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Aims and Scope

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

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 The articles should be original, unpublished, and not in consideration for publication elsewhere at the time of submission to *Educational Technology & Society* and three months thereafter.

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The Effect of Technology-Supported Co-Sharing on L2 Vocabulary Strategy Development

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ABSTRACT

Strategies play an important role in learning a second or foreign language (L2). The aim of the current study was to develop and evaluate a co-sharing-based strategy learning system for L2 vocabulary learning known as "Mywordtools." Mywordtools is designed specifically for lexical learning, enabling learners to use the currently available vocabulary learning strategies (VLSs) as well as e-tools provided within this system to learn L2 vocabulary for both indoor and outdoor settings during learners' free time. The effects of Mywordtools on L2 learners' word learning were evaluated over a 5-week period. Sixty-one sixth-grade learners of English as a foreign language (EFL) participated in this study. The results of this study demonstrate that students using Mywordtools to practice and share VLSs outperformed both those who did not use Mywordtools and those who used the platform but without sharing. It was also found that strategy sharing helped L2 learners to construct more VLSs, and they consequently performed significantly better than those who did not implement strategy sharing. The overall results indicate that the use of co-sharing with Mywordtools not only benefits the development of VLSs by EFL students but also helps them to gain more in L2 vocabulary learning.

Keywords

Second/foreign language (L2), Vocabulary acquisition, Vocabulary learning strategy (VLS), Co-sharing

Introduction

Vocabulary acquisition is important for second or foreign language (L2) learners (Laufer, 1986; Llach & Gómez, 2007; Nation, 1990; Tavil & İşisağ, 2009) since it affects their grammar competence, ability to communicate, and perceptions about the relative importance of vocabulary (Barcroft, 2004). Furthermore, L2 learners' vocabulary acquisition is related to their listening (Smidt & Hegelheimer, 2004) and reading comprehension (Cobb, 2007; Kern, 1989). Unfortunately, acquiring an adequate vocabulary is initially highly problematic for L2 learners (Meara, 1982). Given the important and challenge role of vocabulary acquisition in L2 learners' target language acquisition, the development of approaches to help students to acquire new words has been an important issue in language education (Aist, 2002; Gilman & Kim, 2008; Huyen & Nga, 2003; Kern, 1989; Kojing-Sabo & Lightbown, 1999; Smidt & Hegelheimer, 2004; Stockwell, 2010; Townsend, 2009). The relationship between vocabulary learning strategy (VLS) instruction and vocabulary acquisition is one of the main issues of concern (Gu & Johnson, 1996; Lawson & Hogben, 1996). According to Dansereau (1985) and Rigney (1978), learning strategies are actions performed by learners to aid the acquisition, storage, subsequent retrieval, and use of information. Strategies are especially important for L2 learning because they are tools for active and self-directed involvement, which is in line with the argument of constructionist learning in which learners construct mental models to understand the L2 knowledge. Oxford (1990) further indicated that appropriate language learning strategies (LLSs) result in improved proficiency and greater self-confidence. Numerous studies have confirmed Oxford's arguments, such as in learning Spanish (Morin, 2003) and English (e.g., Fan, 2003; Gu & Johnson, 1996; Kojing-Sabo & Lightbown, 1999).

LLSs are specific actions or behaviors accomplished by L2 learners to enhance their learning. After a certain amount of practice and use, learning strategies—like any other skills or behaviors—can become automatic. Thus, LLSs can be taught and modified through strategy training (Chang et al., 2010; Mayer, 2008; Velluntino, 2003). It has been recommended that strategy training should form an essential part of language education (Oxford, 1990, 2003; RAND, 2002). Through training, L2 learners are able to learn strategies that are useful for their acquisition of the target language, and consequently to take charge of their learning in all respects, including determining the objectives, selecting methods and techniques to be used, monitoring the procedures, and evaluating what has been learned (Holec, 1981). In such an L2 setting, teachers have new roles in the process of language acquisition by L2 learners, acting as facilitators, helpers, diagnosticians, and advisers, and being responsible for identifying students' learning strategies, conducting training in learning strategies, and helping learners to become more independent.

Most research findings on VLSs have been obtained either by using questionnaire surveys to determine what strategies were used by L2 learners (e.g., Fan, 2003; Gu & Johnson, 1996; Kojig-Sabo & Lightbown, 1999) or by investigating the effects of individual strategies on L2 learners' vocabulary acquisition, such as mnemonic VLSs (e.g., Morin, 2003; Sagarra & Alba, 2006). Questionnaire surveys provide rigid information regarding our understanding of how L2 learners use VLSs, while specific strategies provide only a partial knowledge of the effects of VLSs on L2 learners' vocabulary acquisition. However, the development of VLSs is a dynamic continuum. Through training, practicing, and modifying, L2 learners are able to use LLSs automatically, without additional mental effort (Chamot, 1987). Therefore, L2 learners require timely support during the VLS development continuum. Furthermore, because the development of VLSs is a dynamic process, L2 learners usually need scaffolding to first practice and then master and finally automate their strategies. Considering the timely support needed in the development process of L2 learners' VLSs, information that can reveal an L2 learner's strategy-learning status is essential for L2 learners themselves or their teachers to adapt learning approaches or to make appropriate teaching decisions, respectively. However, research into the process of L2 learners' strategy development or how to provide the essential information needed to make teaching or learning decisions for VLSs remains insufficient. Moreover, most previous studies on VLSs have focused on adults or college students, with few having investigated the development of LLSs among children. Even though some research on the effective approaches to helping children learn L2 vocabulary can be found (e.g., Kalaycioğlu, 2011; Tavil & İşısağ, 2009), those research focus neither on children's usage of VLSs in learning L2 vocabulary nor children's development of VLSs. Children's cognitive stages are different from adults' and therefore there is a need to identify what and how VLSs will be used by children.

Language acquisition is a co-construction process (Ellis, 1985; Jacoby & Ochs, 1995). The genesis of new knowledge construction lies in social interactions, since language learning is viewed as a social process rather than as the individual acquisition of vocabulary and language structures (Rogoff, 1994). Therefore, language learning involving the participation in social practices may facilitate the construction of new knowledge (Lan et al., 2011). Numerous studies have shown that collaboratively built activities in which audiences are seen as co-participants benefit language performance (Lan et al., 2008; Regan & Zuern, 2000). Dagenais et al. (2008) also found that knowledge sharing during students' co-construction benefited new target language knowledge. Upon the literature reviewed above and Vygotskian's (1978) "zone of proximal development," are novice L2 learners able to construct skills (here meaning VLSs) in the context of rich peer sharing that they otherwise would be unable to construct on their own during the VLSs development process? It is an interesting question worthy of more researchers' efforts, but has not been investigated yet.

Due to the lack of research on the effects of providing a co-sharing scheme on young L2 learners' VLS development, and on how to provide dynamic and continuous information for young L2 learners regarding VLS usage, the aim of this study was to develop and evaluate a co-sharing-based learning system, known as "Mywordtools," to determine how Mywordtools can help young L2 learners to learn new English words and to construct VLSs, and how co-sharing affects young L2 learners' VLS construction. Three research questions would be addressed in this study as follow. (1) Does Mywordtools help young L2 learners to learn new English words? (2) Is co-sharing beneficial for young L2 learners to construct VLSs? And (3) is VLS usage beneficial for young L2 learners' word performance? The interrelationship between vocabulary strategy use and vocabulary knowledge, with and without the co-sharing, was determined in a cohort of English as a foreign language (EFL) students over a 5-week period. During the experimental period, data were collected and analyzed to evaluate the effects of Mywordtools based on both the L2 EFL learners' performance of the vocabulary test and the results of strategy use.

The following sections briefly describe the VLS learning system (Mywordtools), followed by the methodology. Analytical results for the 5-week experimental period are then presented and discussed, and conclusions are then drawn from the study results.

