score of students increased from 60.33 (pretest) to 72.80 (posttest). A paired-sample t-test was conducted to compare pre-test and post-test scores. A significant difference was observed (t = -7.42, p < .001). This result indicated that the instructional video significantly enhanced the success of mastery learning.

Table 2. Pretest and posttest results for the experimental group

	Average	Individuals	Standard Deviation	t
Pretest Results	60.33	30	18.68	-7.42***
Posttest Results	72.80	30	19.55	

Note. ***p < .001.

Comparison of monopoly and instructional video in the enhancement of mastery learning

Analysis and comparison of pretest and posttest results for the control and experimental groups are as follows:

Comparison of test scores for both groups prior to the exercise

According to the data presented in Table 3, the pretest scores for the experimental group and the control group were close ($t = .43$, $p = .35 > .05$), indicating that prior to the remedial learning activity, students in both groups had similar mathematical knowledge.

Table 3. Independent samples t-test of the pretest assessment results

Group	N	Mean	SD	t
Control Group	30	61.09	18.05	.43
Experimental Group	32	59.24	17.00	

Comparison of posttest scores for both groups following the exercise

According to the data presented in Table 4, there is a significant difference in the posttest scores between the experimental and control groups ($t = -1.81$, $p < .05$). Furthermore, the mean posttest score of the experimental group was significantly higher than that of the control group, indicating that students who received game-based remedial instruction outperformed those who received only video-based remedial instruction.

Table 4. Independent samples t-test of the posttest assessment results

Group	Individuals	Mean	Standard Deviation	t
Control Group	32	64.69	15.74	-1.81*
Experimental Group	30	72.80	19.55	

Note. *$p < .05$.

Conclusions and discussion

The aim of this study was to compare the effectiveness of game-based and video-based remedial instruction on mathematics performance. The results indicate that both forms of remedial instruction have a positive influence on learning performance. These results support the findings in previous studies (Choi & Johnson, 2005; Papastergiou, 2009). This study demonstrated the effectiveness of applying multimedia devices, such as computer games or videos, to the task of learning mathematics. Few previous studies have addressed the issue of game-based remedial instructions. Tsuei (2009) proposed the G-Math Peer-Tutoring System, which is a multiplayer environment designed to facilitate the peer-tutoring activities of elementary students associated with remedial instruction. Four students with low achievement in mathematics participated in the study for four months, and their improvements demonstrated the effectiveness of this approach. Unlike the collaborative learning approach employed by the G-Math Peer-Tutoring System, students in this study faced problem-solving situations on their own. Students who participated in the Monopoly game could not proceed without watching an instruction video pertaining to the unit with which the students had difficulty. The students were forced to solve the problem before proceeding, which is the essence of mastery learning. Computer-based mastery learning can increase the level of proficiency when students study the unit on the "area of a circle."

We found that an integration of mastery learning strategies with game-based learning provides greater benefits for students learning mathematics. When designing digital games for educational purposes, it is important to align the content and learning strategies with the structure of the game (Lin & Liu, 2009). To more effectively integrate mastery learning strategies into game-based remedial instruction, we divided the learning material into several small units to reduce the complexity of individual units. In addition, the system provides students with analytical information related to their learning outcome in each unit. This feedback enables students to monitor their own learning, and to identify their weaknesses in each of the learning units. Furthermore, the full impact of the

multimedia experience and attractive graphics (essential elements of digital games) was fully exploited to enhance the experience of flow and engagement in the learning activities (Chuang & Chen, 2009).

Finally, we identify a number of issues related to game-based remedial instruction for future study. First, investigating the effectiveness of game-based remedial instruction on learning motivation and attitudes related to math learning remains an important issue for future studies. Second, a longitudinal study could be conducted to investigate the effectiveness of game-based instruction for remedial purposes. Finally, it is necessary to determine whether game-based remedial instruction is suitable for other disciplines, such as language learning and computer science.

Acknowledgements

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Situated Poetry Learning Using Multimedia Resource Sharing Approach

Che-Ching Yang[1], Shian-Shyong Tseng[2*], Anthony Y. H. Liao[2] and Tyne Liang[1]

[1]Department of Computer Science, National Chiao Tung University, Hsinchu, 30010, Taiwan // [2]Department of Applied Informatics and Multimedia, Asia University, Taichung, 41354, Taiwan // jerome@cis.nctu.edu.tw // sstseng@asia.edu.tw // liao@mail.isa.asia.edu.tw // tliang@cis.nctu.edu.tw
[*]Corresponding author

ABSTRACT

Educators have emphasized the importance of situating students in an authentic learning environment. By using such approach, teachers can encourage students to learn Chinese poems by browsing content resources and relevant online multimedia resources by using handheld devices. Nevertheless, students in heterogeneous network environments may have different requirements for the resource subject, type, size, etc. The central issue of this study is how to locate appropriate resources to support situated learning based on user context. In an attempt to solve the primary concern, this study proposes a context-based dialogue approach with which students may interact to retrieve adequate poems and multimedia resources. The Poetry Multimedia Resource Index is the basis for the retrieval, which consists of outer lexical resources, multimedia resource information, and Chinese poems. A prototype system has been conducted to evaluate the effectiveness of the approach. The experimental group adopts the situated learning method by using this system, while those in the control group adopt the situated learning method by using textbooks. It is found that our approach can be significantly beneficial to promote students' learning achievements. The majority of students are satisfied with the proposed system and the teacher participant showed a positive attitude toward this system.

Keywords

Chinese poetry, Ubiquitous learning, Multimedia learning, Situated learning

Introduction

Many students find poems difficult to understand since poetry often expresses rich and semantic life experiences using few words. Therefore, assisting learners in understanding profound meanings of a poem is quite important. Previous researches suggested that students may experience a positive learning effect by using situated learning theory (Brown, Collins, & Duguid, 1989; Herrington & Oliver, 1999; Horz, Winter, & Fries, 2009; Hwang, Shi, & Chu, 2011). When learners are situated in an environment similar to what a poem describes, they can understand what the poet meant easily, thus enhancing learning performance (Chen, 2008; Shih, Tseng, Yang, Lin, & Liang, 2012; Su, 2007). Hence, in such an environment, learners could benefit from the learning activity that they can not only browse the content of a poem but also its multimedia resources. By carrying handheld devices, which feature wireless communication capabilities, such as Personal Digital Assistants (PDAs), smart phones, and laptops, such scenario can be realized.

Previous studies show that using multimedia in courses increases students' motivation to learn and bolsters an appreciation of poems (Cai, 2003; Chen, 2008; Lo, Zhang, Lin, Tseng, & Chen, 1999; Sun & Cheng, 2007). A proverb also states that, "A picture is worth a thousand words." As information technology rapidly evolves, an increasing number of multimedia resources regarding Chinese poetry have become more accessible via the World Wide Web. Some of these resources are elaborately tailored to help explain or recite a specific poem, and the others are created to help describe a specific entity (such as people, buildings, or locations) depicted in poems. With the aid of these resources, students could better understand poems (Sun & Cheng, 2007).

To achieve the aim of Web-based e-learning, scholars showed the benefit of using an ontology-based approach for online resource management and reuse (Bedi, Banati, & Thukral, 2010; Wu, Mao, & Chen, 2009). However, the researchers were not concerned with the combination of learning contents and learning resources. Online learning resources could be unavailable or delayed, which may not result in significant positive learning performance. In Sun & Cheng (2007), the researchers also indicated that the use of rich media in an e-learning course like Chinese poetry has a significantly positive effect on learning achievement over the use of media that is low in richness. Therefore, it is important to offer available, accessible and trustworthy multimedia resources (e.g., high rich media) for students while learning. Furthermore, in an outdoor environment, due to the limitations of portable learning devices and the

bandwidth of network environments, learning requirements or learning preferences (e.g., resource subject, type, or size) need to be concerned while retrieving resources for learners. Therefore, an interesting issue concerns how to locate appropriate poems and multimedia resources for learning assistance based on the context information.

However, resource repositories (e.g., Flickr, BaiduMp3, YouTube) have their own indices as well as data structures for assisting users to rapid access to resources. With the aim of facilitating fast, reliable and accurate online trustworthy resource retrieval, it is necessary to fetch and collect multimedia resource information relating to poems for index construction. Hence, three sub-problems occurred; that is, the collection of multimedia resource information, the construction of an index from the contents and multimedia resources, and the retrieval of poems and resources from the index.

To cope with this problem, this study proposes Ubiquitous Poetry Learning Scheme (UPLS) which includes three phases: (1) Prefetch-based Resource Information Collection; (2) Poetry Multimedia Resource Index Construction; and (3) Context-based Resource Retrieval. The proposed system is implemented with the aim to conduct Chinese poetry learning activities in a situated learning environment. The aims of this research have been stated as the following research questions:
1. What are the learning achievements of students after using UPLS?
2. What are students' attitudes toward the use of UPLS?
3. What are teachers' attitudes toward the use of UPLS?

Related works

The following sections review literature about the Chinese poetry research and multimedia learning, since this research is related to poetry learning using multimedia resources in a situated learning environment.

Chinese poetry research

Since instruction of Chinese poetry primarily focuses on didactic education, students tend to have difficulty appreciating poems. Therefore, many researchers have proposed information technology approach for facilitating learners' understanding of poems such as style identification (He, Liang, Li, & Tian, 2007; Yi, He, Li, & Yu, 2004; Yi, He, Li, Yu, & Yi, 2005), photo tagging to express course concepts (Shih et al., 2012; Shih, Tseng, Yang, Weng, & Liang, 2008), learners' writing development (Tseng, Yang, Weng, & Liang, 2009; Wang, Tseng, Yang, & Su, 2005), and poetry comprehension (Lo et al., 1999; Sun & Cheng, 2007; Yang, Tseng, & Liang, 2011; Yao & Zhang, 2010). Among these researches, situated learning is emerging as a promising way to engage and motivate students for learning Chinese poetry (Shih et al., 2012; Tseng et al., 2009; Yang et al., 2011).

Situated learning occurs when learning is situated within authentic activity, context, and culture (Lave & Wenger, 1990). In order to provide learners with the authentic context, tutors create scenarios for learners with the real world setting. Therefore, teachers can lead students to a given scenario by simulating the environments depicted in poems and by using content resources and multimedia resources for understanding Chinese poems. In this study, an index to easily access both of them was constructed to aid in situated poetry learning.

Multimedia learning

Multimedia learning is defined as learning from words (such as printed or spoken text) and pictures (such as photos, animations, or videos) (Mayer, 2009). In other words, multimedia instructions cover a wide range of instructional material ranging from a printed text accompanied by pictures to an elaborate animation in the World Wide Web. This theory draws on many other theories such as Paivio's dual coding theory (Clark & Paivio, 1991; Paivio, 1986), cognitive load theory (Sweller, van Merrienboer, & Paas, 1998), Baddeley's working memory model (Baddeley, 1992), and cognitive theory of multimedia learning (Mayer, 2009). According to Mayer (2009), a learner constructs a verbal representation and a visual representation separately when learning from a multimedia instruction. The learner then constructs an integrated representation which combines auditory verbal information with visual graphical information. Studies in the multimedia learning literature show that humans learn better from picture and text than they learn from

text only because learners are able to construct richer memory representations (Ayres & Sweller, 2005; Mayer, 2009; Ozcelik & Acarturk, 2011; Schnotz & Bannert, 2003). However, simply presenting pictorial and textual information does not guarantee enhanced learning (Sweller et al., 1998). Too much unnecessary elements in instructional multimedia material may distract learners and decrease learning performance (Mayer, Heiser, & Lonn, 2001). To reduce extraneous cognitive load, Mayer advocates understanding and application of several specific principles for instructional design (e.g., coherence principle, signaling principle, redundancy principle, spatial and temporal contiguity principles) (Mayer, 2009).

Nowadays, there has been a considerable increase in the needs of multimedia instructions. However, it is expensive to design and develop instructional multimedia materials (Dan, Feldman, & Serpanos, 1998). Due to the rapid development in ICT, more and more educators/users create instructional materials and learning resources that facilitate students to improve their learning performance. With the rapid increase in the amount of instructional materials, it is a good way to support children's learning by providing online multimedia resources. Nevertheless, these resources may or may not be well designed (Mayer, 2009). To assist learners in developing meaningful learning experiences, trust degree is set for each collected multimedia resources in this study. Students could learn better from trustworthy multimedia resources.

Ubiquitous Poetry Learning Scheme (UPLS)
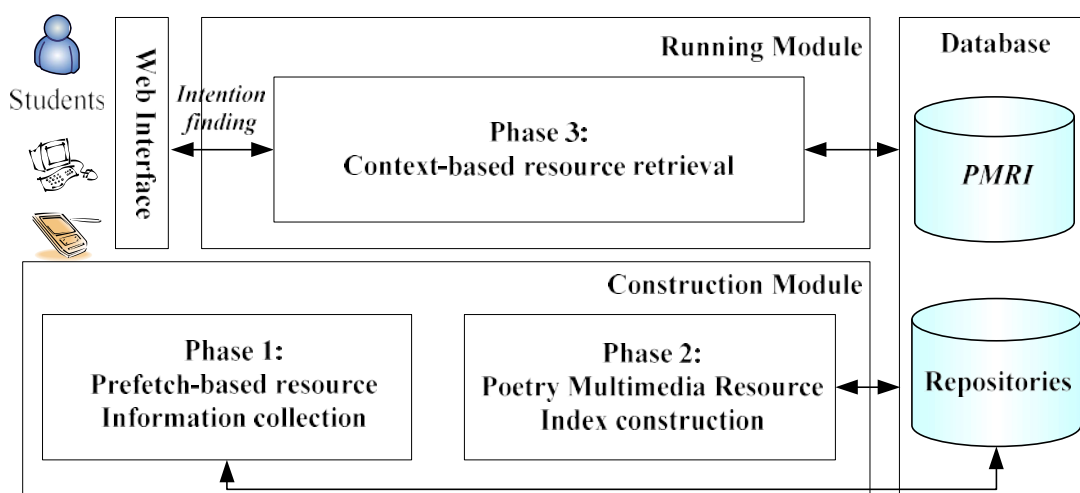
Figure 1. System architecture of UPLS

In this study, a three-phase approach is proposed to locate adequate poems and resources based on context information. Figure 1 illustrates the system architecture of UPLS.

1. **Prefetch-based resource information collection phase:** The information of ROs (Resource Objects) which are related to poems are prefetched and stored in different repositories in this phase. Besides, the context information of retrieved ROs is refreshed after a period of time.

2. **Poetry multimedia resource index construction phase:** The web crawler gives the indexer the full information of ROs it finds. The retrieved information of ROs are stored in the repositories. The index (PMRI) is built by combining TYCCL (Mei, Zhu, Gao, & Yin, 1984) with poems and resources due to the fact that TYCCL is a well-known Chinese vocabulary indexing thesaurus and a well-defined knowledge structure. This data structure allows rapid access to poems that contain user query terms or their concepts.

3. **Context-based resource retrieval phase:** A context-based dialogue approach is proposed to find out learners' intentions on the context information. Appropriate search results (e.g., poems and ROs) will be returned by the indexing service for each search request.

Details of each phase will be described in the following sections.

Prefetch-based resource information collection phase

As mentioned above, some of multimedia resources on the World Wide Web are elaborately tailored to help explain or recite a specific poem, and some of which are created to help describe a specific entity (such as people, buildings, or locations) depicted in poems. Accordingly, to collect the information of these resources, a set of keywords is first selected as representative of 300 Chinese poems by consulting a domain expert. The keyword set is used to construct the index (PMRI) in phase 2. In this phase, some of the keywords (e.g., poem title, person's name, building name, and location name) are used as query words to find corresponding ROs on the web by using a meta-crawler. The other keywords are too abstract (e.g., love, farewell, or sad) to find corresponding ROs. During collection, the keyword-matching principle is used to collect each RO's information. Since the ROs could be unavailable or untrustworthy, the Weblink and related information of each RO is fetched and represented as resource context in the Definition of Context Information. Each definition of Context Information (CI) is defined below.

Definition of Context Information:

CI=(UC, RC), where:
- UC(User Context) = (resourceType, availability, trust, dueTime)
  - A resourceType denotes the type of a RO, where resourceType $\in$ {Image, audio, video}.
  - Availability is the probability that users can access the content of multimedia resources, where $0 \leq$ availability ≤ 1.
  - Trust is the trustworthy degree that a specific multimedia resource can help users become aware of a corresponding poem/entity, where $0 \leq$ trust ≤ 1.
  - DueTime is a few minutes that students will wait to retrieve the corresponding resources.
- RC(Resource Context)=(tag, resourceType, fileType, fileSize, URL, availability, trust)
  - A tag denotes a term assigned to a RO which helps describe this object and allows it to be found again.
  - A fileType denotes the type of file such as jpeg.
  - FileSize denotes the size of a RO.
  - URL (Uniform Resource Locator) is a specific character string that constitutes a reference to an Internet resource.

If the tags of a RO are matched to two query words in the same poem, the trust value of this RO is set to 0.5. However, the context information of a RO may be modified. For example, the resource repositories may change the inner links to the resources or remove the resources altogether. Accordingly, a boundary condition is set for refreshing the context information. If there are dead links, resources will be collected again.

Poetry multimedia resource index construction phase

The aim of this index (PMRI) is to assist users to access adequate poems and multimedia resources. To construct PMRI, we employ a well-known Chinese vocabulary-indexing thesaurus Tongyici Cilin (TYCCL) (Mei et al., 1984) which is a four-level thesaurus. The semantic meaning of a word in a higher level is more abstract than those in a lower level. Based on their semantics, Chinese vocabularies are classified into different classes. Because of its well-defined structure, TYCCL is reused and two extra levels, "poem" and "resource" are added to construct PMRI.

Definition of poetry multimedia resource index:

- PMRI is an extended ontology that consists of seven levels: Root, Category level, Abstract concept level, Concept level, Vocabulary level, Poem level, and Resource level.

Figure 2 illustrates the structure of PMRI. A poem "Seeing Meng Hao-Ran off to Guangling at Yellow Crane Tower" is used as an example displayed in Figure 3. The poem describes the feelings of the poet Li Bai at the Yellow Crane Tower as his friend Meng Hao-Ran leaves. In Figure 2, the three keyword nodes in Level 4, "old friend," "sail," and "Yellow Crane Tower" connect with this poem in Level 5. In Level 6, R_I, R_A, and R_V, the related ROs, link to this poem. In addition, this study records the usage frequency of concepts in PMRI by noting the number of poems that use this concept. For instance, the node "people" in Level 1 is used in 36 poems ($n_p = 36$).
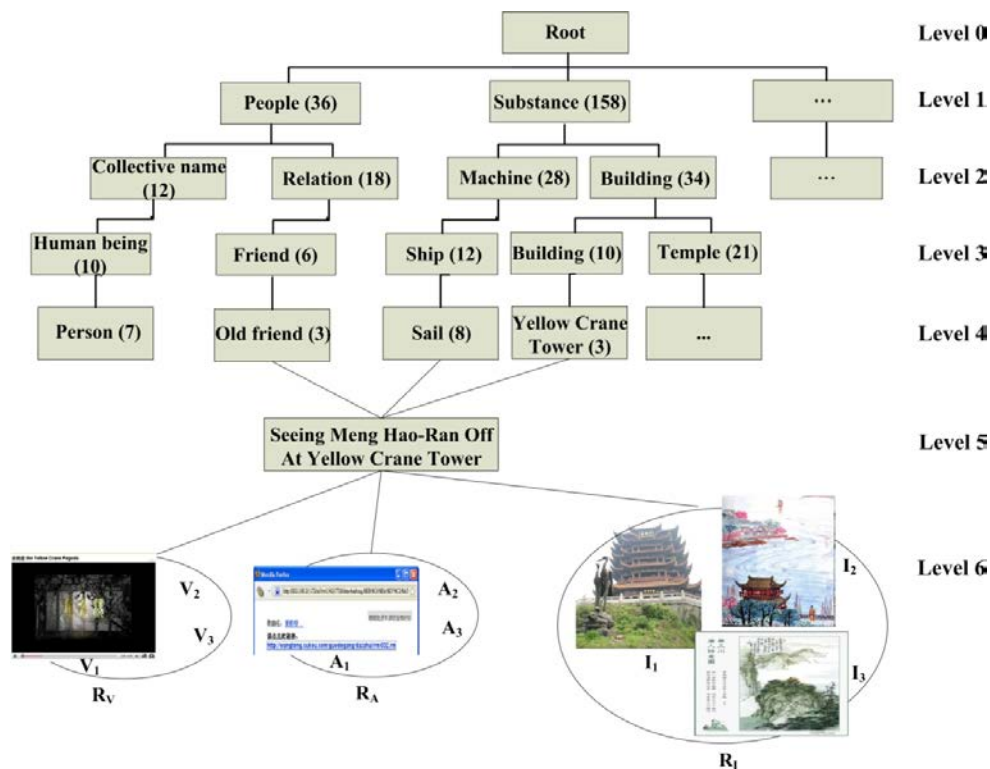
Figure 2. Structure of poetry multimedia resource index

Title: *Seeing Meng Hao-Ran off to Guangling at Yellow Crane Tower*
Poet: *Li Bai*
Poem:
My friend has left the west where the Yellow Crane towers;
For Yangzhou blooming in March with red flowers.
His single sail has been lost in the boundless blue sky;
Where I saw the endless Yangtze River rolling by.
(In Chinese)
《黃鶴樓送孟浩然之廣陵》 李白
故人西辭黃鶴樓，
煙花三月下揚州。
孤帆遠影碧空盡，
惟見長江天際流。

Figure 3. Illustrative example of a Chinese poem

The construction of PMRI starts from the vocabulary-indexing thesaurus TYCCL. Since the resources already link to the poems in the phase of prefetch-based resource information collection, the construction mechanism focuses on the connection between poems and TYCCL. First, these keywords, except poem titles and authors, are matched to the thesaurus entries (the Vocabulary level in TYCCL). Those which do not match the entries are unknown words. The head noun heuristic, such as the one below, is used to deal with this problem.