Mywordtools: A co-sharing-based VLS learning system

The development of Mywordtools focused on learning by doing and co-construction. The design of the system was guided by the intention to support L2 learners to develop VLSs via co-construction and self-regulation. According to Ehrman and Oxford (1990) and Oxford (1990), 12 VLSs (as shown in Appendix A) embedded e-tools were developed. In addition, both schemes for self-regulation and co-sharing were also developed in Mywordtools for the aforementioned purposes. Mywordtools comprises three modules: a learning map for self-regulation, a strategy construct for learning by constructing, and a strategy co-sharing for co-construction.

Learning map module

Self-regulated learning is important to students as it relates to their academic success and lifelong learning. Self-regulating students are not only more likely to succeed academically, but view their futures optimistically (Zimmerman, 2002). Self-regulation skills include: goal setting, adopting new approaches, process or action monitoring, physical and social context restructuring, time management, and reflection. Upon self-regulation, the learning map module provides L2 learners with a scheme with which to manage their learning, including making a learning plan, checking their learning process record, automatically arranging a learning schedule according to learners' plans, and delivering daily learning materials. Three different symbols that acknowledge the learning status of the L2 learners are displayed on the screen, depending upon how well the learner is achieving (behind in the learning plan, up to date with the learning plan, and great strategy construction). Figure 1 shows a screenshot of this module.

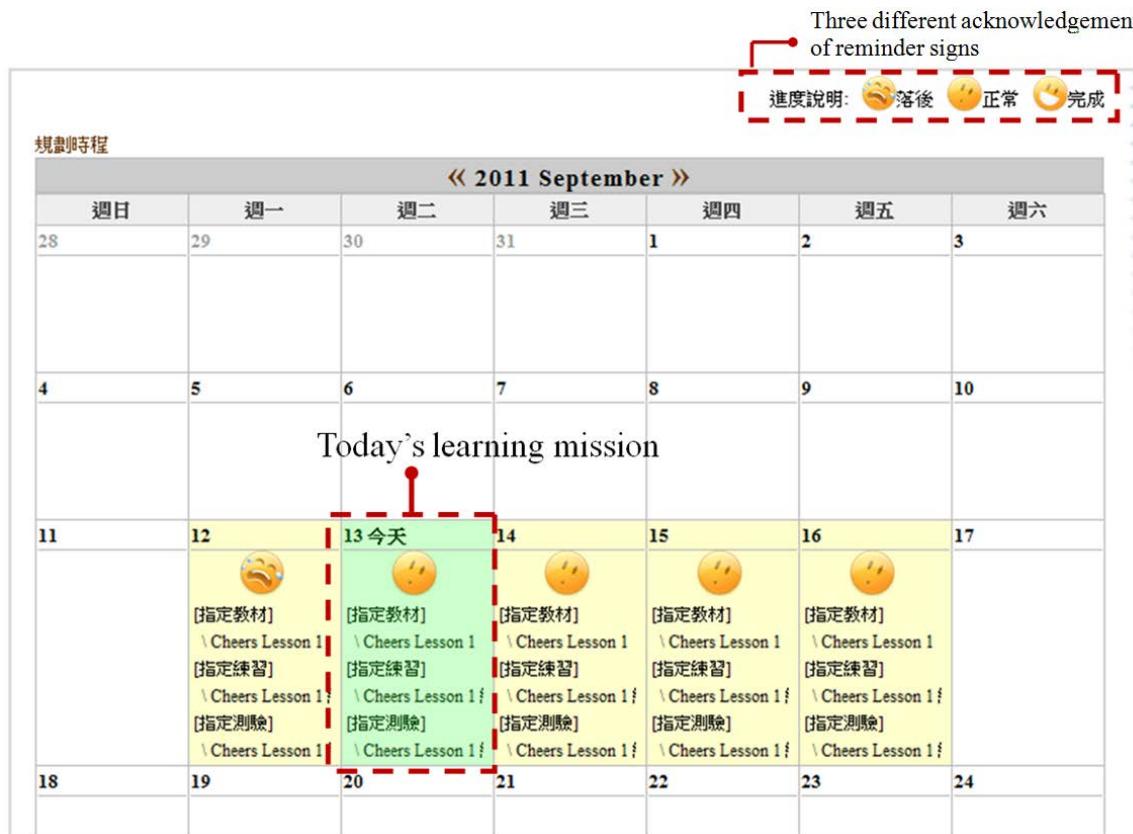


Figure 1. Screenshot of the learning map module

Strategy construct module

L2 students may learn effectively when learning through doing, and producing their target language by themselves (Lan et al., 2009). Additionally, children gain knowledge when learning something which relates to their own environment and experiences (Llach & Gómez, 2007), which is in line with constructive arguments that emphasize a learning process, allowing students to experience a learning environment and to create their own knowledge (von Glaserfeld, 1989). There are 12 different VLSs and 5 different e-tools embedded in the strategy construct module to support young L2 learners construct their own strategies. Table 1 presents the embedded VLSs and accompanying e-tools for constructing each strategy. In Table 1, "V" indicates that L2 learners can use the VLS via the e-tools to learn a new word. For example, if an L2 learner chooses the contextualization strategy, then he/she will have four options (e.g., audio, video, image, and note) to record his/her learning process. An example can be found in Figure 2.

Table 1. The embedded LLSSs and available e-tools for each strategy

e-tools	Practice	Note taking	Key word	Contextualization	Grouping	Imagery	Recombination	Deduction	Analysis	Physical	Translation	Transfer
Audio	V		V	V							V	
Video				V							V	
Image	V			V	V	V					V	
Note	V	V	V	V			V	V	V	V	V	V
Mind map				V		V		V			V	

Once an L2 word is chosen, the L2 learner can select the strategy he/she wants to use to help him/her to learn and memorize the word. Mywordtools will show all of the e-tools that accompany the selected strategy. The L2 learners can then further choose one or multiple e-tools to upload their strategies for helping them to learn and memorize the word. For example, if the L2 learner chooses the word “elephant” and uses contextualization strategy, he/she can first listen to the pronunciation and read the syntactical functions and sample sentence containing the word “elephant” (① and ② in Figure 2); then after he/she selects a contextualization strategy to help him/her to remember the word (③ in Figure 2), Mywordtools will present all of the available e-tools (images, videos, notes, and audio tools) with which the learner can construct his/her strategies. Figure 2 shows a screenshot of VLSs with the accompanying e-tools, as well as the learning materials for the word “elephant.” Figure 3 depicts some strategy examples that were constructed using this tool.

The screenshot displays the MyWordTools platform interface. At the top, there's a banner with the text "MY Wordtools Learning Strategy sharing platform". Below the banner, the main content area shows the word "elephant" in large letters. To the left, a sidebar lists menu items: 上次登入時間 (Last login time: 2012-01-09 17:12:11), Menu (學習教材, 學習地圖, 今日課程, 我的策略, 學過的字, 練習評量記錄), and e-tools (image, video, notes, and audio). The main content area includes a video player for pronunciation, text for syntactical functions and a sample sentence, and a section for choosing learning strategies. A dashed red box highlights the "我的學習策略" (My Learning Strategies) section, which contains various e-tools like drawing, video upload, note-taking, and audio recording. Arrows point from specific labels to their corresponding features in the interface.

- ① Listen to the pronunciation
- ② Read the syntactical functions and sample sentence of “elephant”
- ③ Choose My VLSs

Labels pointing to specific features:

- e-tools (image, video, notes, and audio)
- Functions of different tools
- Uploading pictures
- Online drawing
- Upload video
- Embedding Youtube URL
- Online audio recording
- Uploading video file
- Note taking

Figure 2. Screenshot of the learning materials for the English word “elephant” and the VLSs with their corresponding e-tools provided by Mywordtools

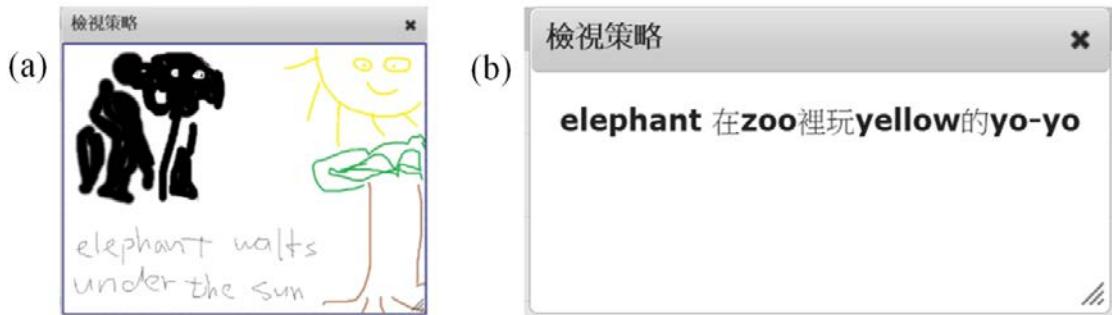


Figure 3. Some contextualization strategy examples constructed by (a) the image tool and (b) the notes tool

Strategy co-sharing module

Soon after L2 learners uploading strategies, this module provides them with the function to look up the strategies that have been used by all of the other learners in Mywordtools. Strategies can be searched either by a specific word or by a strategy. Through using a strategy co-sharing module, it is expected that L2 learners are able to self-evaluate their own strategies, then to be aware of their knowledge gaps, and to finally re-construct their strategies or build their self-confidence, as the input processing argument put forward by VanPatten (2002). In addition, in the present study, the strategy co-sharing module was used especially by those using Mywordtools with the co-sharing function to conduct co-sharing activities. Figure 4 shows the screenshots of vocabulary and e-tools searching results by contextualization strategy.

The screenshot shows the MY Wordtools platform interface. On the left, there is a sidebar with a menu including '我的學習筆記', '策略分享', '字彙學習討論區', '學習管理', and '聯絡我們'. The main area has a title '策略分享' and a sub-section 'Contextualization strategy'. Below this, there is a search bar with dropdowns for '語言' (Language), '班級' (Class), and '教材' (Textbook), and a '搜尋' (Search) button. A red bracket labeled 'Searching results' points to a table with three rows of data:

工具	日期	動作
111tw_md6_60211	2011-10-11 21:40:19	檢視
111tw_md6_60212	2011-10-11 19:04:11	檢視
111tw_md6_60124	2011-09-28 11:03:26	檢視

A red bracket on the right side of the table points to the '檢視' (View) button in the last row, with the text 'L2 learners can view each contextualization strategy constructed by other learners.'

Figure 4. Screenshots of strategy searching results by contextualization strategy

Method

Participants

The participants comprised 61 sixth-grade students attending 3 classes at an elementary school in Taipei, Taiwan. Each class was randomly assigned to three groups: learning with Mywordtools with the co-sharing function (MWT-S,

20 students), learning with Mywordtools without the co-sharing function (MWT, 20 students), and learning under traditional instruction (TSI, 21 students).

Design

This study adopted a quasi-experimental design. Students in the three study groups (MWT-S, MWT, and TSI) recorded their VLSs while learning the assigned materials, which comprised 320 essential words for Taiwanese elementary EFL students, during the experimental period from October 1 to November 1, 2011. The learning activities did not take place in regular EFL classes, but rather during the students' free time (both at school and at home) at anywhere (both indoor and outdoor); therefore, the learning activities in the present study were self-directed. Students in the MWT-S group learned the words and co-share their VLSs with the help of Mywordtools, and especially to take a look at what VLSs their peers had uploaded onto Mywordtools. Students in the MWT group used Mywordtools to learn and record their VLSs, but without co-sharing or discover what their peers had done on Mywordtools. In contrast to these two Mywordtools groups, each student in the TSI group was given a notebook with 320 words in which to record their VLSs and vocabulary learning during the experimental period. Additionally, all three groups were taught by the same EFL teachers.

Both the vocabulary test scores and VLSs constructed by the participants were collected and analyzed. Baseline scores were obtained 1 week before the experiment (pretest), and then after the treatment (posttest), the vocabulary performance scores of all the participants were collected via a vocabulary performance test. In addition to the test scores, for the MWT-S and MWT groups, the VLSs constructed during the treatment were all kept in the Mywordtools database for later analysis; for the TSI group, their notebooks were collected and scanned to analyze the recorded VLSs used by the students. The participants' English scores from their mid-term exam which was administered before the treatment were also provided by the EFL teacher to serve as a covariate during the data analysis process.

Instruments

Vocabulary performance test

This test consisted of two sub-tests for each of 320 words: transformation (e.g., “hospital ①家②學校③醫院④車站”) and a closed test (e.g., “Peter is from Taiwan but ____ can't speak Chinese. ①who ② he ③is ④four”). The answers to all of the test items were confirmed by three EFL teachers. During the test, 7 minutes were allowed for answering each sub-test, and participants tried their best to answer as many as items possible. Each correctly scored item was awarded 1 point.

Learning materials: Essential words for Taiwanese elementary EFL students and 12 VLSs

The learning material comprised 320 essential words for Taiwanese elementary EFL students, as shown in Appendix B. The TSI group was given a printed word list, while the MWT-S and MWT groups were given IDs and passwords to enable them to log into Mywordtools to learn whenever they were available for self-directed learning. An explanation and basic instruction of the 12 VLSs (Appendix A) was also provided to all the participants.

Procedure

The experiment took place over a 5-week period, from October 1 to November 1, 2011. Before the treatment, all of the participants performed a vocabulary performance test, after which the MWT-S and MWT groups received training in the operation of Mywordtools. All of the participants then constructed their vocabulary learning plans for learning all 320 words during this period; the 2 groups learning with Mywordtools made the plan directly via the system, while the students in the TSI group wrote down their plan in their notebooks. After their learning plan was confirmed, they began to learn the 320 words in their free time, either at or after school, as per their plans. The EFL teacher reminded them to check whether their learning progress met their plan every week. In addition, the VLSs

used by the MWT-S and MWT groups were kept in the Mywordtools database, while those used by the TSI students were kept in their notebooks. All of the participants performed the same vocabulary performance test 1 week after the end of the 5-week experimental period. Figure 5 outlines the study procedure.