Heuristic of head noun:

● A head noun is the main noun that is modified by other elements (modifiers) in a noun phrase. In Chinese, the head noun occurs at the end of a noun phrase (Liang & Wu, 2009).

In a noun phrase, the head noun could be the last three-character word, the last two-character word, or the last one-character word. For example, the head noun of an unknown word "abcde" could be "cde," "de," or "e." The long-term priority is adopted for this heuristic; therefore, the last three-character word is assigned the highest priority. After using this heuristic, unknown words are tagged with their senses and stored in PMRI.

Context-based resource retrieval phase

The purpose of this system is to support situated poetry learning under a teacher's guidance. In addition, this system can also support individual learning. For group learning, a teacher uses the user interface to set presentation poems before starting the class and then students learn the prepared poems. For individual learning, students can learn any poem by using the function of poem recommendation.

To assist students with identifying their intentions about user context, we propose a context-based dialogue approach to interact with students. The context-based dialogue for intention finding includes two parts: poem recommendation and multimedia resource retrieval. In terms of poem recommendation, PMRI ontology traversal approach (e.g., listing a specific term's hyponyms) is provided to interact with users to find their intentions regarding the dramatic situations of poems. For reducing the options during dialogue, a higher usage concept heuristic is used as below. Example 1 shows an example of the dialogue process for poems.

Heuristic of higher usage concept

- A higher usage concept denotes a concept used frequently in the poems, which can be used to guide students to select suitable keywords as their intentions. If the n_p of the concept node in PMRI is higher than the threshold, the concept will become one of the options during dialogue.

Example 1: Dialogue process for poems
This example illustrates the dialogue about a student's intentions for poems.
Q: Which subject do you want to describe (*people*, *human affairs*, or *substance*)?
A: People.
Q: Which about people interests you (*identity*, *relation*, or *career*)?
A: Relation.
Q: Which subject within "relation" interests you (*friend*, *classmate*, or *master*)?
A: Friend.
Q: Which subject within "friend" interests you (*intimate*, *acquaintance*, or *old friend*)?
A: Old friend.

To gauge the similarities between the student's intentions and the poems, this study uses the cosine function, used to measure common similarities. The following defines the similarity comparison.

$$Similarity = \cos ine(V_A, V_B) = \frac{V_A \bullet V_B}{|V_A||V_B|}$$

V_A and V_B are the keyword vectors, which represent the student's intentions and the poem's representative, respectively. The larger the value is, the more similar the two vectors are.

In terms of multimedia resource retrieval, individual student can set his/her tolerance degree regarding speed of resource presence, degree of availability, and degree of trust in advance. Then, if these values of ROs fit in with the values of students' preference (e.g., response time of RO is smaller than acceptable due time, $T_{Response} < T_{Due}$), the different types of ROs are ranked and presented based on trust. The definition of response time and bandwidth is defined below. Example 2 shows an example of the dialogue process for ROs. Example 3 shows an example of multimedia resource retrieval.

Definition of Response time:

- This study applies response time to evaluate the length of time a Web site will take to present a resource based on its file size and bandwidth.

$$T_{Response} = \frac{FileSize}{Bandwidth}$$

Definition of Bandwidth:

- Bandwidth is a data transfer rate for the amount of data that can be carried from one point to another in a given

time period. Bandwidth is measured in bits (of data) per second (bps).

$$\text{Bandwidth} = \frac{FixedFileSize}{Transfertime}$$

Example 2: Dialogue process for resources

This example illustrates the dialogue about a student's intentions for multimedia resources.

Q: What kinds of resource types do you prefer (image, audio, video)?

A: image, video.

Q: Please set the value of availability. (Default: 1)

A: 1.

Q: Please set the value of trust. (Default: 1)

A: 1.

Q: Please set the value of due time. (Default: 1 min)

A: 1.

Example 3: Multimedia resource retrieval

Figure 4. Multimedia resource retrieval for Yellow Crane Tower

As Example 1 shows, the intention is "old friend." The overall intentions of the student are: "old friend, farewell, river, and sad." Then, this system computes the similarity degree between the learner's intentions and keyword set of poems and recommends several poems, such as Seeing Meng Hao-Ran off to Guangling at Yellow Crane Tower (Poet: Li Bai), A farewell to a friend (Poet: Li Bai), and Farewell (Poet: Wang Wei). Ultimately, the student chooses to learn Seeing Meng Hao-Ran off to Guangling at Yellow Crane Tower and then multimedia resources related to this poem are pre-selected. As shown in Example 2, the student's intentions of multimedia resource are acquired and then some of the pre-selected multimedia resources will be filtered. Figure 4 shows a snapshot of the retrieval of the appropriate multimedia resources based on the student's intentions.

Experiment and analysis

The UPLS was implemented on a Microsoft Windows Mobile Operating System (OS) platform and JSP Web application. The UPLS contains a user model and an activity model (Griffiths et al., 1998). The user model is used to store the features of users, which includes user profile and group user profile. Regarding the activity model, it is used to provide learning activity for learners, and collect learners' access data.

Teaching preparation

For instructing students on farewell poems, the participant teacher decided to use situated learning in an attempt to stimulate the students' interest in learning this particular type of poems. Before starting the class, the teacher used a desktop computer to design a learning activity. When the teacher participant selected 3 farewell poems from 300 poems as learning materials (e.g., Seeing Meng Hao-Ran off to Guangling at Yellow Crane Tower, A farewell to a friend, and Farewell), related ROs with the selected poems are presented. To offer trustworthy ROs for learners, the teacher browsed related ROs and rated some of them as trustworthy ROs (Sun & Cheng, 2007).

Learning material
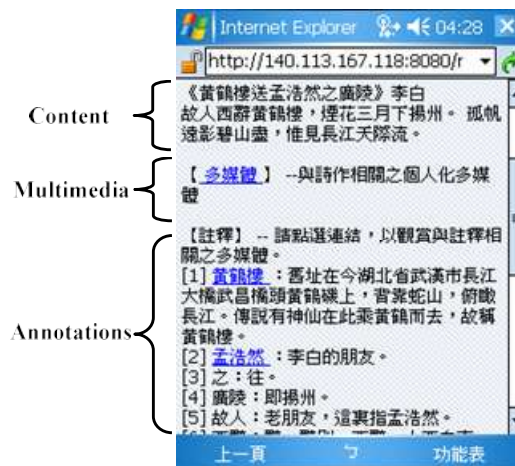
Figure 5. Illustrative example of the learning content

After successful login, students can setup their preferences and see the teacher prepared poems. The learning material offered in this study is shown in Figure 5 and Figure 6. Figure 5 depicts the learning content of a farewell poem, Seeing Meng Hao-Ran off to Guangling at Yellow Crane Tower, which presents poem content, annotations, explanation, and multimedia resources. In Figure 5, learners can click the link of multimedia resource to browse all of the collected resources which relate to this poem. Those multimedia resources are retrieved based on user intentions. As for Figure 6, the student can click one of the annotation links to browse its multimedia resources which also correspond to user intentions. For example, a student clicks "Yellow Crane Tower" to see what the building looks like and what image the poet may have envisioned.

Figure 6. Illustrative example of the resources about annotation

Participants and experimental procedure
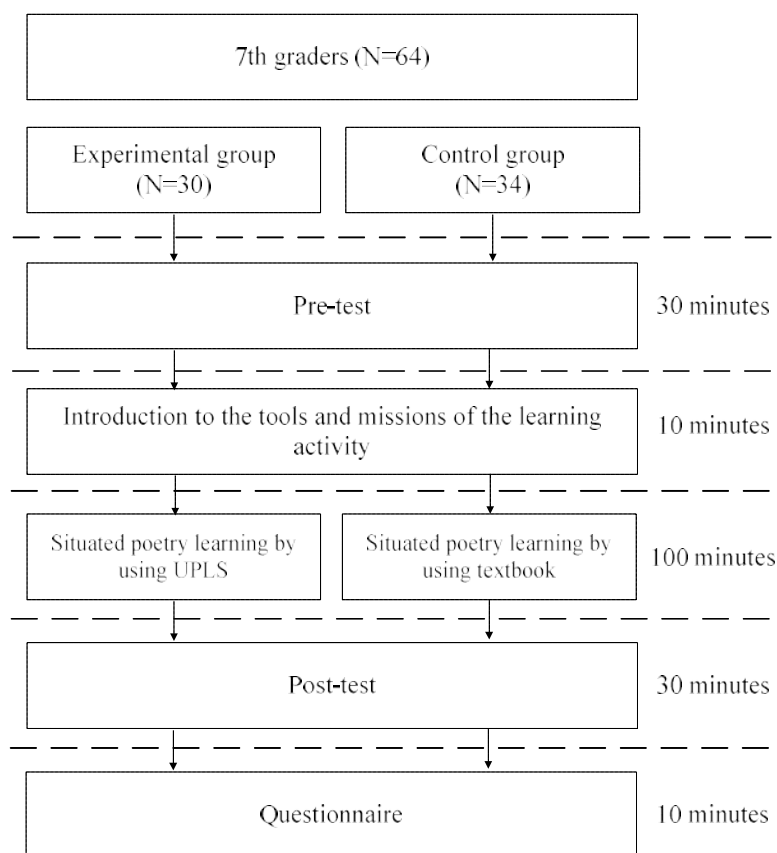
Figure 7. Experimental procedure

The participants were 64 native Chinese speaking seventh grade students from two classes. One class was assigned to be the experimental group (N = 30), and the other class was the control group (N = 34). The students in the experimental group were instructed and guided to participate in the situated learning activity by using UPLS (with multimedia resources), while those in the control group were instructed and guided to participate in the activity by using conventional approach (without multimedia resources). Note that all participants received the same treatment such as instruction, learning materials (e.g., poem contents, annotations, and explanations), and environment.

The procedure of the experiment is presented in Figure 7. The total length of the experiment was 180 minutes. Before the beginning of class, all of the students took a 30-minute pre-test which was used to gauge the students' existing knowledge of Chinese poetry. Then, the experimental group received a 10-minute instruction on the procedure and operation of the PDA. During the next 100 minutes, the experimental group adopts situated poetry learning by using PDAs with wireless communication as learning tools to browse this system. The control group adopts situated poetry learning by using textbooks as the primary learning tools. After the learning activity, all participants took a post-test and the students in the experimental group filled out a learning satisfaction questionnaire to measure their degree of satisfaction toward this system. The total time for this was 40 minutes.

Measuring tools

The pre-test was conducted to evaluate the students' prior knowledge before learning the poems. It consisted of ten true-false questions and fifteen multiple-choice questions, giving a total score of 100. The post-test aimed to evaluate the learning achievements of the students after learning the poems. It consisted of 25 multiple-choice questions, with a total score of 100.

A questionnaire was developed to evaluate students' learning experience with the system developed in this study. A five-point Likert scale was used ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was composed of three constructs, including the learning effects of situated learning and multimedia, satisfaction of the presented results, and satisfaction of this system. The questionnaire contained a total of 11 items, including three items related to the effects of situated learning and multimedia on learning, three related to satisfaction of the presented results, and the remaining five related to satisfaction of this system. During this questionnaire design process, the questions were verified and validated by domain experts. The researchers utilized Cronbach's alpha analysis to evaluate the internal consistency of this questionnaire. The Cronbach α value in each question is higher than 0.70 (total Cronbach α value = 0.8252). This implies all questions can be retained and the reliability of this questionnaire is sufficiently high.

Analysis of learning achievements

For the prior knowledge of the two groups before the experiment, the mean scores of the pretest are 66.90 and 64.82 for the experimental group and the control group respectively, as shown in Table 1. According to the t-test result, no significant difference is found between the two groups; implying that the two groups of students had equivalent base knowledge before participating in this learning activity.

Table 1. t-test result on the pre-test scores of the two groups

Group	N	Mean	S.D.	t
Experimental group	30	66.90	20.69	.301
Control group	34	64.82	16.35	

For the learning achievements of the two groups after the experiment, the mean score of the experimental group, 82.00, is higher than that of the control group, 71.65. The t-test result reveals a significant difference between the two groups, as shown in Table 2. It can be noticed that the situated poetry learning by using UPLS seems to be more effective than the conventional situated poetry learning in promoting the learning achievement of the students.

Table 2. *t*-test result on the post-test scores of the two groups

Group	N	Mean	S.D.	t
Experimental group	30	82.00	10.01	.032**
Control group	34	71.65	16.71	

*Note. *p < .05; ** p < .01.*

Analysis of satisfaction survey

As Table 3 shows, students' attitudes toward the use of this system can be divided into three different dimensions (the learning effects of situated learning and multimedia, satisfaction of the presented results, and satisfaction of this system). The average of the answers for all questions is above 3, implying that most students felt satisfied with the proposed approach.

In terms of the learning effects of situated learning and multimedia, most of students showed positive attitudes toward situated learning and multimedia resources.

In terms of satisfaction of the presented results, most students felt satisfied with the results; implying that students could retrieve their intended multimedia resources and the presented multimedia resources were available and trustworthy. Furthermore, it is interesting to find that students have more interests in images and videos than audios.

In terms of satisfaction of this system, most students felt satisfied with the system. Question 11 is especially high (3.99), and it shows that using this system to learn poems is convenient. The lowest score appeared on question 9, in which students expressed a negative attitude toward the speed of the multimedia resources presentation in the wireless Internet. Compared to question 8, a possible reason for this is that the available bandwidth is fixed, but all participants simultaneously access the multimedia resources. If the teacher divides the participants into several groups, each group has different learning activities, e.g., one group browses poem content, and another group

browses multimedia resources. Fewer participants can simultaneously access the multimedia resources and the bandwidth bottleneck can be alleviated.

#	Questions	Mean	S.D.
	The effects of situated learning and multimedia on learning		
1.	Situated learning is more interesting than conventional learning.	3.94	1.01
2.	I think using text and multimedia resources to learn poems could increase my learning motivation.	3.70	0.97
3.	I think poems can be easily understood by using multimedia resources.	3.67	0.88
	Satisfaction of the presented results		
4.	I am satisfied with the presented images.	3.64	0.92
5.	I am satisfied with the presented videos.	3.70	1.00
6.	I am satisfied with the presented audios.	3.54	0.88
	Satisfaction of this system		
7.	This system is easy to understand and operate.	3.88	0.90
8.	I am satisfied with the speed of this system.	3.70	1.02
9.	I am satisfied with the speed of the multimedia resources presentation.	3.22	1.04
10.	It is interesting to learn poems by using this system.	3.82	0.90
11.	It is convenient to learn poems by using this system.	3.99	0.90

From the teacher interview, it was found that the teacher participant showed a positive attitude toward this system. The opinions are summarized as follows.

Since Chinese poems are filled with imagination and abstract concept in a limited number of Chinese characters, people are not easy to understand their meanings. For example, a scenario "the withered vine, old tree, crows at dusk …" described in a famous Chinese poem "To The Tune Of Tian Jing Sha (天淨沙) ." "Autumn Thought (秋思)" are abstract. In the Web 2.0 era, many multimedia resources about poems can be found from the Internet. Some audio clips recorded the recitation of a specific poem, which may arouse students' learning interests. Some video clips were designed to help explain a specific poem, and images can be used to help illustrate the meanings of a specific poem. Through related multimedia resources, students can not only be aroused their interests, but also see the concrete images to experience and imagine the scenario what the poet may have envisioned. Then, students can understand the rich meanings in the poems. With the aid of resources retrieved from World Wide Web, teaching and learning Chinese poetry become much easier and much effective. Instructors can use Web 2.0 technology to help students learn. Students can learn poems better and appreciate the beauty of poems deeper, especially for those whose learning style is visual or auditory.

However, collecting related multimedia resources about Chinese poetry is a time-consuming and labor intensive process. This study proposes a promising way for teachers and students to collect useful multimedia resources from internet and construct an index to retrieve both of poems and multimedia resources.

In terms of teaching preparation, this system is easy and simple to setup learning activity. By using PMRI ontology traversal approach, the intended poems can be found out easily and then corresponding multimedia resources were presented. During the preparation process, the teacher took around half an hour to select poems and trustworthy resources.

The teacher held a positive attitude about this m-learning mechanism. This approach could also adapt to each child's individual learning progress and condition. With portable learning devices, students could manipulate the learning process and learning speed on their own. Through the use of this technology, students have become more active participants in the learning process.

In addition, the teacher also suggested that each resource can have its own small representative image before students click on them. With the aid of miniatures, students can quickly select the intended resource.

Discussions

As the rapid development of computer and Internet technologies, there are many e-learning platforms such as Moodle. In such platforms, multimedia instructional materials have been shown to attract learner's attention and interests (Cai, 2003; Chen, 2008; Lo et al., 1999; Sun & Cheng, 2007). Researchers have also shown the benefits of using this kind of platforms as teaching tools (Martín-Blas & Serrano-Fernández, 2009). However, teachers need to upload files to the platforms for course use. Compared to the existing e-learning platforms, the proposed UPLS automatically collects the information of relevant multimedia resources, stores the resulting index of words, compares search query to the index and recommends relevant learning materials.

Previous studies suggested the effectives of learning in a situated learning environment (Brown et al., 1989; Herrington & Oliver, 1999; Horz et al., 2009; Hwang et al., 2011). Owing to the popularity of portable devices (e.g., PDAs and smartphones) and wireless communication, the potential of mobile learning or one-to-one learning has been noted (Chan et al., 2006). Several researches have reported the benefit of using mobile technologies in supporting situated learning (Hwang, Hung, & Lin, 2010; Liu, Peng, Wu, & Lin, 2009; Shih et al., 2012). Herrington and Oliver (1999) also stated the benefit of using an interactive multimedia program based on the situated learning. In addition, the integration of situated learning into Chinese poetry instruction can promote students' learning motivation (Chen, 2008; Shih et al., 2012; Su, 2007). These findings show the value of investigating the possibilities of using multimedia resources to support situated poetry learning.

As in Shih et al. (2012), students use smart phones to record, accumulate, organize and share their feelings related to poems by photos while learning Chinese poetry outdoors. An increasing number of multimedia resources are available via the World Wide Web. However, online multimedia resources could be unavailable, delayed or untrustworthy, which may not result in significant positive learning performance (Sun & Cheng, 2007). In this study, new criteria were proposed to assist users in retrieving personalized and appropriate learning resources. To achieve this aim, the collected multimedia resources were represented by sets of metadata in the resource context (such as trust) and then appropriate learning resources could be retrieved based on learners' intentions.

As a result, the experiment results show that the offered multimedia instructional materials effectively help students improve their learning achievement; implying that the presented multimedia resources were available and trustworthy. In terms of students' attitudes, most student participants showed positive attitudes toward situated learning, multimedia learning, the presented multimedia resources and this system; implying that the students could retrieve multimedia resources based on their individual requirements and they were satisfied with the presented multimedia resources in a situated learning environment. In terms of teacher attitude, the teacher participant showed a positive attitude toward using this system as a teaching tool. From the teacher interview, it was found that the teacher participant can quickly design and facilitate engaging learning activities; implying that UPLS as well as the index (PMRI) is suitable and efficient.

Although the experimental results have shown the benefits of using UPLS, there are some limitations in the present study. For example, in order to offer high rich media, teachers need to rate the collected multimedia resources before starting the class. Therefore, two of our future works are to consider trusted users and content adaptation. Some bloggers/Web sites are famous and people trust the materials or articles provided by them. The resources they offer should be trustworthy. In addition, with content adaptation, different content can be transformed to adapt to any mobile device that can provide the best viewing experience for learners.

Conclusion

Due to the popularity of portable devices, learning anytime, anywhere, and any place is feasible. M-learning offers learners access to learning resources by using handheld devices with wireless communication in an authentic learning environment. In this study, teachers can easily setup this system as a learning tool and encourage student participation in using this system to learn poems. While learning, students can retrieve poems and adequate multimedia resources based on their context information. To evaluate the effectiveness of this approach, an experiment was conducted which compared the learning achievements of the students who learned with the UPLS and those who learned with conventional situated learning approach. The experimental results showed that with the help of the UPLS, the learning achievement of the students was significantly better than for those who learned with

the other approach. Meanwhile, the analysis of the questionnaire results showed that most students felt satisfied with the proposed learning approach. The teacher participant showed a positive attitude toward this system.

Acknowledgments

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Using Tangible Companions for Enhancing Learning English Conversation

Yi Hsuan Wang, Shelley S.-C. Young[*] and Jyh-Shing Roger Jang
National Tsing Hua University, No.101 Section 2 Kuang-Fu Road, Hsinchu City, Taiwan 300 //
annywang12345@hotmail.com // scy@mx.nthu.edu.tw // jang@cs.nthu.edu.tw
[*]Corresponding author

ABSTRACT

In this study, the researchers attempted to extend the concept of learning companions from the virtual world to the real physical environment and made a breakthrough in technique development of tangible learning robots. The aim of this study was to explore an innovative way by combining the speech recognition technology with educational robots in the hope that the state-of-the-art technology could provide learners with more opportunities of bi-directional language learning in the English class settings. The quasi-experimental design was adopted in this study and a total of 63 Taiwanese students in the fifth grade participated in the experiment. The results reveal that using the tangible learning companions in learning had positive effects on learners' learning motivation, confidence and engagement especially for the lower-achievement learners. Two learning methods were identified in the study, co-discovery and peer tutoring method. The co-discovery method enhanced the lower-achievement learners' learning involvement and their English speaking ability. Students perceived the tangible learning robots as friendly learning toys or ever like a patient instructor for practicing English conversation. Both English instructor and students agreed that uses of the tangible learning companions effectively improved the class atmosphere, and raised their and positive attitude toward learning English.