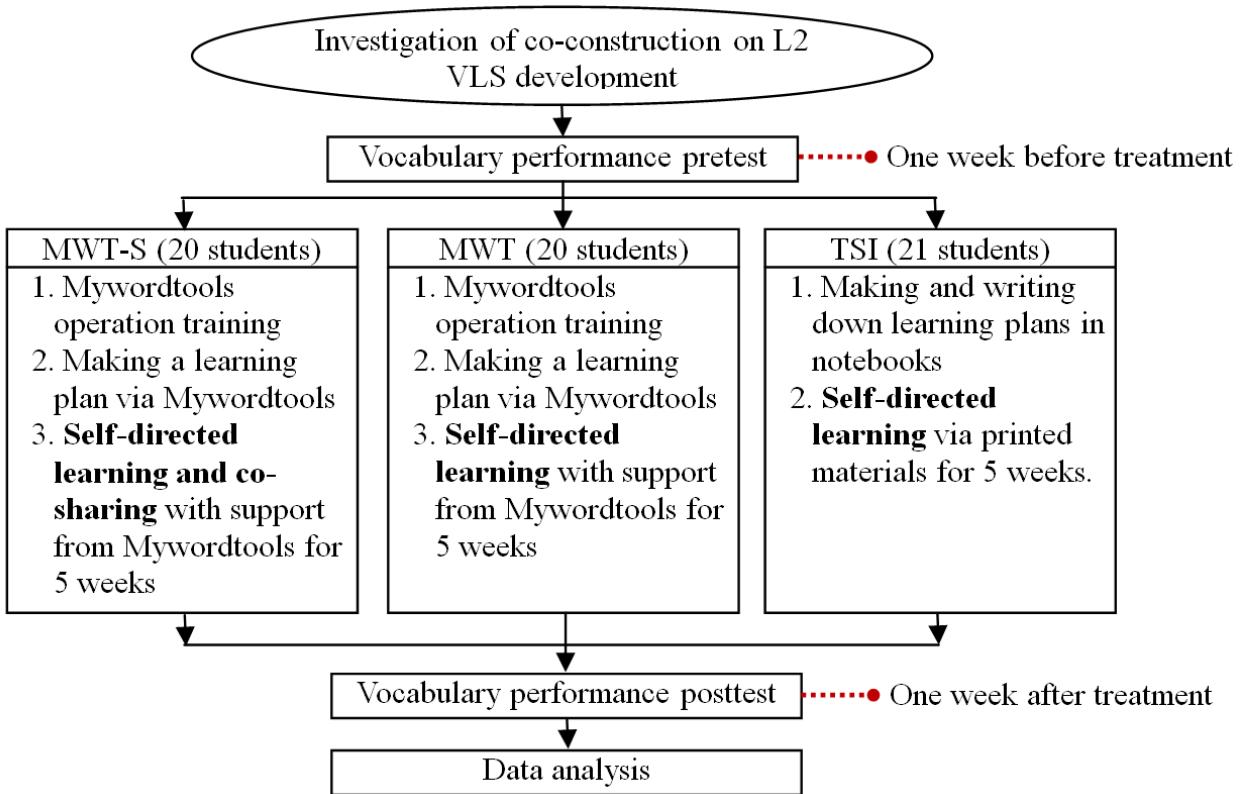


Figure 5. The study procedure

As depicted in Figure 5, the TSI group learned via a paper-and-pencil approach, while the other two groups learned with the support of Mywordtools. Furthermore, since Mywordtools can be run on diverse electronic devices (i.e., PC, smartphone, iPad, or tablet PC), the MWT-S and MWT groups were able to log into Mywordtools in different environments, at their convenience. Figure 6 shows an overview of vocabulary learning via Mywordtools.

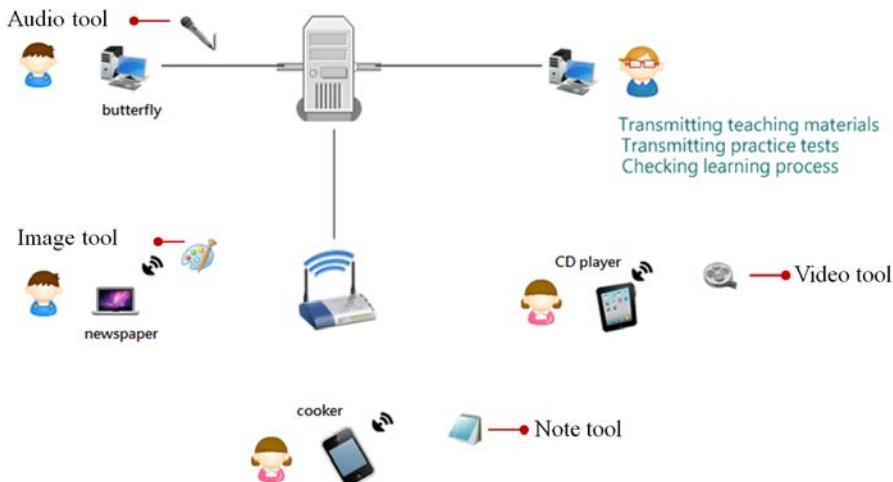


Figure 6. An overview of vocabulary learning via Mywordtools

Results

The analysis focused on answering the three research questions: how Mywordtools benefits L2 learners' vocabulary learning, how co-sharing affects L2 learners' vocabulary learning and VLS construction, and how VLS usage benefits L2 learners' word performance. Word learning achievement was evaluated by analyzing the participants' vocabulary performance test scores, whilst the VLS learning result was evaluated by analyzing the strategy construction records kept in the Mywordtools database.

RQ1: Does Mywordtools help young L2 learners to learn new English words?

To answer the first research question, comparison of the vocabulary performance test results was conducted. All participants took the same vocabulary performance test one week before and after the treatment. A two-way mixed-design analysis of covariance was conducted to determine how the vocabulary performance differed between the participants in the three groups (MWT-S, MWT, and TSI). The independent variables were the group (MWT-S, MWT, or TSI) and the test (pre- or posttest), while the covariate was student EFL scores from the mid-term right before the treatment. The level of statistical significance was set at $\alpha = .05$. Table 2 lists the means and standard deviations for the vocabulary performance test scores.

Table 2. Means and standard deviations (SDs) of the vocabulary performance test scores for the three experimental groups

Test	MWT (N=20)		MWT-S (N=20)		TSI (N=21)	
	Mean	SD	Mean	SD	Mean	SD
Pretest	103.00	53.02	112.35	55.66	100.76	53.69
Posttest	132.00	68.43	153.75	67.65	120.91	46.50

Comparison of vocabulary performance scores between the three groups was conducted. The homogeneity test results for regression coefficients were not significant [$F(1,57) = 0.06, p > 0.05$]. Two-way ANCOVA revealed a significant interaction between group and test scores [$F(1, 58) = 4.51, p < 0.05$], with the magnitude of the difference varying according to level. A simple main-effect analysis demonstrated no statistically significant difference between the three groups in the vocabulary performance pretest scores [$F(1, 53) = 0.67, p > 0.05$]. However, the three groups performed significantly differently in the posttest [$F(1, 53) = 3.26, p < 0.05$], indicating that the performance in the knowledge of English vocabulary was the same in all three groups before the study, while the vocabulary performance differed significantly among the three groups after the experimental period. Post-hoc testing revealed that the MWT-S group performed significantly better in the posttest than both the MWT [$F(1, 37) = 5.52, p < 0.05$] and TSI [$F(1, 38) = 6.00, p < 0.05$] groups, and the MWT group performed better than the TSI group even not reached a significant level.

There was also a significant pre- versus posttest effect on the performances of the three groups in vocabulary performance tests, with all three groups performing significantly better in the posttest than in the pretest [MWT: $F(1, 58) = 19.92, p < 0.05$; MWT-S: $F(1, 58) = 40.59, p < 0.05$; TSI: $F(1, 58) = 10.19, p < 0.05$]. Furthermore, the progress made by the three groups differed: it was greatest in the MWT-S group, followed by the MWT group and then the TSI group.

Based on the comparison of the results, it is proved that Mywordtools can benefit L2 learners' L2 word learning, especially when they performed the sharing of VLSs with other online learners.

RQ2: Is co-sharing beneficial for young L2 learners to construct VLSs?

The VLS usage records of different groups were compared to answer the second research question. Following completion of the experiment, the VLSs used by the three groups were compared based on both frequency percentages and strategy categories. Regarding the strategy usage records, those of the MWT and MWT-S groups were downloaded directly from the Mywordtools database, while those for the TSI group were collected and scanned from the notebooks that they used. However, even though all students in the TSI group were given notebooks in which to document down their strategies, few records were found at the end of the treatment. This may be

attributable to the lack of academic credit given for the activity, and the fact that students do not habitually write down what strategies they have used to learn new words. Furthermore, the experiment itself was a kind of informal learning in which students learned the strategies during their free time, and no additional pressure was given by the teachers to push them to record their strategies.

In order to make up the missing data and figure out how the TSI group learned L2 words, interviews with the EFL teacher and the students of that group were conducted. The interview results depicted that repeated practice (writing a word many times until it is memorized) and oral repetition (i.e., reading aloud and writing a word many times until it is memorized) were the most taught VLS by the EFL teacher and used her students. Table 3 lists only the frequency percentages of strategies used by the MWT and MWT-S groups rather than the three different groups. This is due to the lack of actual strategy records from the TSI group even though the interviews from this group provided us some answers to the phenomenon.