Introduction

English has been an important learning subject in formal education in Taiwan. However, some issues have been observed in English learning and teaching contexts. For example, while students generally are good at reading they do not feel comfortable with speaking. The beginning English learners in specific often feel shy and embarrassed practicing English conversation with a teacher or peer learners because of the fear of making mistakes (Pan, 2001). Furthermore, some learners, particularly the low-achievement ones, often feel uncomfortable speaking English in front of other students or teachers due to the fear of making mistakes. In the long run, they might lose the interest and confidence in learning English. Additionally, it is difficult for teachers to provide every student with equal opportunity of practicing English conversation in the regular classroom and it is also difficult for learners to find partners to practice English speaking together at home due to many newlyweds in Taiwan prefer to have one child only (Chen, 2011). However, the advantages of the developing learning technology could help instructors solve the problems that students meet. Educational learning companions have attracted a great deal of attention in the field of technology enhanced learning. The human-like characteristics enhance students' attention and confidence in learning subjects (Chen, Liao, Chien, Chan, 2011). Nevertheless, most of the existing learning companions are presented in the web-based environment which could only interact with learners on the flat screen. Few studies have been conducted with a focus on physical and tangible companions, particularly those designed to integrate learning companions into the formal English language settings.

On the other hand, the applications of portable robots, physical and tangible learning companions are the interesting topics which catch researchers' interests in recent decades. The characteristics of multiple learning interactions through both visual stimulation and tangible sense benefits learners especially for young children (Xu, Read, Sim & McManus, 2009). Hence, with the idea of combining the learning companions with tangible technology in mind, the researchers extended the concept of learning companions (Chan & Bsdkin, 1988) from virtual world to real world and started from the viewpoint of bettering language learning. Therefore, both the Learning Technology Lab and Multimedia Information Retrieval Lab at National Tsing Hua University, Taiwan, have made a joint effort in associating instructional technology with the advanced speech recognition techniques to develop innovative tangible learning companions in the appearances of popular cartoon characters, which could play the role as the interactive English learning partners in English classrooms.

The study proposes the pedagogical activities and implements the tangible learning companions in the English class settings using the state-of-the-art technology, speech recognition technology, to help improve the practices of learning English conversations. We aim to investigate the pedagogical strategies of using learning companions in classroom settings and evaluate elementary students' learning motivation, performance and perception toward the uses of learning companions.

Research questions

The research questions of this study are as follows:
1. What were the students and instructor's feedback and perception toward applying the learning companions in English classes?
2. How did students' learning process, attitude, effectiveness changed and enhanced with the uses of learning companions in English class? What role would the tangible learning companions play in learning English? Would the tangible learning companions make the classroom atmosphere differently?
3. What learning methods did learners use when they practiced English conversation with the tangible learning companions in groups?

Literature review

Tangible learning companions

Computers as the learning companions could act as learning partners, peer-learners and tutors which help or instruct learners in learning (Chan & Bsdkin, 1988). Research has indicated that using learning companions in learning can strengthen learners' motivation, engagement and concentration and also exert positive learning effects on learners (Chen et al., 2011). For example, My-Mini-Pet system (Liao, Chen, Cheng, Chen, Chan, 2011) is a handheld animal companion learning environment which applies three strategies, pet-nurturing, pet appearance-changing and pet feedback, to encourage students to engage in the learning activities. Another similar application of virtual learning companions is My-Pet v2 system (Chen, Liao, Chien, Chan, 2011). It consisted of three learning flows, nursing phase, learning phase and competition phase, to enhance learners' attention, relevance, confidence and satisfaction while learning. A study compared different kinds of learning media, including real instructors, robots and tape recorders, in learning new things for children; the results showed that learners paid most attention to human instructors, then moving robots and least attention to tape recorders (Draper & Clayton, 1992). It is likely that these learning companions impose different impacts on learners. For instance, virtual learning companions such as agents have been found to allow learners to get familiar with learning environment quickly (Chalfoun & Frasson, 2008). Moreover, robots, physical learning companions, have been found to enhance children's motivation and provide learners with multiple learning interactions through both visual stimulation and tangible sense (Hsu et al., 2007).

Tangible technology has been introduced in the 1990s. The potential of tangible user interface is that it can transform digital information to physical learning objects and it is an appealing learning method with actual operation for younger learners (Xu, Read, Sim & McManus, 2009). Tangible technology can be used for trial-and-error activities and more than one user can be involved at one time (Hall, 2009). The characteristics of tangible technology help learners acquire knowledge easily and obtain special concepts to enhance learning (Ullmer & Ishii, 2001). Besides, researchers (Lou, Abrami & Apollonia, 2001) have pointed out that applying the small group learning strategy can benefit learners and have significantly positive effects than individual learning on student individual achievement when using learning technology in learning. As a result, we combine the idea of learning companions and tangible technology together and apply the small group learning strategy to implement the tangible interactive learning companions enhance English learning in English class. It is our intention that the tangible learning companions can act as a friend, peer learner, tutor in group with which learners can interact.

English learning & scaffolding strategy

In Taiwan, it is a challenge for the beginners to overcome the psychological barrier of learning English, especially spoken English. Most of the students are afraid of speaking due to the language ego and they are afraid of making

mistakes in front of the teacher and the other classmates (Guiora, Brannon & Dull, 1972). Research indicates that the scaffolding strategy could promote positive learning experiences for students and the scaffold instruction is the most efficient way of helping learners being familiar with the learning contents and learning skills (Lutz, Guthrie & Davis, 2006). Besides, the affective filter hypothesis states that whether learners can learn a language effectively is related to emotional factors including motivation, self-confidence and anxiety. In this case, it is important that instructors or parents create an enjoyable learning atmosphere for efficient English learning. The guideline of *audio-lingual method* (ALM) also points out that instructors should give examples of English sentences for learners so that they can practice them repeatedly until they can use them in natural communication (Richards & Rodgers, 1986). The goal of this study is based on the concept of scaffolding learning. It aims to encourage students speak English and make learners more comfortable and enjoyable in learning with tangible learning companions in a low-anxiety classroom atmosphere, and the ALM is used as the interactive design guideline for the interaction between learners and tangible learning companions. Learners therefore could learn comprehensively through repeated practices.

Speech recognition

The process of speech recognition includes front-end processing, linguistic decoding and artificial neural network (Neumeyer, Franco, Weintraub, & Price, 1996). Learners receive immediate feedback as they input voice to the systems or computers. With the aid of speech recognition techniques, learners are offered with interactive and varying learning opportunities of practicing English communication, compared to the traditional teaching and learning method in which tape recorders are used in the classroom. For the last decades, the application of speech recognition technology has been used in the field of *Computer Assisted Language Learning* (CALL). For example, a computer-based speech recognition system, CANDLE, was developed for helping Taiwanese college students enhancing their English pronunciation (Chiu, Liou & Yeh 2007), and another CALL system, ILLSE ,which integrated the technique of Text-to-Speech function has been proven to facilitate high school students' English speaking ability (Tsai, 2011).

Importantly, there are several arduous tasks in applying speech recognition, the accuracy of rate, the size of voice database (Chu, 2005) and the corrective feedback from CALL system (Chen, 2011). A person's speech tone is highly unique, and it is difficult to recognize everyone's speech accurately and provide students with corrective feedback for indicating their language errors. For this reason, a large speech database and feedback library is needed to increase the accuracy of speech recognition and store the suitable feedback for learners. However, setting up such a database is a highly time-consuming and demanding mission. To improve better recognition accuracy, the learning materials should be defined closely so as to limit the range and variation of utterances. Noticeable, the previous study was constrained in the computer-based environment (Chan, 2011). However, in this study, we did a breakthrough in technique development by combining the speech recognition technology with tangible educational robots and extended the application of speech recognition technology from the computer screens to the tangible learning devices so as to provide learners with flexibility, mobility and opportunities of bi-directional language learning.

About the tangible learning companions and developed tools

The tangible learning companions have been developed on the concept of ALM and they are set as the initial-scaffolding roles as well as motivating and patient learning partners for English beginners to practice conversation.

With the embedded speech recognition technology, the tangible talking robots bearing the functions of bi-directional conversation are actualized. The tangible learning companions could automatically respond to learners' utterances within 0.5 seconds. We used the 16-bit micro-controller SPCE061A for voice corpus collection and speech recognition. Two pieces of software, VSTAR Modeler (Bailey, 2006) and U'nSP IDE developed by the Cyberon Corporation and Sunplus Technology Company have been used for acoustic model training and integration tools. *Hidden Markov Model* (HMM) has been used as the sequence-based classifier for speech recognition (Baum & Petrie, 1966). Basically, we need to collect an English speech corpus of children and the corresponding transcriptions for training HMM based on the principal of maximum likelihood estimate. Due to the limited computing power of the micro-controller, the speech feature is based on 26-dimension of Mel-scale Frequency Cepstral Coefficients (MFCC) and its derivative, and the HMM is based on the monophone. The recognition part is based on Viterbi decoding using linear lexicon networks, and the sentence with the maximum log likelihood (greater than a given

threshold) is output as the predicted answer. Then one of the possibility response utterances corresponding to the predicted answer was selected randomly and played back as the learning feedback to the learner (Figure 1-1 & 1-2). According to our test, the recognition accuracy is about 92.5% under a normal quiet office environment. This means the tangible learning companions can answer learners correctly about nine times out of ten.

Part A: Corpus Collection & Training

> (a) Collect the English speech corpus from children around age 10.
> (b) Use the corpus to train HMM-based acoustic models
>   i. Features: 26-dim MFCC
>   ii. Acoustic unit: Monophones of 3 to 6 states
>   iii. Training method: Baum-Welch reestimation

Part B: Recognition

> (a) Perform Viterbi decoding over linear lexicon networks
> (b) Return the predicted answer with the maximum log likelihood

Part C: Feedback Generation

> (a) Preparation: sets of possible response utterances.
> (b) Generation: selected the sentences randomly from the sets corresponding to the predicted answer as feedback.

Figure 1-1. Description of the speech recognizer

Part A

Input: learners' utterance → **Part B** → **Predicted utterance:** calculate and recognize students' utterance → **Part C**
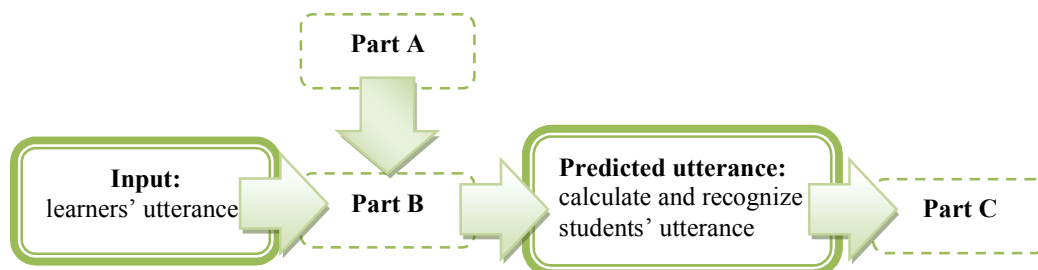
Figure 1-2. Description of the speech recognizer process

The tangible learning companions were created in the shape of the cartoon figures based on the results of our prior study (Young, Wang & Jang, 2010) (Figure 2-1). In addition, the learning companions could act out and move while interacting with the learners in English conversations, including singing English songs, walking forward and flapping wings, etc.

Figure 2-1. The appearances of the tangible learning companions

Basic English learning materials were used for the beginners in this study, including Greetings conversation, Self introduction and Good-bye conversation, etc. Learners could practice the sentences out loudly to the tangible learning companions and they would get immediate accurate oral responses from the tangible learning companions as if the learners were conversing English with a real partner or a teacher. Figure 2-2 shows the example of Greeting conversation and the framework of learning processes between learners and learning companions.
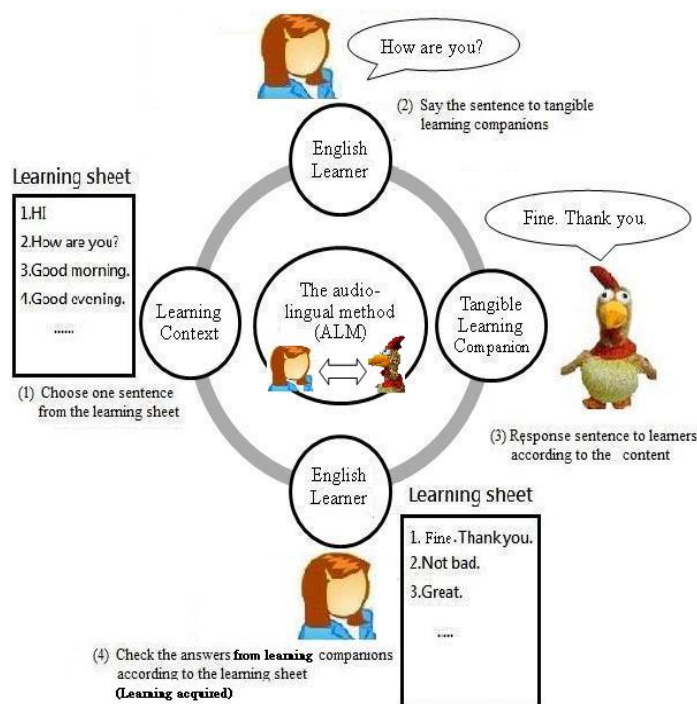
Figure 2-2. The framework of learning processes

Methodology

The quasi-experimental design was adopted in this study. The study used comparative test data and empirical experiments to report on the performance of learning English with and without the tangible learning companions. Both qualitative and quantitative data were collected and analyzed. The triangulation was used to improve the probability so that findings and interpretations could be reliable. Observation forms detailing students' learning performance in English class were recorded by five observers who were graduate students majored in e-learning technology. The observational scales were documented in the observation forms. More specifically, before the experiment, all the five observers were trained for how to categorize students' learning behaviors and the interaction processes with the tangible learning companions and with peers. The content of the evaluation criteria included: did students pay attention to English teachers' instruction; did they engage in the speaking activity with peers and learning companions, and when would students show stronger learning motivation in learning and what might be the reasons or factors to affect this situation etc. Besides, how students' learning involvement and emotion changed during the practice session were also video recorded. To understand the learning effectiveness, learners were required to do both the pre-test and post-test. The contents of the test were developed based on the specific English courseware and discussed with the targeted English teacher. Furthermore, a questionnaire that contains a five-point Likert scale was used to collect learners' attitudes of using the tangible learning companions. Researchers designed the questionnaire and evaluated students' learning performance according to the scales from "Measuring Children's Fun" questionnaire (Read, MacFralane & Casey, 2001). Learners' motivation, self-confidence and anxiety toward learning English conversation with and without the tangible learning companions were observed. Moreover, their learning endurability, engagement and expectation of using tangible learning companions in learning English were also evaluated. In addition, both individual and focus group interviews were conducted.

Participants

A total of 63 fifth graders from two classes of an elementary school of Taiwan participated in this study. Class A was the experimental group that contained 32 learners. In Class A, the tangible learning companions were employed for the students to practice English conversations. Class B was the control group that consisted of 31 students in which the traditional learning method was applied and the students practiced English conversations with their classmates. Learners in both classes were further divided into five subgroups based on their English grades earned in the previous semester. The high-achievement learners were the students whose grades were at the top one third of the class. The grades of low-achievement learners were at the bottom one third of the class. Each subgroup consisted of six to seven students, including high, medium and low-achievement learners.

Data collection

The tangible learning companions were integrated into the class when students were learning English conversations in the Spring semester in 2009. Before the class, learners are required do a pre-test and post-test before and after the class, including the English writing and speaking tests. To assess their writing ability, learners had to take a cloze and pair tests. To evaluate their speaking ability, they were tested on a short English conversation. Five trained English teaching assistants played the role of evaluators to grade students' speaking performance. The rubrics used in the speaking test included two parts: learning performance and learning interaction. For the rubrics of learning performance, the speaking speed and pronunciation were evaluated. For the rubric of learning interaction, were learners confident while uttering the sentences, were they nerves while doing the test, and other reaction of their learning attitude were evaluated. The testing items were five basic English conversation such as "What color do you like?" and "Where do you live?" etc. During the class, the instructor led the learners to practice each sentence in groups. The students in the class A had English interactions with the tangible learning companions. For example, when learners asked a learning companion about its name (What is your name?) and the learning companion would reply to learners automatically. After the interaction sessions, every subgroup in the experimental group was further interviewed for their reflections on using the tangible learning companions for practicing English conversation.

Data analysis

The study applied the triangulation method for data collection and analysis. Following the research questions, the researchers analyzed and reported the study results from pre-test and post-test, questionnaires, classroom observations and interviews. Both of the Independent Samples T-test and Paired Samples T-test were applied for the statistic analysis. Besides, the reliability of the questionnaire was measured with the SPSS software and the Cronbach's α was applied to examine the consistency between each items. The score of Cronbach's α of the questionnaire was 0.874 and the reliability of the questionnaire was achieved. Moreover, the original class observations and interviews were transcribed verbally then coded and reduced them into several scales according to the themes which included the interaction processes with peers and with learning companions, the engagement and concentration during the practice time, and the reflections and attitude toward learning English with the tangible learning companions.

Students' and the instructors' feedback and perception on using tangible learning companions

Students' evaluation on the usability of the learning companion was measured after the English classes. Data related to usability from the questionnaire are shown in Table 1. Students suggested that the learning companions were easy to use and that they experienced no difficulty at operating them. Moreover, the pronunciation of the learning companions was clear and the volume was adequate. Most of the learners liked the appearances of the tangible learning companions. Besides, from the open-ended questions and interview feedback, students reflected that the immediate response from the learning companions made students feel like having a real conversation with teachers. Most of them had positive feedback after using the tangible learning companions in learning English conversation. Moreover, they also indicated that they would like to have a friend like the learning companions used in this study in other learning subjects that they take.

The instructor also showed positive attitude toward using tangible learning companions as a teaching assistant in the English classes. He commented that adopting the tangible learning companions in class gave learners more opportunities to practice English conversation and motivated them to speak out the English sentences bravely compared to the English class before.

Table 1. The questionnaire of usability feedback

Item	Statement	1	2	3	4	5	Mean
Q1	I have some troubles in using tangible learning companions.	25.8%	9.7%	45.2%	12.9%	6.5%	2.64
Q2	It takes lots of time to learn how to interact with tangible learning companions.	16.1%	12.9%	61.3%	6.5%	3.2%	2.67
Q3	The pronunciation of the tangible learning companions is clear.	6.5%	12.9%	32.3%	12.9%	36%	3.58
Q4	The appearances of tangible learning companions are attractive to me.	6.5%	0%	25.8%	16.1%	51.6%	4.06
Q10	I want to have one friend like the learning companion in learning English with me.	3.6%	0%	7.9%	14.3%	64.3%	4.35
Q11	I enjoy learning and feel comfortable to practice English with learning companions.	3.6%	3.6%	14.3%	10.7%	67.9%	4.35

Note. 5 to 1 points: strongly agree, agree, neutral, disagree, and strongly disagree.

Learning process, motivation, attitude and classroom atmosphere of using tangible learning companions

The *Experimental Group* (E.G.), *Control Group* (C.G.) and each small subgroup were observed by trained assistants and tap-recorded learners' interactions in both groups during the instruction and subgroup practicing time. Observation data indicate that learners in E.G. displayed much higher learning concentration and engagement with learning material than those in C.G during the instruction time (Figure 3). Later in the subgroup practicing time, the learners in each subgroup of E.G. were also highly interested in practicing English conversations with the other classmates and the tangible learning companions. Not only did they show higher motivation in practicing English with the tangible companions but they also tried to listen very carefully to the other students who were practicing conversation with the learning companions (Figure 3A).

A. Practicing Time : Experiment Group

A-1   A-2   A-3   A-4

(Learners interacted with each other actively)

B. Practicing Time : Control Group

B-1   B-2   B-3   B-4

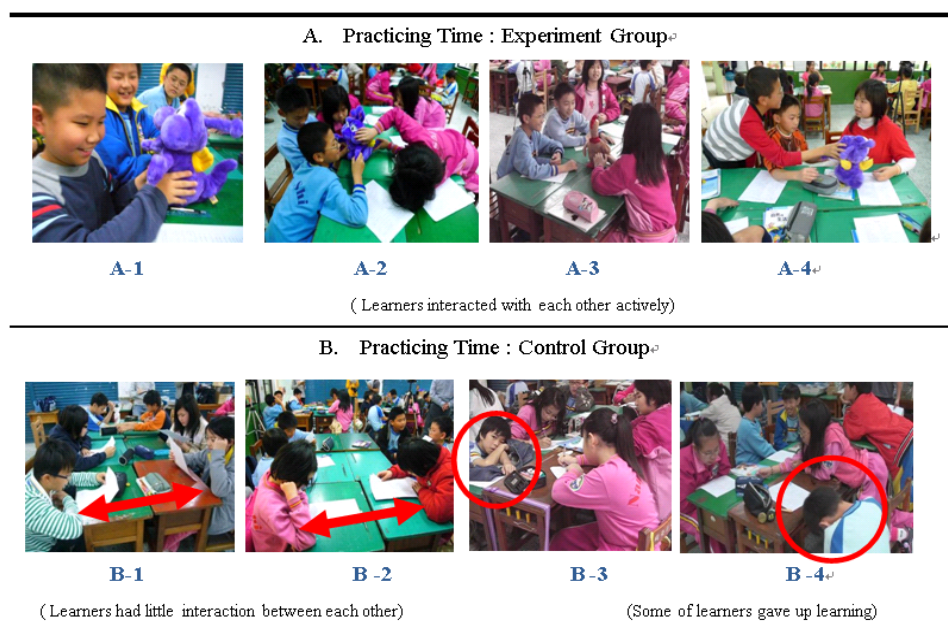(Learners had little interaction between each other)   (Some of learners gave up learning)

Figure 3. Comparison of the two groups

The results of the questionnaires (Table 2) show that the E.G. had more positive attitude, motivation and confidence in learning English than those in C.G. and learners in E.G. had little anxiety when practicing English with the tangible learning companions than those in C.G.. Students were eager to learn the conversation and dared to ask more questions about how to improve their pronunciation of each English sentence. Besides, some positive comments were given from learners such as they felt comfortable with practicing English with the tangible learning companions and that talking with learning companions is like with a real friend and the atmosphere in the classroom was vigorous and vivid than before (Table 3).

The atmosphere of the class was full of joy in E.G.. English instructor had difficulty managing the class in order due to the students' higher motivation and lower anxiety. In addition, trial and error learning was also observed in the group practicing time (Xu, 2009). Contrary to those in the E.G., learners in the C.G. were well-behaved and orderly but their motivation and engagement in learning were not as strong as those in the E.G.. They had little interaction with group members and were easily distracted (Figure 3B). Furthermore, when we focused on the analysis of low-achievement learners in C.G., we found that some of them even gave up learning due to frustration. This situation could be worse in the group practicing time, as the low-achievement learners had nothing to do and felt bored when other students were practicing English conversation in pairs (Figure 3B-3 & B-4).

Table 2. Part of the questionnaire of attitude (motivation, confidence, and anxiety)

Item	Statement	Group	Mean	T	P
Q1_1	I enjoy the way of practicing English in today's class.	E.G.	4.46	2.37	.01
		C.G.	3.83		
Q1_6	I dare to speak English with my classmates loudly after today's practicing activity.	E.G.	3.63	1.67	.038
		C.G.	3.03		
Q1_8	I am still afraid of speaking English because I am not good at English.	E.G.	2.2	-0.21	.41
		C.G.	2.26		
Q2_1	I am willing to practice English in this way over again.	E.G.	3.9	1.42	0.07
		C.G.	3.47		
Q2_5	I feel comfortable and concentrated on the learning activity today.	E.G.	4	1.34	0.09
		C.G.	3.6		
Q2_8	I expect I could use the same way to practice and learn English in the following English class.	E.G.	4.4	2.08	0.02
		C.G.	3.8		

Table 3. The interview feedback from learners

NO.	Advantages	NO.	Things need to be improved
S_EE4	It makes me have courage to speak out the English sentences.	S_EA24	I hope Popodoo could speak loudly when he responded me.
S_CH32	I hope I could have more chances to talk with Popodoo and I felt comfortable practicing English with her because she is just a toy and I can say whatever I want with her.	S_EB25	It will be much better if it can speak more English sentences.
S_E	I feel nervous when practicing English with my teacher but relaxing when practicing with my friends and the chicken.	S_EE12	I hope it can answer me no matter what I ask him

Learning effectiveness of experiment group and control group

We compared students' learning performance between the E.G. and C.G.. Table 4 shows the results of the pre-test and post-test. According to Table 4(a), there is no significant difference in the total score of pre-tests ($t = .681$, $p = 0.499$) and post-tests ($t = .594$, $p = .227$) within both groups according to the results of Independent Sample T-test. However, noticeably, Table 4(b) indicates that according to the results of Paired Samples T-test there are significant differences between the pre-test and post-test speaking scores in the E.G. ($t = -3.78$, $P = 0.00$). In contrast, no obvious differences were found between the pre-test and post-test scores of the C.G. ($t = -1.58$, $P = 0.12$). Moreover, Table 5 indicates that the means of the post-test scores of the speaking part (Low-achievement Learner (L.L.), M = 25.62; High-achievement Learner (H.L.), M = 38.67) are higher than those of the pretest scores (L.L., M = 20.88;

H.L, M = 38.11) which occurred in both the low-achievement and high-achievement learners in the E.G.. Furthermore, there are also significant differences between pre-test and post-test scores from the results of Paired Sample T-test for the low-achievement learners in E.G. (t = -2.44, P = .02).

Table 4. The results of pre-test and post-test of both groups

(a) Independent Samples T-test							(b)Paired Samples T-test					
Total Groups	score	Mean	S.D	F	T	P	Groups part	Speaking	Mean	S.D	T	P
Pre-test	E.G.	82.45	22.26	.60	.68	.50	E.G	Pre-test	30.72	8.76	-3.78	.00
	C.G.	78.48	22.82					Post-test	34.79	7.76		
Post-test	E.G.	84.28	23.07	1.72	.59	.23	C.G	Pre-test	27.52	11.17	-1.58	.12
	C.G.	80.39	27.32					Post-test	30.06	11.13		

Table 5. The results of speaking scores of experiment group

	Paired Samples T-test							
Speaking Part (E.G.)	Pre-test		Post-test		Pre-test – Post-test		T	P
	Mean	S.D.	Mean	S.D.	Mean	S.D.		
Low-achievement Learner (L.L.)	20.88	7.45	25.62	8.78	-5.49	-4.75	-2.44	.02
High-achievement Learner (H.L.)	38.11	1.45	38.67	3.32	-0.44	2.40	.56	.30

The learning methods of using tangible learning companions in experiment group (E.G.)

Further analysis of the E.G. was conducted. It indicates that two learning methods, co-discovery learning method and peer tutoring learning method, could be deducted from the five subgroup while students were interacting with the learning companions in the E.G..

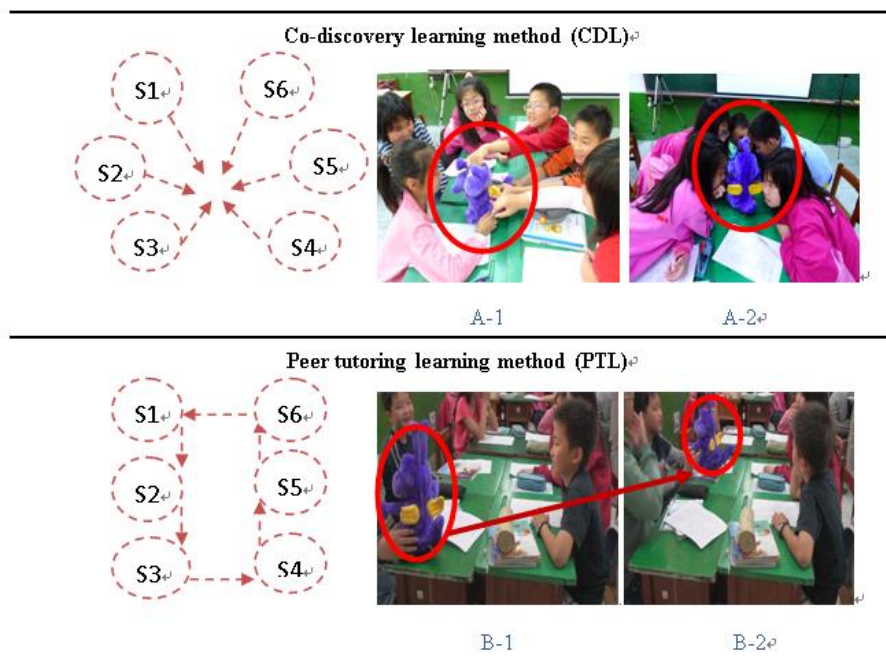*Co-discovery learning method and Peer tutoring learning method*

Figure 4. Two learning methods in experiment class

It was found that the *co-discovery learning method* (CDLM) was adopted by three subgroups and the peer tutoring learning method was adopted by the other two subgroups. In the subgroups in which CDLM was used (Figure 4A), learners put tangible learning companions at the center of the table and concentrated on it. Every member practiced English with the learning companion actively and exchanged the tips of how to operate it correctly. Learners were found to be enjoying practicing English conversation with the tangible learning companions. The subgroups which adopted the *peer tutoring learning method* (PTLM) had a leader to lead all of the members to take turns in practicing English conversation with the tangible learning companions (Figure 4B). Learners practiced English with learning companions one by one and the previous learner taught the next how to use it correctly.

Comparison of the two methods

The speaking scores of the high-achievement and low-achievement learners between the two subgroups of these two different methods in E.G were compared (Table 6). The results indicate that the standard deviation of the speaking grades in the post-test reduced in the CDLM subgroups. Also, the scores of low-achievement learners in those subgroups were much higher than the subgroups which using PTLM (Figure 5 & 6). Both of the low-achievement and high-achievement learners improved more at CDLM subgroup (H.L. improved 10 points and L.L. improved 15 points). Significantly, the CDLM is considered as a more effective approach in helping low-achievement learners practice English speaking because learners could have more opportunities to interact with the classmates. The finding was similar with the preview studies that the co-discovery learning method could enhance students' learning efficiency and motivation (Umar & Tatari, 2008). More detail information will be mentioned in the discussion part.

Table 6. The comparison of the two methods

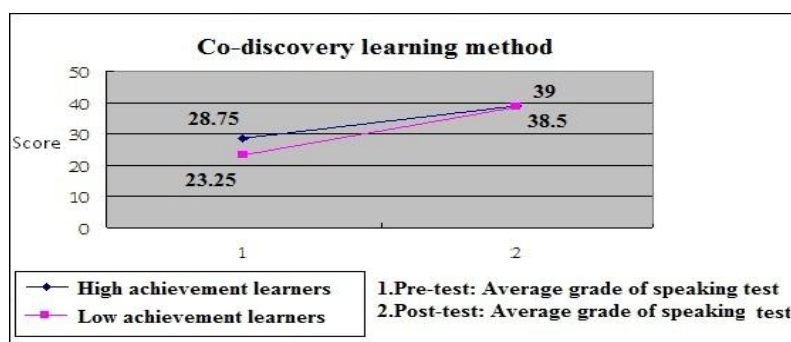|		CDLM		PRLM	
		Mean	S.D	Mean	S.D
Pre-test	H.L.	28.75	1.70	36.00	3.91
	L.L	23.25	8.34	19.25	7.76
Post-test	H.L.	39.00	1.15	40.00	0.00
	L.L	38.5	7.54	25.5	8.42

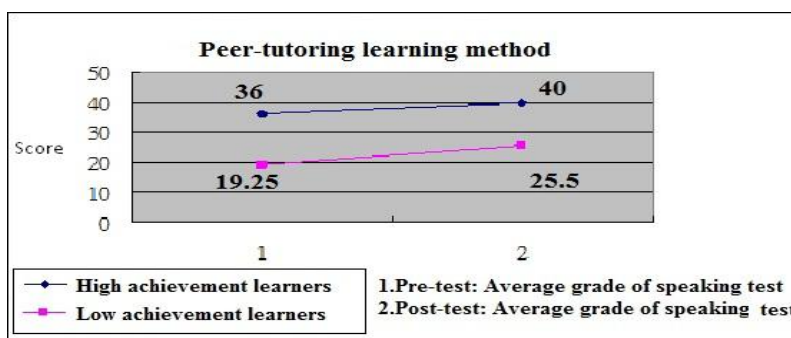*Figure 5.* The comparison of the two methods: CDLM

Figure 6. The comparison of the two methods: PTRM

Discussions

Tangible learning companions and learning atmosphere

The data collected from the classroom observations indicated that there was a big difference between the control and experimental groups. Obviously the students in C.G. had little interaction between each other and those students who were not good at speaking English simply gave up learning and even fell asleep in classroom (Figure 3B). However, the experiment group displayed much higher learning concentration and engagement than those in C.G. in the instructional session and subgroup practicing time. Students in the experiment group got together and formed a circle to learn English conversation through interacting with the learning robots (Figure 3A). Moreover, the data from the self-evaluation questionnaires and focus group interviews show that students revealed high interest in practicing English conversation repeatedly with the tangible learning companions. The interaction between learners was facilitated. Students commented that the learning companions were like friends and won't get angry while they did not speak English correctly so that they were not afraid of speaking English with the tangible robots. For example, student commented: *It makes me happy and the atmosphere in classroom was joyfully. We liked to talk in English much more* (S_ED20).; *I hope I could have more chances to talk with it (the tangible companion) and I felt comfortable practicing English with her because she is just a toy and I can say whatever I want with her* (S_CH32).; *I enjoy practicing English with the interactive chicken because it is a doll and it won't get angry* (S_EA5).

In addition, the results of the study support the results of the previous studies (Hall, 2009) that the trial-and-error learning approach helps learners enhance their activeness and comfortableness in practicing English conversation. The tangible learning companions play an important role in improving the atmosphere of the learning environment. In other words, the characteristics of tangible technology, binding, objects and embodiment (Ullmer & Ishii, 2001), combine the virtual concept of English learning with physical learning media. The immediate English response, the simulated appearance of human being and the movement of the tangible learning companions attracted learners' attention and interest and hence promoted the learning atmosphere in the English classroom. Learning and joyful gaming modes were blended while students interacted with the physical tangible learning companions.

Tangible learning companions and the two learning methods: Co-discovery learning method and peer-tutoring learning method

There are significant improvements between the pre-test and post-test speaking scores in the experiment group (Table 4) especially for the low-achievement learners (Table 5). Besides, it was found that learners used CDLM and PTLM methods to practice English conversation. The students in the CDLM group cooperatively exchanged the tips of how to operate tangible learning and how to pronounce each sentence correctly (Figure A). For the PTLM group, a group leader, usually the more advanced student, helped group members practice the conversation in sequence (Figure 4B). These two kinds of learning methods are similar to the method of cooperative learning conducted by Damon (1984). He observed that students adopted the peer tutoring method and co-discovery method when learning new things with each other. Related studies showed these two methods can enhance students' learning efficiency (Umar & Tatari, 2008). Our study also supports this finding. Furthermore, the data indicated that the low-achievement learners had a great improvement in speaking ability while in the CDLM group (Table 5). Two low-achievement learners in the CDLM group commented that "*I feel nervous when practicing English with my teacher but relaxing when practicing English with my friends and the chicken* (S_EA5)" and "*I like to have English conversation with classmates more than before* (S_EA4)."

Besides, the tangible learning companions played different roles in two methods. For the PTLM group, it played the role as physical peer-partners. One group leader who played the role as instructor guided the learner how to talk with the learning companions and others just watching and waiting. However, in the CDLM group, all the students paid attention on the tangible learning companions. They were looking forward to hearing the responses from the learning companions, and when it "speaks," all the students uttered and discussed in highly engagement about which sentence to practice for next, how to modify their speaking errors and even murmur on each other about the English sentences they just learned. It promotes self-directed learning and the opportunity for self-evaluation through the stimulation of the sense of touch, vision and hearing. The tangible learning companions played the role as instructors, peer-partners and opportunity providers in the CDLM group to motivate students speak out (Figure 7). No advanced leaders would "interrupt" or "guide" students how to speak. Hence, the low-achievement students overcame the learning fear

caused from language ego to actively engage in learning English and their speaking ability could be enhanced. The blending of the co-discovery learning method and tangible learning companions is considered as a more effective approach in helping low-achievement learners. In other words, the tangible nature of learning companions brings students the experiences of English speaking in the real world. The tangible companion scaffolds students to speak English and provides learners with opportunities to co-discover learning with each other in English.
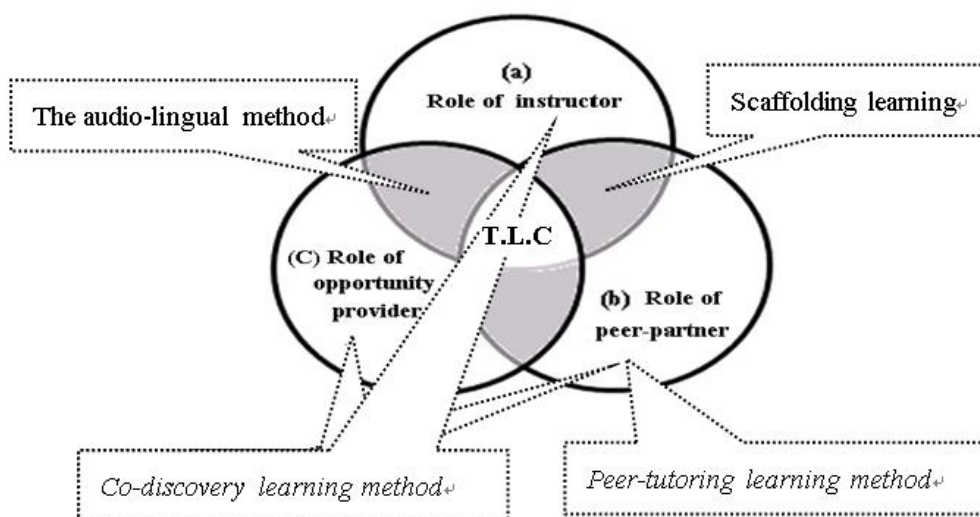

Figure 7. Tangible learning companions and the two learning methods

Speech recognition enhances language learning and teaching

In this study, the speech recognition technology has been integrated into the learning devices successfully. For a long time, technology enhanced language learning has focused more on language reading and writing but few on speaking skills relatively because of the limitation of techniques (Liu et al., 2002). The technique of utterance scoring and immediately interactive conversation with computers is a breakthrough in the field of technology-enhanced language learning. With the aid of the speech-recognition-based learning companions, learners won't feel uncomfortable to speak English in front of instructors. English teachers' load of taking care of each student in the big classroom could be released. The advantage of speech recognition technology brings the flexible opportunities both for teachers and students, so that the language learning and teaching will not be limited in English classroom.

Conclusions

This research extended the concept of learning companions from a virtual world to the real environment. The research teams jointly implemented the tangible learning companions for enhancing English conversation in the primary schools is the pioneering study in Taiwan to date. Results of this study indicate that the tangible learning companions had positive effects on learners' learning motivation, confidence and engagement. Learners viewed the English learning companions as interesting toys, robots, peer-partners or patient instructors for learning English and they felt more comfortable speaking English with less fear on making mistakes. For beginners, this is an exciting and important step to take when the tangible learning companions play the scaffolding role in helping the students learning a foreign language. It is important that the psychological learning barrier, caused by the language ego, could be reduced by using the tangible learning companions so that they could actively engage in learning English. Overall, the English instructor and students agreed that uses of the tangible learning companions effectively improve the class atmosphere, learning interest, and attitude of the learners in English learning.

We can conclude from the current study that uses of the tangible companions in the English-learning setting with the English beginners provide learners with more opportunities of practicing English conversation and motivate them to speak English more freely and comfortably. Meanwhile, it would help reduce English teachers' burden in the given instructional conditions of very limited English class time and very few sessions per week. It is our hope that the affordances of this kind of learning devices could be used to encourage learners to speak English more comfortably and enjoy the process of interactive English learning. In addition, it can enhance learners' English speaking proficiency.

At the current stage, due to the small size of the learning companions along its embedded speech chips, the rate of accuracy is around 92.5% and its capacity of the speech chip allows up to 30 sentences in the system that, to date, is enough for the beginning learners. However, to meet the demands of more complex English learning settings and to achieve higher rates of accuracy as up to 100% eventually, we are tackling the limitation by applying the cloud computing technology. In the future, the research teams will continue to jointly develop more powerful learning companions to address more instructional needs and research issues as well. In addition, we will explore the learning effectiveness between the tangible learning companions and computer-based avatars in language learning settings. Moreover, we attempt to combine the tangible learning companions with online learning. We anticipate exploring this series of tangible learning companions and devices in enhancing language learning and more research findings will be shared.

Acknowledgements

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Structural Relationships among E-learners' Sense of Presence, Usage, Flow, Satisfaction, and Persistence

Young Ju Joo[1], Sunyoung Joung[2*] and Eun Kyung Kim[1]

[1]Ewha Womans University, Korea // [2]Kookmin University, Korea // youngju@ewha.ac.kr // sjoung@kookmin.ac.kr // Jenis35@naver.com
[*]Corresponding author

ABSTRACT

This study aimed to investigate the structural relationships among teaching presence, cognitive presence, usage, learning flow, satisfaction, and learning persistence in corporate e-learners. The research participants were 462 e-learners registered for cyber-lectures through an electronics company in South Korea. The extrinsic variables were sense of teaching presence, sense of cognitive presence, and usage. According to structural equation modeling, each of these variables and flow significantly affected satisfaction. Although sense of teaching presence and satisfaction significantly affected sense of cognitive presence, usage and flow did not significantly affect learning persistence. Accordingly, we established a corrected model after removing insignificant paths and investigated again. We confirmed that learning flow significantly intermediated among sense of teaching presence, sense of cognitive presence, and satisfaction but not between usage and satisfaction. In addition, satisfaction intermediated among sense of teaching presence, sense of cognitive presence, usage, flow, and learning persistence. These findings demonstrate the importance of sense of teaching presence, sense of cognitive presence, and usage for e-learners. We expect that the results will contribute to the formation and improvement of fundamental learning strategies for successful e-learning.

Keywords

Sense of teaching presence, Sense of cognitive presence, Usage, Learning flow, Satisfaction

Introduction

In an information society, where knowledge is a core resource, as the importance of human resource development increases, many enterprises emphasize employee education in order to improve their employees' capabilities. Moreover, as people acknowledge the benefits of e-learning—namely, that they can overcome time and space constraints through use of the Internet and other information and communication technologies—e-learning rapidly has become diffused and generalized. However, regardless of such quantitative growth, it can be difficult to actively engage online learners. Achieving flow in the e-learning process is challenging because e-learning differs from traditional education, which is conducted in e-learning. Thus, online learners may not be motivated to continue due to low learning satisfaction. As advocates have called for investigation of the e-learner's experience in the e-learning process to improve its quality, researchers have sought to understand the sense of presence and its role in e-learning.

Sense of presence is expressing not what exists in the physical environment but rather what one experiences and perceives (Witmer & Singer, 1998). When learners' sense of presence improves, they study content and situations meaningfully and experience flow in learning by actively participating in the learning process. This leads to positive learning outcomes (Garrison & Arbaugh, 2007; Wang & Kang, 2006). Given the importance of a sense of presence for e-learners and its connection to positive learning outcomes, researchers should investigate its role in e-learning environments, observe any causal relationship between flow and learning outcomes, and use the findings to create practical improvement strategies. Garrison, Anderson, and Archer (2001) proposed a community of inquiry model, in which learners develop individual intelligence through reflective thinking and critical discourse, based on social interactions with the instructor. They also emphasized the sense of presence that learners can perceive in their community of inquiry. Garrison and Arbaugh (2007) proposed the senses of teaching presence, cognitive presence, and social presence as indispensable factors for successful learning in the context of a community of inquiry.