Table 3. The frequency percentages of each strategy used by the MWT and MWT-S groups

Groups	Frequency percentages											
	Practice	Note taking	Key words	Contextualization	Grouping	Imagery	Recombinatio n	Deduction	Analysis	Physical	Translation	Transfer
MWT	85.58	2.88	1.55	4.99	0.13	0.03	0.07	0.03	0.13	0.07	3.84	0.69
MWT-S	59.35	9.60	2.43	17.56	4.12	4.07	0.56	0.40	0.73	0.56	0.28	0.34

The five strategies used most often by the MWT group were practice, contextualization, translation, note taking, and key words. By contrast, the five strategies used most often by the MWT-S group were practice, contextualization, note taking, grouping, and imagery. However, although practice was the strategy used most often by both groups, the degree to which they used this strategy differed significantly ($\chi^2 = 27.99, p < 0.05$) between them: over 85% in the MWT group but less than 60% in the MWT-S group.

The total frequencies of strategies used for the two groups were 3024 for MWT and 1771 for MWT-S. The raw frequency was much higher for the MWT group than for the MWT-S group, while the numbers of strategy categories used by the two groups varied in the opposite direction; the relevant data are compared in Table 4. *T*-test analysis revealed that the categories of used strategies between the two groups were significantly different ($t = 5.60, p < 0.05$), indicating that the MWT-S group used more kinds of VLSs to learn new words than did their peers in the MWT group. Therefore, despite the missing data happened in TSI group, the data obtained from the database of Mywordtools provide a preliminary answer to the research question: Co-sharing benefits L2 learners' strategy construction in strategy categories rather than frequency record.

Table 4. Means and SDs of strategy categories used by the MWT and MWT-S groups

MWT (N=20)		MWT-S (N=20)	
Mean	SD	Mean	SD
2.9	1.59	4.4	2.35

RQ3: Is VLS usage beneficial for young L2 learners' word performance?

Due to the lack of printed strategy usage record of TSI group, only the data of MWT and MWT-S are used to figure out the answer to the research question. Synthesizing the data listed in Tables 2, 3, and 4, a positive answer to the question can be obtained. Both MWT-S and MWT groups made significant improvement at posttest. In addition, the former made more progress than the latter. Furthermore, the MWT-S group significantly outperformed the MWT group in posttest. However, the significant differences existed in posttest between the two groups seems not caused by the frequencies of strategy usage but categories. The strategy usage frequency of MWT group is much higher than that of MWT-S group (3024 to 1771); nevertheless, the frequency of MWT group was more centered on fewer categories of strategies. Thus, we can infer that the more VLS categories used, the greater benefits students can get from L2 word learning process.

Discussion

Three research questions were addressed in the current study. In addition to the answers to the research questions based on the data analysis explained above, some further discussion will be given below.

The benefits of Mywordtools for young L2 learners' vocabulary learning

Comparison of vocabulary performance tests among the three groups (Table 2) revealed that while all three groups made significant progress on the tests, the progress was much greater in the two groups that learned with the support of Mywordtools. According to further interviews from TSI group, rote practice was the mostly used strategy by TSI group. In contrast, via the support of Mywordtools, young L2 learners tried different strategies to help them memorize vocabulary. More interestingly, young L2 learners loved to embed vocabulary into the context of a story, (see Table 3). In contrast to rote repetition, connecting vocabulary with their own experiences or imagination to create a story might have benefited young L2 learners' vocabulary learning. The results fit in with young learners' learning characteristics: children's foreign language learning depends on what they experience and they actively try to construct meaning (Cameron, 2001).

Furthermore, this study encouraged young L2 learners to use their free time to learn the target words and to construct their own strategies. Based on the 5-week experimental results, it seemed that Mywordtools encouraged young L2 learners to learn vocabulary, even without the teachers' commands or assignments. Additionally, the learning map module of Mywordtools provided users with a scheme to set learning goals and to monitor one's own learning condition. The self-regulation scheme seemed to help them pursue success in vocabulary learning. To confirm those possible effects of Mywordtools, longer experimental time period, more participants, and multi-perspective evidences are needed in future study.

The benefits of Mywordtools for young L2 learners' VLS construction

According to Table 3, with the support of Mywordtools, L2 learners developed many other VLSs such as contextualization, note-taking, grouping, imagery, and keywords, in addition to the rote practice strategy. This finding is consistent with that of Mayer (2008) and Chang et al. (2010), that VLSs are teachable. Furthermore, according to the current study, it can be said that VLSs are also learnable via scaffolding-based self-construction. The target VLSs embedded in Mywordtools are available for L2 learners to conduct self-learning in their free time. In addition, all of the VLS construction processes are recorded in the Mywordtools database, and so L2 learners can easily view their learning status and review what VLSs have been used by themselves during the process. Reviewing the construction process might contribute to L2 learners' VLS development. This represents a kind of meta-cognitive ability, which has been proven important for L2 learners' performance (Anderson, 2002; Oxford, 1990).

In addition to the process-reviewing function, the multiple e-tools embedded within each kind of VLS are also easy for L2 learners to use in VLS construction. The multiple choices of e-tools or VLSs provided by Mywordtools might also encourage L2 learners to record their VLSs according to their individual preferences, rather than the traditional pencil-and-paper-based recording approach. Numerous examples can be found in the Mywordtools database where L2 learners have tried to use multiple e-tools to construct VLSs to learn a single word. For example, one student used three VLSs to help remember the word "cow": note taking (note tool), contextualization (image tool), and imagery (image tool).

The results obtained from this study also reveal the importance of providing young L2 learners with multiple easy-use tools in teaching VLSs and L2 vocabulary. The students of TSI group did not leave any records in their notebooks. This might be caused by the tools they had, (a paper and a pencil), which were not suitable for recording their strategies. Furthermore, regarding individual differences, whether there exists a relationship between L2 learners' learning styles/genders and the chosen VLSs/ e-tools of Mywordtools is worthy of more efforts to explore.

The effect of co-sharing on young L2 learners' VLS construction

Comparison of VLS categories used by the MWT-S and MWT groups revealed that the former used significantly more kinds of VLSs than the latter. This finding can be explained by the notion of Vygotsky (1978) of a zone of proximal development. Through co-sharing, L2 learners learned from their peers' idea of VLS usage, and increased their VLS construction trials. It appears to echo to vanPatten's input processing theory, in which L2 learners shorten their VLS knowledge gaps through co-sharing and develop more VLSs to support their vocabulary learning. This finding further supports the previously reported idea that VLS is learnable.

However, this result may also be attributable to the "audience effect," as in the research conducted by Regan and Zuern (2000) on computer mediated composition, which found that EFL writers composed articles with higher quality and quantity because of their online audience. Irrespective of the reason for these results, be it peer-learning or the audience effect, the MWT-S participants outperformed their MWT peers in VLS construction records despite the lack of real dialogue or interaction in the social context, in line with the work of Raphael et al. (2009).

Additionally, based on the results obtained from this study, a more detailed analysis of young L2 learners' developing process of VLS should be conducted to provide more evidences to explain how co-sharing influences young L2 learners' VLS acquisition process.

The effects of VLS usage variety on young L2 word learning

Based on the results, it is found that the greater the variety of VLS used, the better the vocabulary would be performed. The MWT-S group used on average more categories of VLSs and significantly outperformed both of the other groups in the posttest vocabulary test performance. They also made more progress. These results might be caused by the difference in the depth of mental processes used while L2 learners learned the words. The MWT-S group not only used more categories of VLS but also more VLSs that require greater levels of processing—such as contextualization, note taking, and grouping—than did the MWT group. The most often used VLS by the MWT and MWT-S groups was practice; even though the total frequency of VLS records was much higher for the MWT group than for the MWT-S group (the raw frequency records for the two groups are 3024 and 1771), the results were inconsistent. According to related research on cognitive models of lexical processing, in both first-language and L2 studies, VLSs requiring deeper processing have been found to result in a better retention of words than strategies involving shallower levels of processing (Au & Glusman, 1990; de Groot & Van Hell, 2005). In the work of Gu and Johnson (1996), simple repetition of new words was the strongest negative predictor of L2 learners' vocabulary size and general proficiency.