Sense of teaching presence refers to a learner's perception regarding a general teaching phenomenon along with aspects of designing and systemizing instruction (Arnold & Ducate, 2006). Anderson, Rourke, Garrison, and Archer (2001) defined the sense of teaching presence as a learner's perception of their guide in cognitive and social processes, design, and facilitation aimed at helping them to realize individually meaningful and educationally

valuable results. The sense of teaching presence is distinct from the sense of *teacher* presence in that it focuses on instruction in e-learning environments. The sense of teaching presence can be divided into instructional design and organization, facilitation of discourse, and directed instruction within the community of inquiry (Garrison et al., 2001). Because the sense of teaching presence, which structuralizes learning content, encourages the learner's continual participation and facilitates discourse, it can lead learners to continue meaningful learning. This is particularly important in e-learning environments, where face-to-face interactions with an instructor are impractical. Sense of cognitive presence is defined as the degree of consistent and confirmed meaning in a learner's reflection and discourse (Garrison & Anderson, 2003). Kang, Park, and Shin (2007) elaborated the concept by defining it as the perception of a learner's ability to understand the learning topic through learning activity and to generate and confirm his or her own knowledge in the e-learning environment. The sense of cognitive presence extends a student's ability to restructure meaning gained through his or her communications and affects critical thinking involved in higher-order thinking and learning (Kanuka & Garrison, 2004). It is an essential component of higher-order exploratory, process-using critical thinking in e-learning, which is based on the learner's inner experience.

Flow is "the whole experience that people feel when they concentrate on some activities" and means the state in which one is fully concentrating on one's task or work and functioning optimally (Csikszentmihalyi, 1990). Csikszentmihalyi (1990) said that *flow* means a state where some behavior happens naturally, like flowing water, and one concentrates fully on one's work, losing one's sense of time, being unconscious of circumstances, and being fully obsessed with one's work. In a flow state, a person's level of concentration upon a project increases; the target of this concentration coalesces within a certain project; and the person's blocks thoughts, concerns, and worries unrelated to the project from consciousness. One feels a sense of control toward the project and feels the self to be in a flow state.

The current study did not adopt the notion of sense of social presence but did adopt senses of teaching presence and cognitive presence as effective variables for learning outcomes. We expected that a learner's learning flow, satisfaction, and learning persistence would not be affected by sense of social presence, as learners find it difficult to communicate with colleagues and creating social relationships in Korean corporate e-learning environments, where individualized learning prevails (Kim, 2009). We also established sense of presence as an effective variable for learning flow, considering that learning flow results from the sense of presence and is a factor in facilitating learning flow. In addition to exploring these initial hypotheses, we also explored the effects of sense of presence on learner satisfaction and persistence in e-learning.

Presence, flow, satisfaction, and persistence

Sense of presence, along with flow, has been the subject of much attention in past studies. Riva (2006) defined it as a mental status in which one feels as though one is "there" when fully engaged in media use. Fountane (1992) explained sense of presence as a matter of focus with psychological interests. On the other hand, Barfield and his colleagues (1995) advocated considering flow as the result of a sense of presence. With regard to the relationship between sense of presence and learning flow, Wang and Kang (2006) introduced the senses of emotional presence, social presence, and cognitive presence as facilitating factors of engaging students in ideal learning through online pedagogy. They proposed an online pedagogy model as an instructional strategy and mentioned the importance of sense of presence for learning flow.

In relation to sense of presence and learner satisfaction, Garrison and Cleveland-Innes (2005) wrote that interactions between instructors and learners more strongly affect learning achievement and learner satisfaction than do interactions between learners. Therefore, sense of teaching presence leads to effective learning, facilitated by direct engagement with an instructor and optimal guides. Wu and Hiltz (2004) also emphasized the importance of the instructor by showing significant correlations among learner cognition, learner motivation, pleasure, and satisfaction in a blended learning class. Cognitive presence is also an important factor that affects learning outcomes, such as satisfaction, achievement, and learning persistence. As cognitive presence increases, so do satisfaction and achievement (Kang, 2005).

In research on cognitive presence and learning persistence, Joo, Kim, and Park (2009) analyzed the relationships among cognitive sense of presence, satisfaction, and learning persistence using structural equation modeling (SEM). The participants were 375 employees of an electronics enterprise who had completed four weeks of a cyber-course. In their results, the cognitive sense of presence had significant effects both on satisfaction and on learning persistence. Similarly, Shin (2003) studied the relationships among teaching presence, satisfaction, learning achievement, and learning persistence

on 506 students registered for cyber-courses at K Cyber University and found that the sense of teaching presence had significant correlations with learning achievement and learning persistence.

Usage, satisfaction, and persistence

This study established usefulness as an effective variable for learning flow, given that learning flow comes from the results of usefulness and is a factor facilitating learning flow. In addition, previous studies have reported the effects of usefulness on learner satisfaction and persistence in e-learning. Kim (2006) investigated the relationship among perceived usefulness, perceived ease of use, learner's attitudinal flow, and behavioral flow using SEM in an e-learning community. The participants were 62 undergraduate and graduate students registered for a cyber-course for pre-service teachers. The results showed that perceived usefulness and perceived ease of use affected attitudinal flow and that attitudinal flow affected behavioral flow. Kim and Oh (2005), in their research on corporate e-learning, also reported that usefulness directly affects ease of use and behavioral intention and that ease of use affects behavioral intention. Further, they confirmed that usage indirectly affects flow by intermediating behavioral intention.

Roca, Chiu, and Martinez (2006) reported that usage significantly affects satisfaction in their research on the effects of usage on satisfaction and learning persistence. In their study, 184 participants completed e-learning courses provided at the United Nations System Staff College and International Labor Organization. The results confirmed that usage indirectly affects learning persistence, as satisfaction intermediates them. In another study examining the relationships among usefulness, satisfaction, and learning persistence for 183 e-learners who had completed an asynchronous e-learning educational course at a university in Taiwan, usefulness had significant effects on satisfaction, and satisfaction had significant effects on learning persistence. In addition, the study proved the importance of usefulness in e-learning by empirically demonstrating the significant indirect effect of usefulness and the intermediation effect of satisfaction (Chiu, Hsu, Sun, Lin, & Sun, 2005). No, Lee, and Chung's (2008) study on the effects of perceived usefulness and perceived ease of use on persistent intention, using 203 e-learning users who had cyber-learning experience, showed usage had significant effects on persistent intention of use.

Flow, satisfaction, and persistence

The current study established flow as an effective variable for learner satisfaction and persistence in e-learning. Kim (2005) examined the relationship between flow and satisfaction among 366 graduate students participating in cyber-courses. The research confirmed that flow significantly affects satisfaction. That is, learners themselves can affect their degree of satisfaction according to their perceived degree of flow in e-learning courses. According to Kang (2005), as cognitive presence increases, so do satisfaction and achievement. Flow is very important in education; once learners experience flow in the learning process, the learning process becomes pleasant. Accordingly, flow leads to active participation in learning and cooperative activities. It also gives the student a sense of satisfaction and achievement (Park & Kim, 2006). Shin (2006) conducted a study targeting 525 undergraduate students who had completed e-learning courses in order to examine the relationships among prerequisite variables and flow and the resultant variables of flow. The findings indicated that flow in e-learning is a significant variable affecting satisfaction in a study.

In the field of leisure and sport, Kim and Lee (2008) investigated the relationships among motivation, flow, and learning persistence for 199 aquatic sports participants. They reported that flow had a significant effect on persistent intention for participation. Cabrera, Nora, and Castaneda (1992) established a research model of learners' learning persistence based on previous literature reviews and analyzed their reliability using SEM. Their results show that flow in both learning objectives and educational organization had significant effects on the learning persistence of new university students.

Distinctive significance of the study

First, this study attempted to clarify the cause-and-effect relationships among sense of teaching presence, sense of cognitive presence, flow, satisfaction, and persistence within an integrated view. Despite the importance of sense of teaching presence, sense of cognitive presence, and usefulness for e-learners, the research investigating their effects on learning

outcomes from an integrated view remains insufficient. Previous studies related to successful e-learning investigated simple correlation or effects between two variables rather than integrating the variables related to learning persistence. For example, studies have examined the relationship between teaching presence and satisfaction (Wu & Hiltz, 2004) as well as the effect of cognitive presence on satisfaction and presence (Kang, 2005), of teaching presence on persistence (Shin, 2003), of usage on satisfaction and persistence (Roca et al., 2006), of usage on persistence (No et al., 2008), of flow on satisfaction (Kim, 2005), of cognitive presence on satisfaction and achievement (Kang, 2005), and of flow on satisfaction and achievement (Park & Kim, 2006). Since learning outcomes in cyber-environments, such as satisfaction and learning persistence, are complex phenomena affected by assorted variables (Willging & Johnson, 2004), observers should consider the relevant variables' causal relationships with an integrative structural view.

Second, previous studies on the relationships among flow, satisfaction, and persistence using SEM have not addressed important variables in predicting successful e-learning. Joo et al. (2009) did not include the sense of teaching presence in e-learning but did suggest the necessity of investigating it. Kim (2006) investigated the relationships among usefulness, ease of use, and behavioral and attitudinal flow but did not include the outcome variables of flow. Chiu et al. (2005) investigated the relationships among usefulness, satisfaction, and persistence with the intermediation effect of satisfaction but did not include the teaching and cognitive sense of presence prior to looking at usefulness and outcome variables. Moreover, the results of previous studies are somewhat contradictory. Thomas's (2000) investigation of the effects of students' social networks on learning persistence in a university setting found that the relationships among social networks, scholastic integration, social integration, grades, flow in objectives, flow in educational organization, and learning persistence were not significant.

Research purpose and hypotheses

The purpose of this study is to explain the relationships among the sense of teaching presence, usage, and learning outcomes, which facilitate learner flow in corporate e-learning, by integrating all the variables in a single structural model. Based on a review of the previous literature, we established research hypotheses and hypothetical research models of corporate e-learning. These are shown in Figure 1.
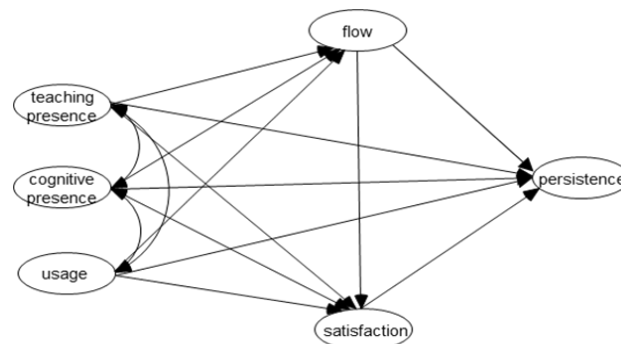
Figure 1. Hypothetical research model of corporate e-learning

First, the sense of teaching presence, sense of cognitive presence, and usage affect flow. Second, the sense of teaching presence, sense of cognitive presence, usage, and flow affect satisfaction. Third, the sense of teaching presence, sense of cognitive presence, usage, flow, and satisfaction affect learning persistence. Fourth, learning flow intermediates the sense of teaching presence, sense of cognitive presence, usage, and satisfaction. Fifth, satisfaction intermediates the sense of teaching presence, cognitive presence, usage, flow, and persistence.

Method

Research participants

This study investigated the structural relationships among sense of presence, ease of use, learning flow, satisfaction, and learning persistence for e-learners at Enterprise A. Enterprise A was selected for its use of the same registration

and management systems, learning service, and evaluation and grade generation systems for all its sub-branches. It is engaged in electronics, chemistry, and communication services and owns 30 sub-companies, 130 corporations, 70 branches, 40 factories, and 70 research institutes. Enterprise A first created five courses in 1998 and has since systematically offered job-related educational course to its employees, including "Business Skills-Up," "Business Creativity," and "Project Master." We chose to investigate a single enterprise for the consistency of its registration system and learning management system. Because the course was established to meet Korea's employee insurance refund policy, enacted in 2009, most students have completed it in order to meet the policy standard. We issued a survey to 462 participants to measure sense of teaching presence, cognitive presence, usage, learning flow, satisfaction, and learning persistence. There were 375 male participants (81.2%) and 87 female participants (18.8%). The participants' ages ranged from 24 to 54. Their job statuses were as follows: 29.5% staff, 21.4% deputy section chiefs; 17.3% section chiefs, 15.1% deputy department heads, 7.4% department heads, and 9.2% other.

Measurement instrument

To measure the sense of presence, we used the validated instrument designed specifically for measuring sense of presence by Garrison, Cleveland-Innes, and Fung (2004) and extracted only the sense of teaching presence and sense of cognitive presence. This instrument derives from the community of inquiry model by Garrison, Anderson, and Archer (2001). The sense of teaching presence is measured by 13 items (e.g., "I am satisfied with interactions with the professor, such as questions, answers, etc."). The sense of cognitive presence is measured by eight items (e.g., "I understood the subjects and problems given during class"). For both variables, the inter-item consistency had a Cronbach's α of .94. We removed the second item in one instance of duplicated items ("I am well adapted to the online environment" and "I am well adapted to my learning environment") out of the 13 items measuring sense of teaching presence. Thus, the final measurement used 12 items for sense of teaching presence and 8 for sense of cognitive presence. The construct reliability of sense of teaching presence (the reliability of the dormant variable) was .99, and the average extracted variance was .99. The construct reliability for sense of cognitive presence (the reliability of the dormant variable) was .95, and the average extracted variance was .91. Thus, we confirmed the instrument's convergent and discriminant validity.

We measured usage by extracting items from Davis's (1989) Technology Acceptance Model instrument. Usage consisted of usefulness and ease of use. Usefulness (e.g., "I think that it is useful to study the current course") and ease of use (e.g., "It is possible to study the current course without serious effort") each had four items. Inter-item consistency had a Cronbach's α of .87 for usefulness and .86 for ease of use. The construct reliabilities of usefulness and ease of use were both .99, and the average extracted variance was .97. Thus, we confirmed that the instrument had convergent and discriminant validity.

We used nine items from the Flow State Scale instrument validated by Martin and Jackson (2008) to measure learning flow (e.g., "I feel that I am able to control my environment when I study"). The inter-item consistency for learning flow items had a Cronbach's α of .83 for participants in high school gym class and .84 for those in high school music class. The construct reliability was .99, and the average extracted variance was .99. Thus, we confirmed that the instrument had convergent and discriminant validity.

We defined satisfaction as the degree to which learners felt satisfied with their e-learning experience. To measure this variable, we revised Shin's (2003) measurement instrument for corporate settings. The instrument consists of eight items (e.g., "It was a valuable experience to study the current course") rated on a 5-point Likert scale. The inter-item consistency had a Cronbach's α of .96, the construct reliability in the current study was .99, and the average extracted variance was .99. Thus, we confirmed the instrument's convergent and discriminant validity.

This study derived an instrument to measure learning persistence, including the perceived importance of completing the course, ability to overcome hindrance factors for learning persistence, and motivation to take the e-learning course, by revising Shin's (2003) measurement instrument. We used six items (e.g., "I will successfully complete the course regardless of my difficulty with the current lecture"). Their inter-item consistency had a Cronbach's α of .83. After we examined content reliability, we removed two items ("I am not likely to continue studying at KNOU" and "I would like to quit my studies") that were not appropriate for a corporate e-learning environment. Thus, the final instrument measuring learning persistence consisted of four items. The construct reliability in the current study

was .97, and the average extracted variance was .99. Thus, we confirmed the instrument's convergent and discriminant validity.

Research procedure

To investigate the structural causal relationships among sense of teaching presence, sense of cognitive presence, usage, learning flow, satisfaction, and learning persistence, we conducted an online survey for e-learners enrolled in courses at Enterprise A. We administered the survey the week prior to the e-learners completing the four-week course.

The main instructional methods were lectures given by the instructor delivered by video. Students were able to engage in individualized learning at any time. There were no online projects or discussions. Students were allowed to ask any questions through e-mail or online discussion boards. The e-learning platform was the LMS system developed based on SCORM 2.0 by the enterprise itself. The main contents of lectures were accessible in PowerPoint slides. Students were able to download the instructional materials at any time.

The course required three hours a week for four weeks. Each week's instructional materials were delivered separately. Evaluation consisted of multiple-choice tests that the students took online. The main topic of the course was job-related training. There was one instructor, whose primary role was to deliver video lectures, and one assistant instructor, who managed student requests.

Data analysis

To investigate the causal relationship between sense of teaching presence and sense of cognitive presence in corporate e-learning, we established the hypothetical research model shown in Figure 1 (see Section 1.5) and the statistical model in Figure 2. As seen in the statistical model, we established each dormant mathematical variable using index variables from the research model.
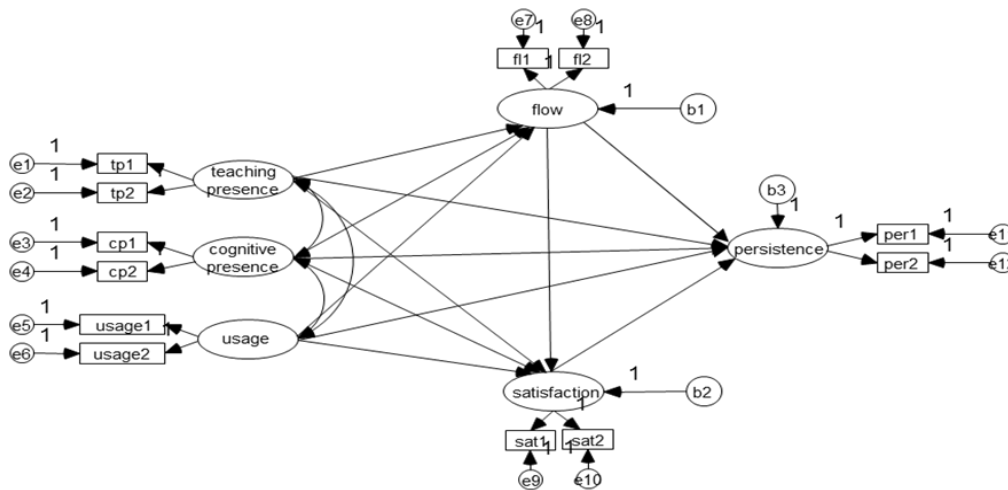
Figure 2. Statistical model of corporate e-learning

In establishing the model, we used an item parcel method to avoid overweighting on the measurement model since there are single-factor measurement variables in exploratory factor analysis results among sense of teaching presence, sense of cognitive presence, usage, learning flow, satisfaction, and learning persistence. Item parceling is using a total or average by randomly binding the first-level variable, which measures the same causal factors (Kishton & Widamn, 1994). By using the item parcel method, we can reduce the number of index variables that measure each dormant variable and ultimately reduce the prediction error. Furthermore, this method allows us to confirm the

multivariate normal distribution assumption better than individual item analyses would (Bandalos, 2002; Sass & Smith, 2006).

To determine the prediction method for the statistical model, we examined multivariate normal distributions of eight variables of the SEM using AMOS 6.0. As a result, we were able to satisfy the conditions of skewnesses and kurtoses for single variables. We predicted the model fitness and parameters using a Maximum Likelihood Estimation (MLE) procedure, given that the multivariate normal distribution assumption was satisfied. We evaluated the model fitness through CMIN, TLI, CFI, and RMSEA. We also examined statistical significance among variables with a confidence level of .05.

Results

Descriptive statistics and correlation analysis

In SEM, if each measurement variable is not normally distributed, the assumptions of the multivariate normal distribution cannot be satisfied. As a result, the model will give distorted values, and the researcher will be unable to achieve an exact statistical investigation. Therefore, to confirm the goodness of fit for the multivariate normal distribution of the collected data, we examined means, standard deviations, skewnesses, and kurtoses.

The variable means ranged from 3.55 to 4.22, standard deviations from .66 to .73, skewnesses from .12 to .67, and kurtoses from .10 to .30. This satisfied the basic assumptions of SEM, as the skewnesses of the measurement variables were less than 3, and their kurtoses were less than 10 (Kline, 2005). Therefore, the variables satisfied the basic assumptions of a multivariate normal distribution for SEM examination. The results of analysis of the correlations among the cyber-learners' sense of teaching presence, sense of cognitive presence, usage, learning flow, satisfaction, and learning persistence showed that all variables were significant. Table 1 displays the specific means, standard deviations, and correlation of each variable.

Table 1. Means, standard deviations, and correlation matrix

Measurement variable	Correlations of measurement variable											
	1	2	3	4	5	6	7	8	9	10	11	12
1. teaching presence1	1											
2. teaching presence2	.85*	1										
3. cognitive presence1	.67*	.68*	1									
4. cognitive presence2	.65*	.68*	.85*	1								
7. usefulness	.57*	.60*	.68*	.68*	1							
8. ease of use	.52*	.53*	.56*	.56*	.66*	1						
9. flow1	.70*	.75*	.73*	.74*	.65*	.55*	1					
10. flow2	.69*	.72*	.71*	.73*	.62*	.53*	.89*	1				
11. satisfaction1	.65*	.72*	.69*	.76*	.69*	.49*	.79*	.76*	1			
12. satisfaction2	.67*	.72*	.71*	.78*	.68*	.48*	.79*	.76*	.93*	1		
13. persistence1	.57*	.65*	.62*	.66*	.64*	.43*	.70*	.64*	.82*	.81*	1	
14. persistence2	.66*	.67*	.61*	.63*	.59*	.45*	.72*	.69*	.76*	.76*	.73*	1
Mean	3.55	3.69	3.81	3.90	3.93	3.73	3.86	3.81	4.11	4.06	4.22	3.98
Standard Deviations	.70	.70	.68	.67	.72	.73	.66	.67	.66	.68	.68	.72
Skewness	.20	-.13	-.20	-.40	-.30	-.32	-.15	-.12	-.54	-.57	-.67	-.42
Kurtosis	-.29	.13	.19	.30	-.13	.10	-.27	-.25	.28	.34	.27	-.25
N	462	462	462	462	462	462	462	462	462	462	462	462

Note. $^*p < .05$.

Measurement model investigation

Before examining the structural regression model's possibilities for model prediction and goodness of fit, we predicted the measurement model's fitness by the MLE method based on the second step of possibility confirming model prediction process (Kline, 2005). The prediction results of goodness of fit are displayed in Table 2. As seen in Table 2, all goodness of fit indices for the measurement model, including RMSEA (.054-.082), show the measurement model has goodness of fit.

Table 2. Overall model fit indices for measurement model

	CMIN	*df*	TLI	CFI	RMSEA (90% Confidence Interval)
Measurement Model	121.426	39	.977	.986	.068 (.054-.082)

Note. n = 462.
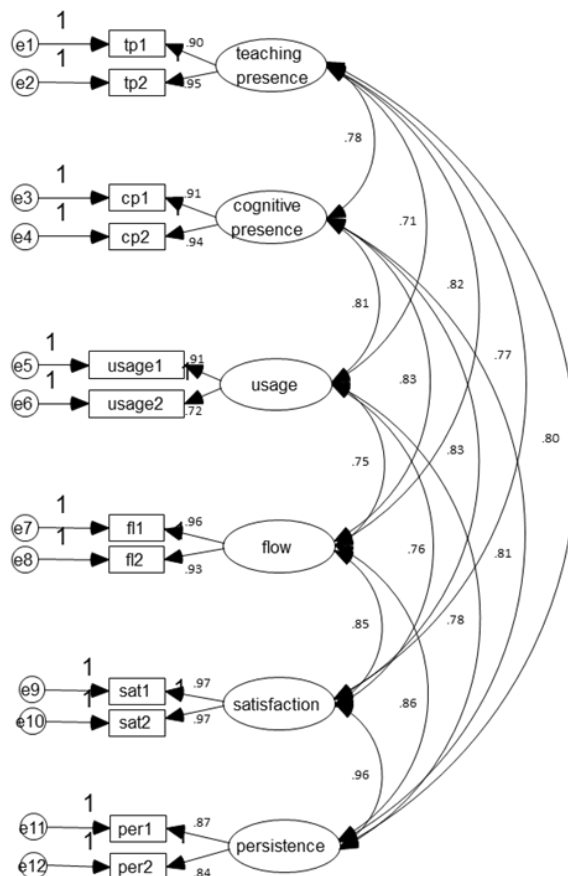
Figure 3. Measurement model parameter estimation result

Figure 3 shows that an examination of the relationships among the latent and index variables revealed the average factor load value for each path of the measurement variables ranged from .726 to .968, which was significant at an alpha level of .05. Considering the factor load value must be more than .30 (Hair, Anderson, Tatham, & Black, 1992), the measurement variables appeared to properly measure the corresponding latent variables. That is, the established measurement variables measured each latent variable under each research model with enough convergent accountability and apparently discriminated enough among the latent variables, with no corrections necessary regarding the measurement model. Since the measurement model appeared to statistically measure all latent variables of the research model accurately and with accountability, the causal relationships among measured latent variables predicted the established fitness and parameters of the structural regression model.

Structural model examination

Table 3 shows the specific results examining the fitness of the initial structural model to the collected data. Since the initial fitness of the structural model was TLI = .977, CFI = .986, and RMSEA = .068 (.054-.082), we confirmed that the fitness index of the initial structural model indicated it was a good model.

Table 3. Initial structural model fitness examination result

	CMIN	*df*	TLI	CFI	RMSEA (90% Confidence Interval)
Initial Structural Model	121.426	39	.977	.986	.068 (.054-.082)

Note. n = 462.

Accordingly, we examined the direct effects among sense of teaching presence, sense of cognitive presence, usage, satisfaction, and learning persistence. The results were as follows. First, examination of the effects of sense of teaching presence, sense of cognitive presence, and usage on learning flow showed the following: sense of teaching presence, β = .413 (t = 8.200, p < .05); sense of cognitive presence, β = .411 (t = 6.174, p < .05); and usage, β = .122 (t = 2.027, p < .05).

Second, examination of the effects of sense of teaching presence, sense of cognitive presence, usage, and learning flow on satisfaction revealed the following: sense of teaching presence, β = .109 (t = 2.091, p < .05); cognitive presence, β = .272 (t = 4.054, p < .05); and usage, β = .144 (t = 2.550, p < .05). Third, examination of the effects of sense of teaching presence, sense of cognitive presence, usage, learning flow, and satisfaction on learning persistence showed the following: sense of teaching presence, β =.136 (t = 12.687, p < .05) and cognitive presence, β = .797 (t = 12.687, p < .05). The effect of usage was not statistically significant.

The initial structural model of this study reveals the significant fact that removing the paths between sense of cognitive presence and learning persistence, between usage and learning persistence, and between learning flow and learning persistence did not affect the model fitness. Accordingly, we established a simplified model, as seen in Figure 4, in which we removed the paths mentioned.
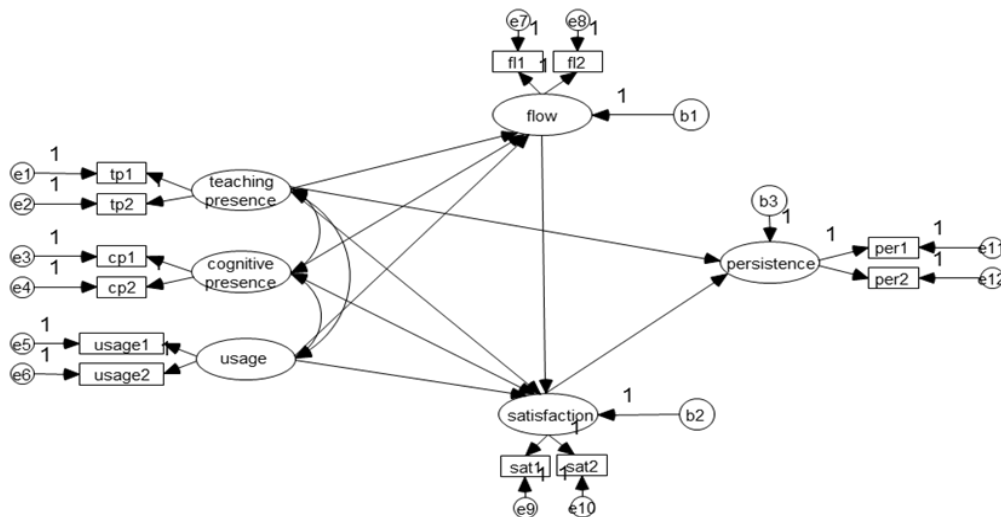
Figure 4. Revised research model of corporate e-learning

Because the initial structural model and revised model have hierarchical relationships, we conducted a chi-square test to determine whether there was a statistically significant difference between the two. The result showed no difference between the models in their goodness of fit (CMIN_D = 5.389, p = .145). Accordingly, although there was no difference in goodness of fit between the models, we selected the revised model and estimated the goodness of fit and parameters because the revised model was simpler. Table 4 shows the results of the revised structural model's

goodness of fit. By confirming the goodness of fit index, we confirmed that the model fitness was good ($CMIN_D = 5.389$, $p = .145$).

Table 4. Examination results of fitness of corrected model

	CMIN	*df*	TLI	CFI	RMSEA (90% Confidence Interval)
Corrected Structural Model	126.815	42	.978	.986	.066 (.053~.080)
Initial Structural Model	121.426	39	.977	.986	.068 (.054~.082)

Note. n = 462.

As seen in Table 4, the model's overall fitness index appeared similar to the initial structural model, but the absolute fitness index value χ^2 was 5.389 higher. The fitness indices were statistically significant; all the fitness indices of the revised structural model satisfied the fitness criteria. Figure 5 displays the structural estimation parameters of the revised model.
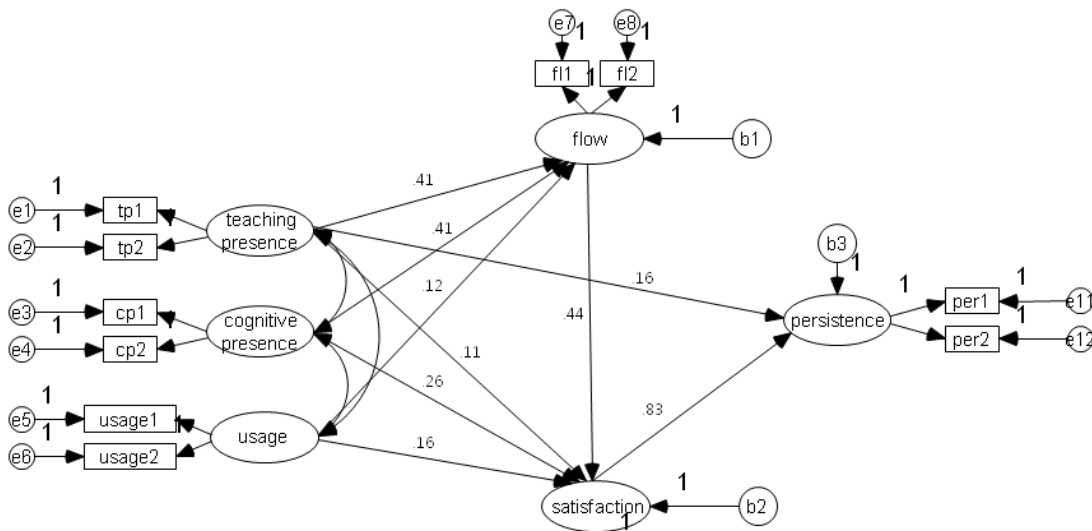
Figure 5. Standard path coefficient of revised model

The results of the parameters regarding the revised model path coefficients are as follows. First, the effect of sense of teaching presence on learning persistence was $\beta = .413$ ($t = 8.220$, $p < .05$). The effects of sense of cognitive presence and usage on learning flow were $\beta = .414$ ($t = 6.178$, $p < .05$) and $\beta = .119$ ($t = 1.968$, $p < .05$), respectively. Second, investigation of the effects of sense of teaching presence, sense of cognitive presence, usage, and learning flow on satisfaction revealed the following: sense of teaching presence, $\beta = .105$ ($t = 2.011$, $p < .05$); sense of cognitive presence, $\beta = .257$ ($t = 3.011$, $p < .05$); usage, $\beta = .155$ ($t = 2.727$, $p < .05$); and learning flow, $\beta = .437$ ($t = 7.143$, $p < .05$).

Third, investigation of the effects of sense of teaching presence and satisfaction on learning persistence revealed the effect of sense of teaching presence on learning persistence was $\beta = .161$ ($t = 3.648$, $p < .05$) and that of satisfaction was $\beta = .833$ ($t = 17.917$, $p < .05$). These results showed the significant effects of sense of teaching presence, sense of cognitive presence, and usage on satisfaction. In addition, the sense of teaching presence and satisfaction had significant effects on learning persistence. Among the variables affecting learning flow, sense of teaching presence, sense of cognitive presence, and usage had relatively stronger effects than the others had. Table 5 summarizes the direct model effects.

Table 5. Direct model effects

Direct			Non-standardization	Error of	C.R.	p	Standardization
Flow	←	Teaching presence	.40	.05	8.22	*	.41
		Cognitive presence	.42	.07	6.18	*	.41
		Usage	.14	.07	1.97	*	.12
Satisfaction	←	Teaching presence	.11	.05	2.01	*	.11
		Cognitive presence	.27	.07	3.84	*	.26
		Usage	.19	.07	2.73	*	.16
		Flow	.46	.06	7.14	*	.44
Persistence	←	Teaching presence	.14	.04	3.65	*	.16
		Satisfaction	.75	.04	17.92	*	.83

Note. $^*p < .05$.

These results of this study show sense of teaching presence, sense of cognitive presence, and usage had significant effects on learning flow. In addition, sense of teaching presence, sense of cognitive presence, and usage had significant effects on satisfaction. Satisfaction also had significant effects on learning persistence. Moreover, learning flow had significant effects on satisfaction, and satisfaction had significant effects on learning persistence. Therefore, we found that sense of teaching presence, sense of cognitive presence, and usage had significant effects on satisfaction by intermediating learning flow. Further, sense of teaching presence, sense of cognitive presence, and usage were found to have significant effects on learning persistence by intermediating satisfaction. This shows the possibility that learning flow has significant effects on learning persistence by intermediating satisfaction. Accordingly, the Sobel test was applied to examine the significance of the indirect effects.

The indirect effect of sense of teaching presence on satisfaction by intermediating learning flow was $Z = 5.41$ ($p < .001$), and that of sense of cognitive presence on satisfaction by intermediating learning flow was $Z = 4.69$ ($p < .001$). On the other hand, the indirect effect of usage on satisfaction by intermediating learning flow was $Z = 1.90$ ($p = .057$), which was not statistically significant. At the same time, the indirect effect of sense of teaching presence on learning persistence by intermediating satisfaction was $Z = 2.01$ ($p = .04$). This number was $Z = 3.73$ ($p < .001$) for sense of cognitive presence and $Z = 2.65$ ($p < .001$) for usage. The indirect effect of learning flow on learning persistence by intermediating satisfaction was statistically significant, $Z = 6.65$ ($p < .001$). That is, learning flow is able to intermediate between sense of teaching presence and satisfaction, between sense of cognitive presence and learning persistence, and between sense of cognitive presence and satisfaction. In addition, we found that in corporate e-learning environments, satisfaction intermediates between the following pairs of variables: sense of teaching presence and learning persistence, sense of cognitive presence and learning persistence, usage and learning persistence, and learning flow and learning persistence. Table 6 displays the indirect effect analysis of the variables affecting learning outcomes.

Table 6. Direct and indirect effects of the modified model

Relevant variables			Total effect	Direct effect	Indirect effect
Flow	←	Teaching presence	.40	.40*	-
		Cognitive presence	.42	.42*	-
		Usage	.14	.14*	-
Satisfaction	←	Teaching presence	.30	.11*	.18*
		Cognitive presence	.46	.27*	.19*
		Usage	.25	.19*	.06
		Flow	.46	.46*	-
Persistence	←	Teaching presence	.22	.14*	.08*
		Cognitive presence	.20	-	.20*
		Usage	.14	-	.14*

Flow	.35	-	.35*
Satisfaction	.75	.75*	-

Note. *p < .05. n = 462.

Discussion and conclusion

This study analyzed the structural causal relationships among learners' sense of teaching presence, sense of cognitive presence, usage, learning flow, and learning outcomes (satisfaction and learning persistence) using SEM. It explained the learning process connections to learning outcomes by using an integrative view to investigate how learners experience the learning process in e-learning environments. Based on the research results, we find the following.

First, we confirmed that sense of teaching presence, sense of cognitive presence, and usage have significant effects on learning flow in corporate e-learning. The significant effects between teaching and cognitive presence on learning flow are consistent with previous research findings (Barfield, Zeltzer, Sheridan, & Slater, 1995; Wang & Kang, 2006). The significant effect of usage on learning flow is also consistent with previous research results (Kim, 2006; Kim & Oh, 2005).

Second, we confirmed that sense of teaching presence, sense of cognitive presence, usage, and learning flow have a significant effect on satisfaction in corporate e-learning. The significant effects of teaching presence (Garrison & Cleveland-Innes, 2005; Shin, 2003; Wu & Hiltz, 2004), cognitive presence (Joo et al., 2009; Kim, 2008; King, 2005), usage (Chiu et al., 2005; Roca et al., 2006), and flow on satisfaction (Shin, 2006; Kim, 2005) are consistent with previous research results.

Third, we confirmed the significant effects of sense of teaching presence and satisfaction on learning persistence in corporate e-learning. The significant effect of teaching presence on learning persistence is consistent with previous research findings (Shin, 2003). The significant effect of satisfaction on learning persistence is consistent with previous studies that reported if learners are satisfied with overall aspects, such as the instructor, teaching method, process, and learning environments, they are likely to continue their learning after completing the course (Levy, 2005; Müller, 2008). On the other hand, in this study, sense of cognitive presence, flow, and usage did not directly affect persistence. This finding is not consistent with previous studies, which reported opposite results (Joo et al., 2009; Kim, 2008). This suggests the possibility that the sense of cognitive presence does not directly affect learning persistence. Further, findings on the effect of usage on persistence are not consistent with previous studies (Noh et al., 2008). Although previous studies (Chiu et al., 2005; Roca et al., 2006) did not observe direct effects of usage on learning persistence, they reported that usage significantly affects learning persistence by intermediating satisfaction. Then, the findings regarding the effect of learning flow on learning persistence are also not consistent with previous studies, which reported opposite results, namely, that flow does affect persistence in sports environments (Kim & Lee, 2005; Kim & Lee, 2008). These results likely differ due to the environmental distinction: Flow in a sports environment means that participants are deeply engaged in attitudes or behavioral aspects of the sport rather than in cognitive processes.

Fourth, satisfaction intermediated among sense of teaching presence, sense of cognitive presence, usage, learning flow, and learning persistence. These results mean that when learners' perceived sense of teaching and cognitive presence improve, they can experience flow. Accordingly, learners' overall satisfaction improves, and learning persistence in taking relevant courses increases even after the students complete the current course. This finding is consistent with the results of Chiu et al. (2005).

The suggestions and contributions from the current research results are as follows: First, the results of this study confirmed the significant effect of a sense of teaching presence on flow, satisfaction, and learning persistence. E-learning designers, therefore, should increase learners' sense of teaching presence by providing them with opportunities to ask questions about class content as part of the learning process in order to confirm what the learners know and to correct any misunderstandings. Educators should also encourage each learner's consistent participation by managing his or her learning process through e-mail, short message services, or a webpage.

Second, the results of this study confirmed the significant effect of a sense of cognitive presence on flow and satisfaction and the indirect effect on persistence. To increase the sense of cognitive presence, e-learning designers should structure learning content appropriately, allow learners themselves to generate new knowledge, and develop systems to help learners manage their learning resources and time.

Third, the research results confirmed the significant effect of usage on flow and satisfaction and the indirect effect on persistence. E-learning designers, therefore, must improve usage by providing practical cases closely related to the students' work so learners can feel that the system is very useful and easy for them to use.

Fourth, the current research results confirmed the significant intermediation effects of flow between teaching presence and satisfaction and between cognitive presence and satisfaction. Accordingly, it is expected to devise strategies to increase flow in the e-learning process for learning outcome achievement. Since usage is also an effective variable on flow, it is important to construct the environment for flow by increasing learning usage in the learning environment. In order to increase usage, therefore, e-learning designers should devise strategies to raise flow in the learning process, improve learning outcomes, avoid distractions for learners, and consider the learners' convenience so that they are not hindered in their studies.

Fifth, the current research results investigated the significant intermediation effects of satisfaction between teaching presence and learning persistence, between cognitive presence and learning persistence, between usage and learning persistence, and between flow and learning persistence. This means that regardless of cognitive presence and flow, learners' learning persistence cannot be guaranteed without satisfaction. Accordingly, strategies to increase learners' satisfaction are necessary in the e-learning design and management aspects. It is reported that a learner's satisfaction can be divided into both internal satisfaction caused by intellectual curiosity and self-achievement and external satisfaction caused by rewards and incentives achieved by time and efforts that one invested (Keller & Suzuki, 1988). Thus, it is necessary in curriculum management for learners to gain satisfaction in the learning process where learners flow by achieving intellectual curiosity; to feel external satisfaction through external compensation by grade, reward, or external incentives; and to reflect consistent learning outcomes with invested time and effort.

Sixth, if we practically apply the current research results for the corporate learning environment, we can assume that successful e-learning would be guaranteed by the e-learner's sense of cognitive and teaching presence because the sense of cognitive and teaching presence will increase the learner's flow, satisfaction, and learning persistence, as the current study concluded. We can also expect an increase in return on investment (ROI) due to the employees' performance improvement in their knowledge, skills, and attitude improvement by the successful e-learning. At the same time, we can consider the cost effectiveness of corporate learning by extending e-learning programs rather than off-line training programs.

The limitations of the study and our suggestions for further research studies are as follows. First, the results of this study have limited generalizability: We used 462 participants, all employees of Enterprise A in South Korea, who received an employment insurance refund of the course cost. Future studies should investigate whether different e-learning settings or cyber-universities produce the same results. Second, since we expect that the perceived degree of a sense of cognitive presence differs for individual learners. Further research is needed to investigate various motivational variables rather than simply reflect learner characteristics. Third, we administered the study to reflect corporate e-learning characteristics after removing sense of social presence and focusing on sense of teaching presence and sense of cognitive presence. However, future studies should consider the sense of social presence that learners experience in e-learning environments because successful learning occurs through the integration of the senses of teaching presence, cognitive presence, and social presence. Fourth, the current research examined satisfaction and learning persistence as a learning outcome variable. The current research removed learning achievement from the learning outcome variable. It was hard to decide that learning achievement explains learning outcomes because learners receive the employment insurance refund from Enterprise A only if they give out more than 70% correct answers. However, since achievement is an important variable for measuring learning outcomes, further studies should include achievement as a learning outcome variable. The ultimate purpose of corporate educational training is not a better grade but to improve employees' performance through their application of the knowledge and skills obtained in e-learning. We suggest future research include studies on learning transfer or return on investment.

Acknowledgements

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Exploring Students' Language Awareness through Intercultural Communication in Computer-supported Collaborative Learning

Yu-Fen Yang

Graduate school of applied foreign languages, National Yunlin University of Science & Technology, Yunlin, Taiwan, R.O.C. // yangy@yuntech.edu.tw

ABSTRACT

Students seldom think about language unless they are instructed to do so or are made to do so during learning activities. To arouse students' awareness while learning English for Specific Purposes (ESP), this study formed a computer-supported collaborative learning (CSCL) community to engage teachers and students from different domains and countries in intercultural communication. Participating were 208 students, including 83 international students from one of the eight vocational and technological universities which composed the CSCL community. Organized according to activity theory, the results indicate that students' language awareness is stimulated when students monitor the accuracy of their language usage (process-oriented) and assess their language performance (product-oriented) during intercultural communication with their peers from different backgrounds (across majors, colleges, and universities) and countries (China, Denmark, Indonesia, Malaysia, Netherlands, Thailand, and Vietnam). The intercultural characteristics of the CSCL community fostered students' language awareness as they acquired expressions from different cultures and contexts on the levels of lexical, syntactic, and textual organization. As a result of such intercultural communication, students' improvement of language awareness was further revealed by nine assessments examined by means of a repeated one-way analysis of variance. This study lays a foundation for promoting online intercultural interaction.