The findings discussed above also draw forth the effect of co-sharing on both L2 learners' VLS construction and word performance during the dynamic VLS construction process. This is an important finding because it adds to the knowledge about the relationship between VLS and L2 learners' vocabulary acquisition. As mentioned in the Introduction section, most research on VLSs has focused on distinguishing the strategies used by higher-performing L2 learners via questionnaires, from which instruction suggestions were made to L2 teachers. Furthermore, many studies have concluded that more VLSs were used by higher-performing L2 learners (e.g., Sagarrà & Alba, 2006; Gu & Johnson, 1996). However, the current study found that young L2 learners with same level of word performance at the beginning of the experiment performed significantly differently thereafter depending upon whether or not they used Mywordtools and whether they co-shared their VLSs: those who constructed more VLSs via co-sharing outperformed their peers who did not use co-sharing.

Conclusion

The purpose of this study was to develop and evaluate a co-sharing VLS system for young L2 learners' vocabulary learning and VLS development. Several important findings have been obtained in this study. First, it is confirmed that VLS is learnable. Second, scaffolding-based self-construction and co-sharing appear to be able to effectively enhance young L2 learners' VLS development and vocabulary learning. Third, through co-sharing, young L2 learners seem to be able to develop the VLSs beyond their cognitive stage. Some issues for future research are also suggested, including the effects of self-regulation, gender difference, and learning styles on young L2 learners' VLS

development via Mywordtools; and the detailed analysis of young L2 learners' VLS development process. In addition, how L2 learners speaking a different first language develop VLSs with the support of Mywordtools is also an important issue for future study. In sum, this study can be viewed as a first step in building the knowledge of L2 learners' VLS development via technology supports and definitely more efforts should be made. It is a precious goal to pursue even it is a long way to go.

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Appendix A

The 12 embedded VLSs in Mywordtools

Strategies	Explanation
Practicing	Simply practice the vocabulary by repetition, such as by writing it down on a piece of paper, or by speaking it out repeatedly.
Note-taking	To take note of the vocabulary and its important or useful information, such as its meaning, pronunciation, word structure (e.g. prefix, root, stem, suffix.), or the parts of speech, etc.
Key word	Connect the word pronunciation to the similar pronunciation of another word in students' L1 or the words they have learned, and try to connect the meaning of the original word and the homophone word to reinforce learners' memory. For example, the word <i>dilemma</i> , which means a difficult situation requiring a choice between equally undesirable options, sounds like "a landmine" in learners' L1, Mandarin. Thus, we can connect the original word "dilemma" by enhancing the image of the difficult choice of stepping on a landmine, which makes it difficult to choose what to do.
Contextualization	Give the target vocabulary a context as to narrate a simple story or a plot. For instance, here we use four words to make a short story: <i>waffle, lizard, church, and Korea</i> . <i>Mr. Lizard</i> goes to a <i>church</i> in <i>Korea</i> to eat a <i>waffle</i> .
Grouping	Group the vocabulary by their shared characteristic. For example, <i>airplane, bicycle, ferry</i> and <i>boat</i> can be categorized in the group of "transportation".
Imagery	To utilize visual aids such as images and pictures to enhance vocabulary learning.
Recombination	To combine the words learners have learned with the words being learned to learn new vocabulary, such as the following example: combine the words students have already known with the new word " <i>post</i> " to learn new words such as: <i>post office, postmark postman, postbox, postcard</i> , etc.
Deduction	Remember the elements or rules to use or structure words, to reason or infer the meaning of the vocabulary being learned. For example, " <i>un-</i> " is the prefix for "not, against", which helps learners to reason the following words: <i>unarm, unsure, uncomfortable</i> , etc. Another example is " <i>over-</i> " as "excessive or above", which reasons the words overbook, overdose, overdress, etc.
Analysis	Analyze the word structure with prefix, stem, root, suffix, etc. and learn how to use them. For example, the word <i>unkindness</i> could be analyzed as three parts: <i>un-</i> (not) + <i>kind</i> + <i>-ness</i> (noun as state, condition, or quality).
Physical response	This is based on the coordination of language and physical movement. Learners' respond with the corresponding movement as they think of the target vocabulary being learned. For example, learners could show the action of drinking when they are learning the vocabulary " <i>drink</i> ".
Translation	Directly translate the target vocabulary base on learners' L1, or the words learners have learned. For example, pet shop, book store, blueberry, etc.
Transfer	To understand the concept of new vocabulary by understanding from learners' L1, or utilizing vocabulary's rules, structure, grammar, etc. For example, the word "smooth" and "smoothly" are used for describing the texture of objects, as the basic concept (e.g. the table looks smooth). However, they could also infer a situation goes without interruption, such as, "The meeting went smoothly." Hence, the noun "smoothie" for food could be connected to the smooth texture as well.