Introduction

The potential of computer-supported collaborative learning (CSCL) has dominated the new discussions on second language (L2) learning in higher education over the past decade (Ayala & Yano, 1998; Cekaite, 2009; Dlaska, 2002). The purpose of practicing CSCL for L2 learning is to generate peer communication in the target language for meaningful purposes in and out of the class (Liu & Sadler, 2003; Zeng & Takatsuka, 2009). From the socio-cultural constructivist perspective, language learning and acquisition are described as the construction of shared meanings through social interaction among students (Tannenbaum & Tahar, 2008; Vygotsky, 1978). Through the reciprocal and intensive interactions raised in CSCL, students from diverse backgrounds and countries engage in intercultural communication to discuss a specific topic for meaning negotiation (Osman & Herring, 2007; Solimeno, Mebane, Tomai, & Francescato, 2008).

Intercultural communication refers to "the symbolic exchange process whereby individuals from two (or more) different cultural communities negotiate shared meanings in an interactive situation" (Ting-Toomey & Chung, 2005, p. 39). In this study, the term "intercultural communication" refers to the communication among students from diverse backgrounds (majors, colleges, and universities) and countries (China, Denmark, Indonesia, Malaysia, the Netherlands, Thailand, Vietnam). In the CSCL environment, intercultural communication takes place when students engage in the task of learning English for Specific Purposes (ESP) that has its own culture such as an organizational culture or hospital culture. In the CSCL community where various contexts of ESP are discussed, students might become engaged with different cultures to raise their language awareness, exchange and share knowledge of ESP (de Laat, Lally, Lipponen, & Simons, 2007; Pifarre & Cobos, 2010).

Language awareness is accordingly stimulated through the intercultural communication in CSCL (Bull & Ma, 2001; Ho, Nelson, & Müeller-Wittig, 2010; Phielix, Prins, & Kirschner, 2010; Wenger, 1998; Yang, 2010). Language awareness, which refers to learners' development of an enhanced consciousness of the forms and functions of language, helps students reflect on language in use (Callies & Keller, 2008; Lucas, 2005). Enhancement of language awareness can be process-oriented involving students' monitoring of explicit knowledge in analyzing and describing

language accurately, or product-oriented involving self-assessment of language performance (Kiely, 2009; Roberts, 1998). Some collaborative learning activities in the CSCL environment such as role-playing, task-based activities, or group discussions where students are engaged in context-based learning were designed to raise students' language awareness in ESP (Bosher & Smalkoski, 2002; Colomar & Guzmán, 2009; Hyland & Hyland, 1992; Jackson, 2005). In expanding language awareness through these activities, language learning is improved as well as the broad domain of pragmatics and more specifically intercultural communication (Hamilton & Woodward-Kron, 2010; Littlewood, 2001).

Students seldom think about their language unless they are asked to do so explicitly or by way of learning activities (Hartley, 2001). Recent studies have suggested the development of CSCL to engage students in intercultural communication with the aim of raising their language awareness (Raybourn, Kings, & Davies, 2003; Schreiber & Engelmann, 2010; Wang & Chen, 2010). For example, Liaw (2006) presents the impact of the CSCL community on fostering EFL students' intercultural competence through reading articles on topics about their own culture and communicating their reflection with peers of another culture. Her findings demonstrate that students not only acquire different kinds of cultural meanings on the levels of lexical, syntactic, and textual organization, but also obtain knowledge about cultural differences. Deutschmann and Panichi (2009) utilized a CSCL community to engage students in intercultural communication with the support of a teacher to raise students' language awareness in ESP. Their findings indicate a change in students' linguistic behaviors among various topics from different themes. The findings of other studies (e.g., Mokhtari & Reichard, 2004; Yashima & Zenuk-Nishide, 2008) emphasize the importance of being aware of the differences between L1 and L2 in the terms languages use by exchanging perspectives in the target language with peers from different backgrounds in a specific context such as Engineering English or Medical English. This awareness leads to continuous intercultural communication and prevents misunderstandings. By concentrating on the lexical level of their conversations, students are trained to reflect on failed communication in order to correct misunderstandings and repair communicative breakdowns.

Background of this study

This study aimed to arouse college students' language awareness through intercultural communication in a CSCL community within ESP contexts. Students and teachers from eight technological and vocational universities in central Taiwan were recruited for intercultural communication in the CSCL community where five ESP contexts for knowledge sharing—Vocational, Business, Technical, Travel, and Medical English—were developed. Some important features of a CSCL community are revealed in this study: (a) It is a common ground for knowledge sharing among Taiwanese students as well as international students from various disciplines and domains; (b) It allows students to develop cross-domain awareness when they participate and involve themselves in intercultural communication for knowledge sharing; (c) It provides students with choices in terms of selecting topics related to their background knowledge or for their future goals; and (d) It assists teachers in co-teaching without being constrained by the limitations of time and space. While engaging in intercultural communication with peers from various backgrounds and countries in different contexts, students were expected to develop their language awareness in English.

In order to investigate how intercultural communication supports language awareness in the CSCL community within ESP contexts, activity theory has been employed in some studies (e.g., Basharina, 2007; Greenhow & Belbas, 2007; Thorne, 2003). Activity theory is relevant to learning in that it depends on people's construction of the world which is built through the interaction between the internal and external worlds of experience (Crooks, 2003). Jonassen, Peck, and Wilson (1999) explain that constructivist learning involves knowledge that is constructed and not transmitted and embedded in an activity. Activity theory has served as a useful framework for helping researchers examine an individual in a large activity system (Baran & Cagiltay, 2010; Engeström & Miettinen, 1999). It describes the relationships among the six components—subject, object, tool, community, rule, and division of labor—in a sociocultural context. In activity theory, the subject refers to the individual or group of individuals engaged in an activity; the object is the outcome of an activity; the tool is whatever is used by the subject for acting on the object; the community consists of those individuals or groups that focus on the object; rule refers to the regulations guiding the community; division of labor refers to the roles and relationships among the members of the community (Engeström, 1987). By identifying the relationships among these components, the dynamics of students' language awareness can be differentiated.

Figure 1 shows the theoretical framework of this study. In order to understand the development of students' language awareness during intercultural communication within ESP contexts, the CSCL community was structured based on activity theory, thus enabling the identification of the relationships in triangle sub-activities. The sub-activities of Subject-Tool-Object, Subject-Rule-Object, Subject-Community-Object, and Subject-Division of Labor-Object described how students' language awareness was supported by intercultural communication. Based on the research purpose, which was to foster and explore college students' language awareness through intercultural communication in an ESP CSCL community, two research questions were addressed in this study: (1) How is college students' language awareness identified according to activity theory in the CSCL community?; (2) How do college students develop language awareness in the CSCL community in different ESP contexts?
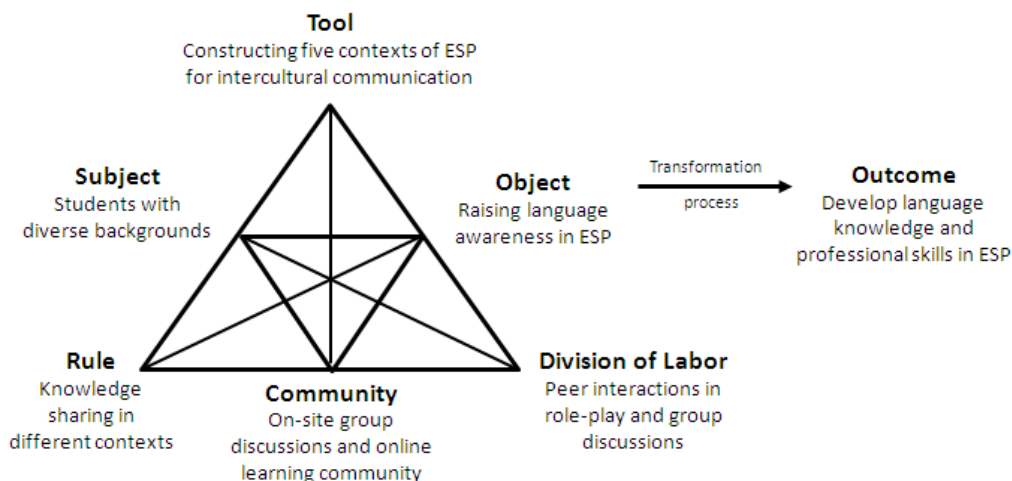
Figure 1. The research framework of this study

Method

This section describes the recruitment of the participants, the research design, as well as the procedures of data collection and analysis.

Participants

A total of 208 students from eight technological and vocational universities in central Taiwan voluntarily registered to participate in the CSCL community within ESP contexts. Demographic statistics reflected that 83 international students were from countries such as China, Denmark, Indonesia, Malaysia, the Netherlands, Thailand, and Vietnam (see Table 1). The sample was made up of 48.56% females, 50.69% undergraduates, and 49.31% postgraduates. Moreover, the students came from different majors: 47.59% from the College of Management; 38.46%, College of Engineering; 10.09%, College of Design; and 8.65%, College of Humanities and Applied Sciences.

Table 1. The demographic data of the participants

Nation	Number	Grade	Number	Grade	Number
Taiwanese	125	undergraduate	105	postgraduate	103
China	28	**Major**		**Major**	
Demark	4	College of Management	44	College of Management	45
Indonesia	5	College of Engineering	42	College of Engineering	38
Malaysia	10	College of Design	12	College of Design	9
Netherlands	6	College of Humanities and	7	College of Humanities and	11

		Applied Sciences		Applied Sciences
Thailand	5			
Vietnam	25			
Total	**208**			

Research design

A CSCL community with five ESP contexts was formed based on activity theory in order to engage students and teachers in intercultural communication. As shown in Table 2, each university constructed different ESP contexts and had different numbers of teachers prepare for the discussion topics. Teachers from each of the eight universities chose one or two ESP contexts to prepare the learning materials, discussion topics, and assessment. In total, there were 28 teachers specializing in different domains and 153 topics for various purposes with over 400 learning materials and 72 assessments. Under each topic were several topics for discussion.

Table 2. Knowledge sharing in the virtual learning community

School	No. of teachers	Focus	No. of Topics	Example of Topic
1	4	Business English Travel English	18	Financial Advice The Independent Traveler
2	5	Technical English Travel English	17	The Internet and Internet Language Moon Festival
3	2	Business English Travel English	18	Reports Directions
4	2	Medical English Travel English	18	The Hospital Team Space Tourism
5	2	Vocational English Travel English	18	The Job Interview Hotels and Transportation
6	3	Technical English Travel English	18	Computer Hardware Dining Out
7	5	Vocational English Travel English	18	Talking about Workplace Events Culture Shock
8	5	Vocational English Business English Technical English Travel English	28	Bring Copies of Your Resume Stock Market E-books and Kindle Immigration & Car Rental
Total	**28**		**153**	

Students were encouraged to join on-site group discussions which were held for two hours each, twice a week as well as to participate in the CSCL community at anytime and anywhere. There were several collaborative learning activities such as role-play or group discussions to raise students' language awareness in intercultural communication, and knowledge sharing or meaning negotiation in the online discussion forum (Chen, Looi, & Tan, 2010).

In the on-site group discussion, the teachers, including native speakers and non-native speakers, served as role models not only to guide students to have intercultural communication but also to share their cultural experiences to enlarge students' world view. In each on-site group discussion, 15 to 20 students were divided into four to five small groups and given a situation where they were asked to work out solutions to a specific problem. During the discussion, the teacher acted as a coach to monitor students' conversations and train them in metapragmatic and intercultural awareness. Then, students presented their group performance by doing a role-play.

In the CSCL community, students were provided with a culturally diverse context for knowledge sharing and intercultural communication across domains and universities. As a result, students were able to become aware of the differences in language use in various contexts. As shown in Figure 2, students participated in the CSCL community by clicking on one of the five contexts or selecting a university from the drop down menu. This engaged students in

intercultural communication as they were encouraged to learn English in different contexts and interact with peers from various backgrounds. For example, a student from an engineering college might discuss the topic of job interviews, business meetings, and hotel reservations with other students from the college of management or design. To further support the student discussions, the CSCL community offered users learning materials consisting of sample dialogues or case studies as shown in Figure 3.

To develop students' language awareness, the CSCL community not only provided learning materials that showed the features of language use in specific contexts, but also constructed assessments for evaluating the students' language awareness which they had gained through intercultural communication in each topic. There were nine assessments adapted from the Test of English for International Communication (TOEIC). The reliability of the TOEIC test is reported to be 0.90 (Chun Shin Limited, 2009). An example with 5 test items in an assessment is presented in Appendix A to show how language awareness was assessed in this study. The nine assessments were presented as multiple-choice test items for lexical, syntactic, and textual organization (see Figure 4). After students submitted their answers, the CSCL community gave instant feedback by highlighting correct answers in red. In addition to the assessments for each discussion topic, the CSCL community also provided a series of nine assessments to evaluate students' language performance in their topic. Each of the nine assessments involved 15 test items from all of the five ESP contexts.

In addition, log files were created to record the actions of the students and teachers in the virtual learning community. The details (types, frequencies, and duration) of their actions such as login and logout time, learning materials downloaded, questions answered or raised in the discussion forum, and scores for assessment were all recorded in log files.

Figure 2. The five ESP contexts in the eight universities
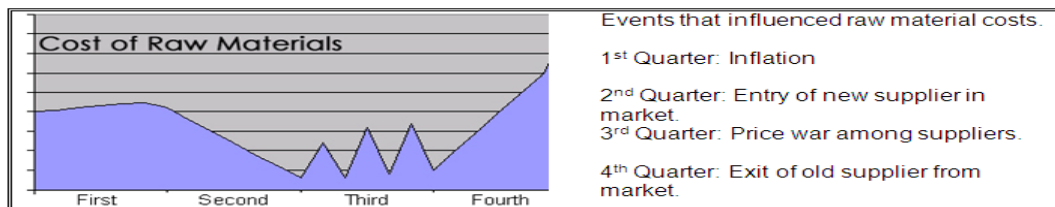
Figure 3. Shared learning materials in the virtual learning community

Figure. 4 Assessment with instant feedback from the system

Procedures of data collection

This study was conducted in 2010 from September 23rd to December 2nd. First, students filled in their background information when registering for the membership in the CSCL community. Second, students set their ESP learning goals in the system based on their future career and English language proficiency. Third, students' on-site discussions with peers were video-recorded to reflect on their language use in a specific context. Fourth, log files were employed to record students' online discussions, engagement in intercultural communication, and performance on assessments. Finally, students took the nine assessments for evaluating their language awareness in their chosen subject. All of the data regarding students' background information, learning goals, group discussions, and language performances were recorded in the log files for further investigation.

Procedures of data analysis

Students' performance in language awareness across different domains, countries, and ESP contexts was examined by evaluating the nine assessments in the CSCL community. The difficulty levels of the assessments were differentiated at less than .05. In order to investigate the differences among the scores in the assessments, repeated one-way analyses of variance (ANOVA) were conducted. Students' actions in relation to intercultural communication were revealed by the log files. Conversations among students and between students and teachers in on-site and online discussions were analyzed by means of critical discourse analysis (Onrubia & Engel, 2009). Critical discourse analysis is one of the main approaches in analyzing students' language awareness gained during intercultural communication, and it enables the researcher to study the objectives of the discourse in the social context (Belz, 2002; Rogers, 2004). Data interpretation driven by these research methods is further explained in the following sections.

Results

This section will report college students' language awareness gained through intercultural communication in an ESP CSCL community as revealed by the log files. Data presentation is based on activity theory to show four sub-activity triads: (1) Subject-Tool-Object; (2) Subject-Rule-Object; (3) Subject-Community-Object; (4) Subject-Division of Labor-Object (Baran & Cagiltay, 2010; Greenhow & Belbas, 2007). The students' progress in language awareness was also revealed by their scores in the nine assessments.

Subject-Tool-Object

The Subject-Tool-Object refers to the use of the CSCL community within ESP contexts to develop students' language awareness. One of the participants, herein referred to by the pseudonym Brian, was randomly selected to represent a Taiwanese student's intercultural communication in the CSCL community within ESP contexts. As shown in Table 3, the system recorded his 153 texts posted across the online discussion forums of six universities.

His texts were especially high in number for universities 1 and 2, where he posted 91 and 40 texts respectively. The system also reported that he had raised 27 questions, thereby inviting peer discussion, and answered 126 questions from teachers and peers. This indicated the numerous opportunities afforded to him in the CSCL community to communicate with peers and teachers in different ESP contexts.

Table 3. Numbers of Brian's statements in different universities' online discussion forums

University	No. of statements
University 1	91
University 2	40
University 3	8
University 4	6
University 5	0
University 6	3
University 7	0
University 8	5
Total	**153**

In order to understand the ESP contexts he had engaged in, Table 4 shows that Brian had participated in 62 online discussion forums among each of the five ESP contexts. More than half of his participation was in the context of Travel English. His language awareness was raised by focusing on Travel English and revealed from his registering as an undergraduate student in the College of Management and setting his future career goal in the recreational field. This gave evidence of the student's language awareness in acquiring ESP associated with his future needs.

Table 4. Frequencies of Brian's joining online discussion forums in different contexts

Context	Frequency	Percentage
Travel English	33	53.23%
Vocational English	13	20.97%
Business English	11	17.74%
Technical English	4	6.45%
Medical English	1	1.61%
Total	**62**	**100%**

Subject-Rule-Object

The Subject-Rule-Object refers to the regulations in the CSCL community. Brian's log file of a specific date was randomly selected to show his knowledge sharing with students from various universities and in different ESP contexts in the CSCL community. Through intercultural communication with different peers, Brain raised his language awareness while acquiring Travel and Vocational English expressions in different contexts.

As shown in Table 5, Brian raised 6 questions to invite peer discussion and answered 9 questions from teachers and students on October 22, 2010. On that day, he participated in online discussion forums in three universities (universities 1, 2, and 4) and three contexts (Vocational, Travel, and Medical English). First, Brian presented his language knowledge of "flight attendants" regarding their duty to serve passengers' needs on the plane in the context of Travel English in his own university. Then, continuing in the context of Travel English, he joined two discussions in university 4 (action No. 2-5) and raised four questions such as "When it comes to Halloween, what will come to your mind?" Some feedback from an international peer (Netherlands) was "Halloween activities include trick-or-treating, wearing costumes and attending costume parties, carving jack-o'-lanterns, ghost tours, bonfires, visiting haunted attractions, pranks, telling scary stories, and watching horror films will come to my mind." He raised a good question to engage his Taiwanese as well as international peers in the discussion concerning a holiday from other cultures. Finally, he participated in two other discussions, but these were in the context of Vocational English. One was associated with the topic of "Job Interview Practice for ESL Students" and another with "Preparing a Job Application Package" (action No. 6-8 & 11-14). He not only responded to teachers' questions but also provided feedback to his international peers' doubts about doing business. This engaged more students in the extended

discussions. From Brian's log file, which shows his consciousness of language uses, it was noticed that he had presented his language awareness in the contexts of Travel and Vocational English.

In addition to his understanding of language uses in different contexts, Brian also presented himself for evaluation of language awareness by taking 72 assessments for some specific topics. Since Brian repeatedly took each assessment, the total number of assessments he completed was 237. As reported in the system, his average frequency of taking a single assessment was 3.29 times and his average score was 93.37. Table 6 shows how Brian repeatedly took an assessment in order to improve his language awareness in the ESP virtual learning community. For example, according to actions 226 to 228, he took the same assessment three times and achieved scores of 57, 80, and 100 respectively. The same situation of having repeatedly taken an assessment can be found for other actions such as 1-2, 3-4, and 123-124. This gives evidence of Brian's consciousness of needing to improve his language awareness in some specific contexts.

Table 5. Brian's log file on October 22, 2010

No.	Time	Questions/Answers	Topic	School	Context
1	01:47:40	Who serves the passengers' needs on the plane? Flight attendances do serves the passengers' needs on the plane.	Conversation on the Plane	1	4
2	01:52:32	When it comes to Halloween, what will come to your mind?	October Holidays	4	4
3	01:54:39	Do you have some special experiences of Halloween?	October Holidays	4	4
4	01:57:56	What is Ecotourism?	Ecotourism	4	4
5	02:00:08	List some examples of the Ecotourism.	Ecotourism	4	4
6	13:06:18	What kind of work do you want to do in the future? Tax consultant.	Job Interview Practice for ESL Students	1	1
7	13:14:01	Would you be upset if your boss was a woman? No, I would not. I think the ability and the talent of the boss are more important than what their gender are. Besides, it shouldn't have that kind of gender discrimination.	Job Interview Practice for ESL Students	1	1
8	13:16:39	When you were a child, what job did you want to have when you grew up? In my childhood, I wanted to be a teacher when I grew up.	Job Interview Practice for ESL Students	1	1
9	13:27:48	Have you ever been to the British Museum, which is one of the famous museums in the world? Can you share the experience with us?	Cultural Visiting: Museums	2	4
10	14:00:32	What is your opinion about euthanasia? Do agree with it? Or disagree with it? Why?	Pain Assessment	4	5
11	14:05:05	Would you like to have your own business? No, I think it is too risky to have my own business, since I don't have strong capital to backup.	Preparing a Job Application Package	1	1
12	14:08:14	Who would be your business hero? I regard Wang Yung-Ching as my business hero.	Preparing a Job Application Package	1	1

13	14:11:04	How would you define business? Business is a legally recognized organization designed to provide goods, services, or both to consumers in exchange for money	Preparing a Job Application Package	1	1
14	14:12:37	What are the dangers of having your own business? Shortage of money.	Preparing a Job Application Package	1	1
15	21:15:30	Do you prefer to shop in stores or on the Internet? Why? I prefer to shop on the Internet because of convenience.	Shopping	1	4

Table 6. Brian's repeated actions of taking an assessment

Action No.	School	Context	Topic	Time	Score
1	7	1	Meeting and Greeting Colleagues	2010-10-20 15:48:36	80
2	7	1	Meeting and Greeting Colleagues	2010-10-20 15:49:17	100
3	7	2	Engaging in Small Talk	2010-10-20 15:56:49	60
4	7	2	Engaging in Small Talk	2010-10-20 15:57:21	100
123	1	2	Rumors and Headlines in Business	2010-10-22 15:02:08	53
124	1	2	Rumors and Headlines in Business	2010-10-22 19:07:53	93
226	5	1	Job Hunting	2010-10-26 12:55:19	57
227	5	1	Job Hunting	2010-10-26 12:56:07	80
228	5	1	Job Hunting	2010-10-26 12:56:44	100

Subject-Community-Object

The Subject-Community-Object refers to the CSCL community and on-site discussion groups formed by 125 domestic students and 83 international students with the objective to enhance their language awareness in five different ESP contexts. As shown in Table 7, there were 153 ESP discussion groups in total with more than 3,000 instances of participation across the eight universities. Among these discussion groups, Travel English was the most popular context, raising 63 discussion topics and 1,094 instances of participation. That is, on average, each individual student participated approximately five times on or off campus in the context of Travel English. A further investigation into the log file of the 208 students indicated that each student participated in more than one context. This means that they were engaging in intercultural communication with peers on or off campus in various contexts. However, students had the fewest discussions in the context of Technical English, even though 38.31% of them were from the College of Engineering. This implies that students' interests might be different from their majors, and their learning needs might vary for multiple purposes.