Appendix B

320 essential words for Taiwanese elementary EFL students

Grades 1-2	Grades 3-4	Grades 5-6
a (an)一個 apple蘋果 am是 are是 is是 bag袋子 ball球 bird鳥	and和,而且 apple蘋果 arm手臂 at(介)在... bag袋子 ball球 baby 嬰兒 banana香蕉 bear熊 bed 床 bee蜜蜂	angry生氣的 art藝術,美術 aunt阿姨,伯母 back(n)背部,後面的 bad壞的 bike腳踏車 bathroom浴室 bedroom臥房 bookstore書店 bread 麵包 breakfast 早餐 brother兄弟,弟 brown咖啡色 bus巴士 but但是 candy糖果 card紙牌,卡片 cloudy多雲的,陰天的 Chinese中國人,中國的 coat外套 chicken雞,雞肉 coffee咖啡 clean乾淨的,(v)打掃 close(v)關閉,接近的 classroom教室 cold冷的,感冒 come (v)來 computer電腦 cook (v)煮做,(n)廚師 cookies餅乾 cool涼快的 cry (v) (n)哭,叫喊 drive (v)開車 dance(v)跳舞 dear親愛的 dirty髒的 dinner晚餐 drink(v)喝,(n)飲料 draw(v)畫圖
blue 藍色,藍的 book 書 box 盒子 boy 男孩 cake 蛋糕 cat 貓 color 顏色 cow 母牛	bird鳥 black黑色,黑的 blue藍色,藍的 car汽車 cake蛋糕 can(助v)能,會 chair椅子 class級班級 color顏色 cow母牛 cry (v) (n)哭,叫喊(11) day天,白天 desk書桌 doctor醫生 doll洋娃娃 door門 down (副)向下 eat (v)吃 eye(s)眼睛 ear(s)耳朵 eight 8 elephant 大象 (11)	duck鴨子 easy容易的 e-mail電子郵件 eraser橡皮擦 English英語 eleven11 eighteen 18 fan風扇; 粉絲 eighty80 excited感到興奮的 fall (n)秋天(v)落下 fast快的,快地 father爸爸 feel (v) 感覺,覺得 fire火 food食物 from(介)來自,從...起 fries薯條 fourteen14 for(介)為了,給... forty40 flower花 fifteen15 fifty50 fruit水果 fly (v)飛 get (v)獲得;得到,到達 give (v)給
cup杯子 Dad 爸爸 dog狗 egg蛋 fish魚,魚肉 girl女孩 green綠色,綠的	face臉 fan風扇;粉絲 five 5 fine 美好的 fly (v)飛 foot腳,足 for(介)為了,給... four 4 from來自 friend朋友 fun樂趣,有趣的 go(v)去 (12) game遊戲,比賽 green綠色,綠的 hand(s)手 (11) has(v)有,吃 have (v)有,吃 head頭 grandma祖母 grandpa祖父 hamburger漢堡 he他 happy快樂的 in(介)在...裡面 juice果汁 jump(v)跳 key鑰匙 kid小孩 kite風箏 leg腿 like (v)喜歡 lion獅子 long長的 make (v)做;使 marker麥克筆 (12)	glasses眼鏡 good好的 gray灰色 head頭 help (v)(n) 幫助 here這裡, (副)在這裡 her她的,她 his他的 him他 home家, (副)在家 hot熱的 house房子 how(副)怎樣,如何 hundred百 hospital醫院 hungry餓的 ice cream冰淇淋 jacket夾克 job工作;職業 Japan日本 jump(v)跳 (14) kitchen廚房 know(v)知道;認識 late遲的晚的 leg腿 learn(v)學習;得知 let (v)讓,允許 library圖書館 love愛;喜愛 listen(v)聽 live(v)住 living room客廳 lunch午餐 mad生氣的 many許多(後加可數名詞) math數學 my我的 Monday星期一 moon月亮 music音樂 MRT捷運 much許多(後加不可數名詞)
I我 it它,牠 Mom媽媽 my我的 pencil鉛筆 pig豬 red紅色,紅的	in(介)在...裡面 juice果汁 jump(v)跳 key鑰匙 kid小孩 kite風箏 leg腿 like (v)喜歡 lion獅子 long長的 make (v)做;使 marker麥克筆 (12) milk牛奶 monkey猴子 mouth嘴 mother媽媽 name名字 no不,沒有 nose鼻子 not nine 9 one 1 on(介)在...上面 orange柳橙,橘色(12) park公園 pen筆 pencil鉛筆 pet寵物 pig豬 pink粉紅色,粉紅的 play (v)玩,打球 pizza比薩 red紅色,紅的 ruler尺 run(v)跑 read(v)讀 (12)	need (v)需要 new新的 nice美好的 nineteen 19 ninety 90 now (副)現在 noodles麵條 nurse護士 o'clock點鐘 old 老的,舊的 open(v)打開,打開的 our我們的 park公園(v)停放(車) pants長褲 PE 體育課 pie派 plane飛機 police officer警察 police station警察局 pull(v)拉 push(v)推 post office郵局 purple紫色 rain雨,(v)下雨 rainy下雨的 rabbit兔子 read(v)讀 restaurant餐廳 rice米飯 ride(v)騎,乘 sandwich三明治 Saturday星期六 science科學 shop商店,(v)購物 ship船 shoes鞋子 shorts 短褲 sick生病的,噁心的 sky天空 slow慢的 small小的 smile (v)微笑 song歌曲 socks襪子 sofa沙發 soup湯 some一些,某個 spring春天 speak (v)演講 student學生 stand(v)站立 star星星,(v)主演 story故事 study書房,(v)研讀
that那個 this這個 what什麼 yellow黃色 you你,你們 yo-yo溜溜球 zoo動物園	sad難過的 say(某人)說 see(v)看見 school學校 sing (v)唱歌 singer歌手 sister姊,妹 six 6 sleep(v)睡覺 she她 short 矮的,短的 seven 7 (12) talk(v)說話 tall高的 that那個 the 這... these這些 they他們 tea茶 thin瘦的,薄的 this這個 tree樹 three 3 those那些 today今天 (13) tiger老虎 time時間 toy玩具 two 2 ten 10 up (副)向上 under(介)在...下面 want(v)想要 we我們 what什麼 who誰 white白色,白色的 your你的,你們的 (13)	sit (v)坐 sixteen 16 sixty 60 summer夏天 sun太陽 sunny晴朗的 supermarket超市 swim(v)游泳 sweater毛衣 seventeen 17 seventy 70 table桌子 Taiwan台灣 take (v)拿,取 tape膠帶 taxi計程車 think (v)想,認為 teacher老師 tell (v)告訴 test測驗,考試 thank感謝 their他們的 tired累的 today今天 train火車 T-shirt T恤 there(副)在那裡 time時間 Tuesday星期二 Thursday星期四 twelve 12 thirteen13 thirty30 twenty 20 use (v)使用,利用 uncle舅,叔,伯 (13) the USA美國 the UK英國 walk (v)走;散步 wash (v)洗 watch (n)手錶 (v)注視 water (n)水(v)澆水 warm溫暖的 weather氣候 wear(v)穿 Wednesday星期三 week週,星期 when(副)何時, (連)當...時 where在哪裡 why為什麼 window窗戶 with(介)和,有... work工作(n.v) write (v)寫 windy刮風的;多風的 winter冬天 year年, 歲數

An Interactive Teaching System for Bond Graph Modeling and Simulation in Bioengineering

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ABSTRACT

The objective of the present work was to implement a teaching system useful in modeling and simulation of biotechnological processes. The interactive system is based on applications developed using 20-sim modeling and simulation software environment. A procedure for the simulation of bioprocesses modeled by bond graphs is proposed and simulators containing biochemical bond graph elements are designed. These simulators are organized in libraries that exploit the modularity of the method, very useful for master students, who will be able to model and simulate complex bioprocesses. In order to evaluate the learning performance of this teaching system, an analysis was performed using a pre-test/post-test scenario, with a multiple-choice knowledge test.

Keywords

Bioengineering education, Improving classroom teaching, Interactive learning environments, Simulations, Teaching/learning strategies

Introduction

At the university level, the teaching of bioengineering involves a variety of topics ranging from biology, biochemistry, medicine, automation, and informatics. Therefore, training in this domain is a difficult problem (Akpan, 2001; Djordjevic, Gerla, Huptych, Lhotska, & Krajca, 2010; Gonzalez-Cruz, Rodriguez-Sotres, & Rodriguez-Penagos, 2003). Within the design process of a bioengineering course, significant problems are the modeling of bioprocesses and the simulation of these complex systems (Dochain, 2008; Petre, 2006; Roman, Şendrescu, Bobaşu, Petre, & Popescu, 2011; Roman & Selișteanu, 2012; Selișteanu, Roman, & Şendrescu, 2010). Another important problem is the choice of teaching system to pass from theory to practice. The teaching material in the field of bioengineering can be classified as simulators, laboratory bioreactors, pilot bioreactors, and industrial bioreactors.

As was demonstrated by the large number of studies, the interactive computer simulations, designed to teach complex processes, have become very popular in all domains of science education, such as physics, chemistry, and biology (Holzinger, Kickmeier-Rust, Wassertheurer, & Hessinger, 2009). Nowadays, technological developments such as computer simulations can implement more effective the so-called inquiry learning (de Jong, 2006). By using simulations to model a phenomenon, students can perform experiments by changing some variables and then observe the effects of their changes; thus, they discover the properties of the original model (de Jong, 2006). Simulations as learning tools are engaging and can be valuable for bioengineering. On the whole, a major advantage of learning with interactive simulations can be seen in the highly constructivist nature of such learning processes (Gülbahar, Madran, & Kalelioglu, 2010; Holzinger et al., 2009).

Several works, such as (de Jong, 2006; Keselman, 2003; Lawson, 2002; Manlove, Lazonder, & de Jong, 2006), reported that the students have significant problems with different inquiry learning processes: they have difficulty choosing the right variables to work with; they do not necessarily draw the right conclusions from experiments; they may have difficulty linking experimental data and hypotheses; they fail to make predictions; they make mistakes when interpreting data; and more. Therefore, research currently focuses on finding cognitive tools that help to surmount these problems and produce efficient learning situations. More precisely, computer environments can integrate these cognitive tools with the simulation (de Jong, 2006).

However, essential practical details can be lost if engineering teaching is reduced only to lectures and digital simulations, bypassing physical/biochemical experiments because of their relatively high costs (Precup, Preitl, Rădac, Petriu, Dragoş, & Tar, 2011). For that reason, most of universities try to purchase or to develop real

bioreactors (laboratory or pilot reactors); in this way the laboratories can be achieved by using real bioprocesses. Of course, it is essential to apply the theory on real bioprocesses, but in most cases this method is expensive, and in some situations there are biological risks; therefore, in many cases simulators are used (Gonzalez-Cruz et al., 2003). Linked to this approach, in the last period a lot of interactive, computer and web-based teaching systems were reported, but especially related to physics/chemistry/biology education (Bunce, VandenPlas, & Havanki, 2006; Chang, Chen, Lin, & Sung, 2008; Gibbons, Evans, Payne, Shah, & Griffin, 2004; Limniou, Papadopoulos, & Whitehead, 2009, Milrad, 2002). Consequently, the use of software simulators is common and it constitutes an alternative to real bioreactors.