From the CSCL community, the log files of university 1 were retrieved as an example to reveal students' actions for language awareness. As shown in Table 8, it can be seen how students in university 1 participated in the various learning activities, such as 5,992 viewings of course information, 1,241 reviews of photos, 1,664 downloads of learning materials, 776 instances of participation in online discussion, 20 raised questions, and 251 answered questions. Except for taking the assessments, these other action frequencies were much higher than at other

universities. There were 259 students who took assessments in their own university while 502 took assessments in university 7 and 469 in university 5. Both universities 5 and 7 placed an emphasis on the ESP contexts of Vocational English and Travel English. This suggests that students consciously evaluated their language awareness in the collaborative learning activities.

Table 7. Students' participation in the five contexts

Context	No. of discussion groups	No. of participation
Travel English	63	1,094
Business English	27	618
Vocational English	28	607
Medical English	6	361
Technical English	29	326
Total	**153**	**3,006**

Table 8. Participation of the students in university 1 among the eight universities

Action No.	School	Context	Topic	Time	Score
1	7	1	Meeting and Greeting Colleagues	2010-10-20 15:48:36	80
2	7	1	Meeting and Greeting Colleagues	2010-10-20 15:49:17	100
3	7	2	Engaging in Small Talk	2010-10-20 15:56:49	60
4	7	2	Engaging in Small Talk	2010-10-20 15:57:21	100
123	1	2	Rumors and Headlines in Business	2010-10-22 15:02:08	53
124	1	2	Rumors and Headlines in Business	2010-10-22 19:07:53	93
226	5	1	Job Hunting	2010-10-26 12:55:19	57
227	5	1	Job Hunting	2010-10-26 12:56:07	80
228	5	1	Job Hunting	2010-10-26 12:56:44	100

The on-site group discussion, "Financial Advice", has been randomly selected to be the example to show students' intercultural communication with peers from diverse backgrounds. As shown in Table 9, the descriptive data presents 9 undergraduate students and 11 graduate students from different departments and nations. Most of them were from the Colleges of Engineering and Management. Three of them were from China, two from Malaysia, two from Indonesia, and one from Vietnam. Although they were from diverse backgrounds and different countries, the students were given a common discussion issue, "Making Money", after practicing the role-play—a meeting between a bank manager and an entrepreneur asking for a loan to develop and market a new invention.

Table 10 shows students' newly acquired vocabulary and sentences from the on-site discussion. Some students acquired common language knowledge such as flea market (4 students), tuition fee (3 students), and "What amount of loan do you want to apply for?" (3 students). This implied that students from different backgrounds could share common understanding in intercultural communication aimed at building language awareness.

Subject-Division of Labor-Object

The Subject-Division of Labor-Object involves the role of students and their relationship with peers and teachers in the on-site group discussion and the CSCL community. The students' role-plays during the on-site discussions were video-recorded to show their language awareness gained through intercultural communication in an ESP context. Extract 1 shows the conversations between student 1 (S1) and student 2 (S2) regarding the topic "Rumors and

Headlines in Business." S1 was an international student from Denmark and S2 was a Taiwanese student. Acting in the role of employees, they followed the teacher's direction to exchange greetings first and then talk about the rumors in the company by asking such questions as "Did you hear that…?" and "How are things going with…?" Afterward, good news and bad news of the company were discussed. In the realistic role-play, the students acting as employees were engaged in intercultural communication as they discussed such things as delayed construction and cheaper raw materials.

Table 9. Descriptive data of the students in a discussion group

College	Undergraduate	Graduate
College of Engineering	6	4
College of Management	2	7
College of Humanities and Applied Sciences	1	0
College of Design	0	0
Total	**9**	**11**

Table 10. Students' shared understanding in building language awareness

Vocabulary	Sentence
date of product launch	Is there any time when you were strapped for cash?
flea market (4)	What amount of loan do you want to apply for? (3)
strapped	How many products do you aim to sell in a year?
tuition fee (3)	How much personal investment are you prepared to make?
apply a bank loan	When do you expect to launch the product?
ethical	How much do you expect production costs to be?
tuition amounted to	How much are all the other operating costs?
euros	What will the selling price be?
inherit	What sales channel do you expect to use?

Extract 1
S1: Good morning. (-) How=How was your weekend?
S2: Relaxing. (--) I spent the weekend (.) at home. (-) Hey, uh:: (---) did you hear : (.) that the BOSS go back=got back from CHIna (-) on Saturday?
S1: [He did?] Good. (2.0) How (-) are (-) things (--) going with the new FACtory?
S2: Well, (.) do=you=want the GOOD NEWS (-) or the BAD NEWS first?
S1: Give me (.) the BAD news first.
S2: The bad news is that (-) construction is behind : schedule. (--) He said that (-) they were having PROblems (.) get=getting building (.) permits (-) from the local government (.) officials.
S1: I see. (.) So :: what is the GOOD news?
S2: Well, (-) the good news is that (-) costs were LOWer than expected. (---) He told me that (-) they ma=managed to (.) get a good deal (-) on raw materials.

Transcription conventions adapted from Knapp's (2010) transcription notation:
[.]   Overlap and simultaneous speaking
=   Quick, immediate connection of new turns or single units
:   Lengthening (: or:: or::: according to its duration)
(.)   Micro-pause
(-)   Pause of approximately 0.25–1 s ((-) or (- -) or (- - -) according to its duration)
(2.0)   Estimated length of pause (more than 1 s)
ACcent Primary or main accent

In the CSCL community, students were also involved in meaning negotiation with the teacher during extended interactions. The teacher-student and the student-student interactions in the CSCL community raise students' language awareness on the levels of lexical, syntactic, and textual organization. With respect to the interaction between teachers and students, Table 11 shows an example of a teacher's feedback to a student's responses. In their messages, the student first explained his difficulty in understanding the first question. In answering the second question, the student believed that economic health was not the only way to determine how healthy a country was

and he provided his arguments and reasons. The teacher first expressed appreciation for his efforts in answering the questions and then corrected some grammatical errors in the student's text. In the end, the teacher explained the first question and encouraged more discussion from the student. A comparison between the student's response and the teacher's revision is presented in Table 12. With the comparison, the student was provided with the opportunity to raise his language awareness by reflecting upon appropriate words and statements in reconstructing his manner of expression.

Table 11. Meaning negotiation between a Taiwanese student and a teacher

Topic	Financial Advice
Questions	1. "Academic qualifications are important and so is financial education. They're both important and schools are forgetting one of them." (Robert Kiyosaki). Do you agree or disagree with this? Why? 2. "We can tell how healthy a country is by looking at its economic health." Do you agree or disagree with this? Why?
Student's response	I want to answer the second question cause I don't really understand what the first question means in Chinese. And I wanna to say is economic is not the only one way to show the how healthy the country would be. Including policy, freedom of public, national consciousness...etc. Especially environment issue is the most important thing to attract me to know the country's system of organization, so i don't agree just looking one's economic to know the healthy of country. It's my opinion.
Teacher's feedback	Thank you for taking the time to answer the question. Because of your enthusiasm, I would like to provide you with some assistance on grammar. So, below is an edited version of your answer: Your answer: I would like to state that I do not think economic health is the only one way to judge how healthy a country is. Other criteria, including government policy, actual freedom the public enjoys, national consciousness, and a host of others are also important. The environment of a country is the most important issue that I take into account when judging a country's system of organization. Hence, I do not agree that just looking at a country's economic health is enough to determine the health of a country. My response: I would also like to provide my response to your question. I believe that in the long term it is difficult for any country to have economic health if it is not good on its environmental policies, education system, community development plan, and several other standards. Therefore, I believe that long-term economic health is the best way of judging how healthy a country is. About the first question: Finally, the first question basically wants to know if you agree or disagree that school's provide students with academic education but often forget about financial education.

Table 12. Indicating the differences to arouse students' language awareness

~~And~~ I ~~wanna~~ would like to ~~say is~~ state that I do not think economic ~~health~~ is ~~not~~ the only one way to ~~show the~~ judge how healthy ~~the~~ a country ~~would be~~ is. ~~Including~~ Other criteria, including government policy, actual freedom ~~of the~~ public enjoys, national consciousness~~...etc.~~ and a host of others are also import. ~~Especially,~~ The environment ~~issue~~ of a country is the most important ~~thing to attract me to know the~~ issue that I take into account when judging a country's system of organization~~, so I don't~~. Hence, I do not agree that just looking ~~one's~~ at a country's economic health is enough to ~~know~~ determine the ~~healthy~~ health of a country. ~~It's my opinion.~~

The student-student interactions in the CSCL community were also found to foster students' language awareness on the lexical level. Table 12 showed that in an online discussion forum, several students from different majors and

countries autonomously participated in the context of Travel English to discuss the issue about independent travelers (Table 13). At the beginning, student A raised a question to initiate peer communication. Six peers (students B to G) expressed their opinions in L2 using some key words such as hotel, guidebook, map, and information. While they were discussing a common issue, students were able to observe peers' language performance and compare it to their own so that their language awareness could be enhanced.

Table 13. Intercultural communication among students

Student A's question	How to be independent when traveling alone?
Student B's response	You should prepare something before traveling, such as information about hotel, a guidebook and map. The most important thing is don't be afraid of communicating with other people.
Student C's response	If you have many experience, or you may travel with others.
Student D's response	First, you have to search some information about your trip in advance, such as hotel information, train or subway information etc. Secondly, you may bring a map with you, then you won't get lose easier. And the third opinion is "you should use your mouth more often", when you have any question, don't be afraid to ASK local people. I believe you will have a very good experience when you travel alone and an unforgettable culture experience.
Student E's response	Before you going to other places unacquainted, you should bring a guidebook with you in case of losing your orientation.
Student F's response	Try to open your mind to communicate with other people.
Student G's response	Bring all the things that you could do it alone, and trying to raising your foreign language abilities.

Students' progress in language awareness

The 208 participating students' language awareness gained through intercultural communication was evaluated by the assessments in the CSCL community. As shown in Table 14, the mean report showed a stable increase in students' scores from Test 1 to 9. One-way analysis of variance (one-way ANOVA) was also used to test whether the scores of each assessment were significantly different (Table 15). The result of the ANOVA test showed that the F values ranged from 9.12 to 1180.68 and were significant at the 0.001 level. Since the difficulty levels of the 9 tests were differentially less than .05, the result indicated that students made progress in the assessments on language awareness. This suggested the effectiveness of intercultural communication in the CSCL community for raising students' language awareness in an ESP context.

Table 14. Mean report of the assessments

Test	Mean	SD
1	38.86	29.46
2	34.42	24.33
3	41.38	31.35
4	44.40	32.09
5	49.38	24.99
6	53.35	30.63
7	53.32	25.46
8	58.75	33.52
9	59.73	35.42

Table 15. ANOVA analysis of the differences among the assessments

		SS	*df*	*MS*	*F*	*p*
Test 2	Between groups	120460.30	7	17208.61	292.27	.001*
	Within groups	11775.83	200	58.88		
	Total	132236.13	207			
Test 3	Between groups	50482.80	7	7211.83	9.12	.001*

	Within groups	158240.83	200	791.20		
	Total	208723.63	207			
Test 4	Between groups	163708.59	7	23386.94	110.33	.001*
	Within groups	42393.33	200	211.967		
	Total	206101.92	207			
Test 5	Between groups	102803.12	7	14686.16	236.38	.001*
	Within groups	12425.83	200	62.13		
	Total	115228.95	207			
Test 6	Between groups	95447.34	7	13635.34	47.66	.001*
	Within groups	57224.53	200	286.12		
	Total	152671.88	207			
Test 7	Between groups	58417.42	7	8345.35	128.13	.001*
	Within groups	13026.22	200	65.13		
	Total	71443.64	207			
Test 8	Between groups	63941.67	7	9134.52	18.32	.001*
	Within groups	99713.33	200	498.57		
	Total	163655.00	207			
Test 9	Between groups	212124.20	7	30303.46	1180.68	.001*
	Within groups	5133.22	200	25.67		
	Total	217257.42	207			

Note. $* p < .01$.

Discussion

In this study, activity theory helped to categorize the students' language awareness into four dimensions. First, Subject-Tool-Object revealed participants' development of language awareness by means of their engagement in the CSCL community. Students' language awareness was revealed to support the idea that the CSCL community provided the students with opportunities to communicate with peers and teachers among different universities and ESP contexts. Second, Subject-Rule-Object indicated the effectiveness of regulating students' knowledge sharing among different universities on their consciousness of language uses in specific contexts. Third, Subject-Community-Object emphasized the integration of online and on-site collaborative discussions to achieve students' various learning goals, needs, and purposes. Fourth, Subject-Division of Labor-Object indicated the extended interaction between students and the teacher in meaning negotiation as well as the collaboration among students in role-play. The students' language awareness was identified as they acquired expressions from different cultures and contexts on the levels of lexical, syntactic, and textual organization as well as their engagement in collaborative learning activities. As the students from different backgrounds shared common understandings during their intercultural communication, language awareness was developed.

Different from previous studies (e.g., Deutschmann & Panichi, 2009; Liaw, 2006; Mokhtari & Reichard, 2004; Yashima & Zenuk-Nishide, 2008) that investigated students' language awareness in the CSCL community within a single context, this study examined students' language awareness in an intercultural CSCL community where students and teachers from different colleges and universities discussed diverse topics within five ESP contexts. The CSCL community in this study not only enabled students to meet peers with common learning goals but also engaged them in different learning contexts without the limitations of time and space. This increased the effectiveness and efficiency of developing students' language awareness and problem solving abilities in different contexts.

This study has provided further evidence of the value of forming a CSCL community which combines all kinds of collaborative learning activities from different colleges and universities. In the CSCL community, students are trained to be independent learners who take control of their own learning goals, strategies, and evaluation. In the CSCL community, the role of the teacher should be as a facilitator who monitors students' learning processes and provides them with appropriate scaffolding when necessary.

Although language awareness gained through intercultural communication in the CSCL community within ESP contexts was supported by this study, some limitations should be mentioned. First, the duration of data collection

was less than three months which might not be long enough to adequately investigate the development of language awareness. Comparisons between students' language awareness before and after participating in different contexts could be further analyzed to investigate the development of language awareness in the long-term. Second, students' pragmatic awareness was excluded in this study because the study focused mainly on the levels of lexical, syntactic, and textual organization. Third, not all of the students and universities were analyzed in terms of their intercultural communication and language awareness. Examples of some cases were presented within the limitation of length. Finally, students' majors, language proficiency levels and career plan in relation to selecting an ESP context were not investigated in this study. Students might participate in as many discussions as possible without clearly understanding their learning needs and goals. Further research is suggested in terms of understanding the relationship between students' resumes and learning portfolios so as to raise their language awareness in learning ESP through intercultural communication.

Conclusion

The results of this study indicate that college students' language awareness was stimulated during intercultural communication in different ESP contexts in on-site group discussions and online CSCL community based on activity theory. The multi-discipline CSCL showed that students expressed their perspectives in on-site group discussion to figure out solutions toward the problems in different social and cultural contexts. Based on their different perspectives, cultural backgrounds, and majors, students engaged in intercultural communication and raised their language awareness in the learning community.

In the CSCL community, the students discussed various topics in the contexts of Vocational, Business, Technical, Travel and Medical English. They were also engaged in knowledge sharing since the learning resources such as learning materials, photos, discussions, and assessments were shared online among the eight universities. Moreover, in the on-site discussion groups, students were provided with opportunities to meet with peers from different colleges such as the College of Engineering, Management, Humanities and Applied Sciences, and Design. Through discussions of a common issue, students from diverse backgrounds developed shared language knowledge and meanings in a specific context. Students were able to increase their language awareness through on-site group discussion and the online CSCL community on the levels of lexical, syntactic, and textual organization with the support of peers from different majors and universities in a multicultural context.

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Appendix A

Question 1	What does a company's specially refer to?
	○A. A company's requirements.
	○B. A company's business environment.
	○C. A company's line of work.
	○D. A company's industries of focus.
Question 2	Glebco's (see description A of handout) main office of operation is in _____.
	○A. West Nile
	○B. Madrid
	○C. Paris
	○D. Hamburg
Question 3	A pharmaceutical company produces _____.
	○A. medications
	○B. electronics
	○C. accessories
	○D. furniture
Question 4	Which of these will NOT be dealt with by corporate law firms?
	○A. Mergers
	○B. Bankruptcy
	○C. Financial fraud
	○D. Spousal abuse
Question 5	Which of the following is NOT true about Bob and Sons (see description C of handout)?
	○A. Its head offices and branch offices are in South East Asia.
	○B. It definitely hires builders and architects.
	○C. It focuses on large scale housing projects.
	○D. It clients are other business.

Teenagers and Technology

(Book Review)

Reviewer:
Dermod Madden
Associate-Superintendent, Aspen View School Division
EDDE student, Athabasca University
derm.madden@aspeview.org

Textbook Details:
Teenagers and Technology
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"Teenagers and Technology" is the seventeenth volume in the Adolescence and Society series, edited by John C. Coleman. The book examines the various ways, and the extent to which emergent technologies have impacted the lives of teenagers in the UK. Extensive research has shown that not only does technology have significance for teenagers, but it is during these teenage years that technology enabled practices are established. The authors indicate that technology may provide a context which enables young people to transition from the care and protection of family life to the autonomous and self-determinant world of adulthood.

The primary focus of the book is to determine the extent to which young people are engaging the two key characteristics of technological devices identified as "convergence and multi-functionality." The authors postulate that the capacity and ability to transition to and from activities on multiple devices and platforms constitutes a sub-culture available to young people and increasing accessible to most. The authors stipulate that the book tries to answer three central questions: "what does the normality of teenagers' technology use involve; is that normality common to most young people; and what are the implications for the significant numbers of young people who remain excluded from it."

The book is successful in identifying key aspects of what is deemed as the complex nature of teenagers' technology experiences. The authors identify social networking, online engagement in an ever expanding social world, and the importance of the metacognitive processes necessary for the development of an online sense of self-identity and group membership; the significance of game/role playing, the development of ICT skills and using these skills to enhance individual learning; acquiring the skills to deal with the risk factors of online environments; and utilizing technology resources to assist in the transition from adolescence to adulthood.

The authors identify the need for a shift away from traditional thinking about technology which tends to be rather simplistic and which focuses on the impacts or effects of technology, what it does to us; rather than focusing on the influences or experiences we encounter, the complexity of the interaction between and amongst people, the technology, and the context of the interaction. The perspective of the authors is one that views technology within a political, economic, social and cultural context. In so doing they focus not on the impact that technology has on the lives of teenagers, but rather on the ways in which technology is being experienced, discovered and understood, within a framework that must also accommodate, physiological and psychological change, social significance, multiple changing expectations and choices.

The authors achieved the stated aim of the book, 'to build up a fair and balanced picture of how digital technologies figure in the lives of teenagers in the technology-rich parts of the world', in Great Britain. They also made the important point that many so-called technology related issues are becoming increasingly global issues as mobile technology becomes more affordable and accessible worldwide.

The book consists of eight sections or chapters, each with a specific purpose, central to the theme of the content, teenagers and technology. Chapter one introduces the reader to the digital world of the teenager in Great Britain in the twenty-first century. Chapter two, entitled "Uses," provides an overview of the degree of utility that teenagers have for technology, the range of activities and engagement, and the subsequent sub groups of users that emerge from this profile. Chapter three, "Contexts," is a review of how technology may be affecting and possibly changing the context of the home and the school, and whether the digital world has now become a third context in the life of a

teenager. Chapter four, "Identity," explores the significance of networked technologies in the development of individual and group identities. Chapter five, "Learning," presents an historical overview of the significance of technology and technology use in formal education, and the emergence of new forms of constructivist pedagogies and student learning which promote 'self-directed independent learning. Chapter six looks at equity of access to technology, and the significance that this disparity may have on student success and on society as a whole in the near future, if access to technology is not universal. Chapter seven presents an overview of adolescent perspectives on technology and technology use, and the degree to which this may influence or promote the development of individual autonomy and dependency. The book concludes with a speculative glance at the future and the significance that technology and access to technology will have on teenagers worldwide.

"Teenagers and Technology" is an important book for several reasons. It challenges convention by acknowledging the significance of the relationship between teenager and technology. It provides evidence of seminal research in this area, based on extensive qualitative data collection. The findings of the research have significance for teaching and learning right now, and as foundational data for future research. The authors summarize their findings as follows:

1. "Teenagers choose from much the same range of technologies as adults, but are strongly influenced in what they do with these by the shared and distributed practices of the peer group; to that extent it is reasonable to contend that there is such a thing as a specifically teenage technology subculture."

2. "Teenagers align themselves to these technology practices and this subculture in widely varying ways: some embracing them wholesale, others engaging in them rather more selectively, and a small number frustrated by their lack of opportunity to use them at all."

3. We believe that the technology practices and subculture of teenagers can play a valuable role in helping them cope with the experiences of adolescence and the transition towards adult hood. We recognize also, though, that a case can be made for seeing them also as a worrying distraction from the serious demands of education, and as unmediated access to the worst aspects of the adult world" (p. 135).