Concerning the choice of a particular teaching tool for biotechnology education at undergraduate and/or master level, it is obvious that this education requires intensive training in laboratory procedures. One of the key elements is the need to allow the student to familiarize laboratory techniques in balance with regular theory (Diwakar, Achuthan, Nedungadi, & Nair, 2011). The only way to achieve this goal with low costs is to use interactive, computer, and web-based teaching systems, including virtual labs. This tendency was reported in several works of the last decade, such as (Akpan; 2001; Gibbons et al., 2004; Gonzalez-Cruz et al., 2003; Palladino, 2002; Palladino & Cosentino, 2001; Smith & Emmeluth, 2002), and in numerous recent papers (Cid & Rajal; 2011; Diwakar et al., 2011; Roman et al., 2011).

The reasons to focus on interactive computer-based teaching systems for bioengineering are many (Diwakar et al., 2011). First, as already we outlined, the experimental setup cost is a big problem. Another motivation is the need to introduce computer-based teaching systems and virtual labs, which use mathematical modeling and computational methods. From the learning perspective, such systems allow students to manipulate advanced but common-to-use simulation tools. For biotechnology, a strong motivation for the shift to computer-based-and-virtual-lab paradigm, is the explosion of data-rich information sets, which are difficult to understand without the use of analytical tools. Another reason is the increasing interest in *in silico* experimentation due to ethical considerations, risk, and complications involved in human and animal research (Diwakar et al., 2011).

Combining theory will software simulators achieves good training results. In this paper, which is an extended work of (Roman et al., 2011), we present an interactive teaching system developed by using the 20-sim modeling and simulation software environment (registered trademark of Controllab Products B.V., Netherlands). This system uses friendly graphical user interfaces and comprises sets of different experiments. First, a set of experiments with 20-sim software package is designed; the final task is to achieve bond graph prototype simulators, which can be combined to obtain simulators for complex bioprocesses. Second, a set of modeling exercises is designed to achieve the mathematical models of these prototype bioprocesses. Every experiment consists in a short tutorial, the body of experiment and several questions and tasks for master students.

These sets of modeling and simulation experiments are grouped into a teaching system, which is implemented at the University of Craiova's Department of Automation, Electronics, and Mechatronics, within the Automation of Complex Systems master program (the Bioengineering course). At the University of Craiova, the curricula and structure of this master program are organized in the electrical-engineering domain, and it follows the Bologna process (see, for example, Martins, Thiriet, Bonnaud, Hoffmann, Robert, Benloch et al., 2008).

The proposed teaching system can be seen as a pre-laboratory setup, in which we performed both an analysis of learning performance of this teaching system, which showed promising results, and assessed the learning technique.

The paper is organized as follows. First, we provide a short introduction in the field of bioprocesses modeling via the bond graph approach. Then, we present an overview of the teaching system. As well, we examine the implementation of some prototype bioprocess simulators in a 20-sim environment and present a simulator for two interconnected bioprocesses. Subsequently, this section deals with a set of modeling exercises, which help the students to construct the mathematical model of prototype bioprocesses, obtained from bond graph simulators. The next section deals with an analysis of the learning performance of proposed teaching system. The analysis is performed by using a group of master students from the bioengineering course. The subsequent section presents several results obtained by using the analysis of variance. Finally, we present some remarks.

Technical background: Bioprocess modeling issues and bond graph approach

In industry, the bioprocesses take place inside biological reactors (bioreactors) in which several biological reactions occur simultaneously in a liquid medium (Dochain, 2008; Petre, 2006). The bioreactors can operate in three modes: continuous, fed-batch, and batch mode. A fed-batch bioreactor (FBB) initially contains a small amount of substrates and micro-organisms and is progressively filled with the influent substrates. When the FBB is full, the content is harvested. A batch bioreactor is filled with the reactant mixture: substrates and micro-organisms and allows for a particular time period for the reactions inside the reactor; after some time the products are removed. In a continuous stirred tank bioreactor (CSTB), the substrates are fed to the bioreactor continuously and an effluent stream is continuously withdrawn such that the culture volume is constant.

The bioprocesses are characterized by several difficult issues such as strongly nonlinearity of kinetics, unavailability of cheap, online instrumentation, etc. Therefore, there are problems concerning the development of a unified modeling approach. However, even if the bioprocess modeling is a difficult task, by using the mass balance of components and obeying some modeling rules, we can obtain a dynamical state-space model (described using nonlinear differential equations) by using either classical modeling methods (Dochain, 2008) or the bond graph methodology (Roman & Selișteanu, 2012; Selișteanu et al., 2010). The bond graph method is a relative new approach for bioprocess modeling, but the results are quite encouraging, from both modeling and simulation points of view. Therefore, it is appropriate to implement teaching systems (especially for master and PhD studies) based on this approach.

The bond graph method uses the effort-flow analogy to describe physical processes. A bond graph consists of subsystems linked together by lines representing power bonds. Each process is described by a pair of variables, effort e and flow f , and their product is the power. The direction of power is depicted by a half arrow. In a dynamic system the effort and the flow varies and, therefore, the power fluctuates in time (Karnopp & Rosenberg, 1974; Thoma, 1975). A specific approach adapted to physical system particularities, the pseudo bond graph, is more suitable for the modeling of chemical and biochemical reactions due to the meaning of effort and flow variables involved whose products do not have the physical dimension of power (Dauphin-Tanguy, 2000; Thoma & Ould Bouamama, 2000). Pseudo bond graphs keep both the unitary characteristic and basic methodology benefits. Two other types of variables are important in describing dynamic systems, and these variables (energy variables) are the generalized momentum p and generalized displacement q (Karnopp & Rosenberg, 1974).

An advantage of bond graph method over other techniques is that models of various systems belonging to different domains can be expressed using a set of only nine elements: inertial elements (I), capacitive elements (C), resistive elements (R), effort sources (Se) and flow sources (Sf), transformer elements (TF) and gyrator elements (GY), effort junctions (J0), and flow junctions (J1). I, C, and R elements are passive elements because they convert the supplied energy into stored or dissipated energy. Se and Sf elements are active elements because they supply power to the system, and TF, GY, 0 and 1-junctions are junction elements that serve to connect I, C, R, Se, and Sf, and constitute the junction structure of bond graph model. The concept of causality is an important bond graph concept. Causality is represented on a model by causal stroke placed perpendicular to the bond at one of its ends, indicating the direction of effort variable. Causal stroke assignment is independent of the power flow direction. This leads to the description of bond graphs in the form of state-space equation. The sources (Se and Sf) have fixed causality, the dissipative element (R) has free causality depending on the causality of the other elements of bond graph, and the storage elements (I, C) have preferential causality (integral causality or derivative causality) but it is always desirable that C and I elements be in integral causality. Transformers, gyrators, and junction elements have constrainedly causality.

One of the simplest biological reactions is the micro-organism growth process (Dochain, 2008; Petre, 2006) with the next reaction scheme:



with S the substrate, X the biomass, and ϕ the reaction rate.

This growth reaction represents in fact a prototype reaction, which can be found in almost every bioprocess. The dynamic of the concentrations of components from scheme (1) can be modeled considering the mass balance of

components. In the next section, we will achieve in 20-sim the bond graph models for two prototype bioprocesses: the first one for a bioprocess taking place into a batch bioreactor and the second one for a CSTB case. We will also develop a bond graph model of a bioprocess carried out in two interconnected bioreactors. These prototype simulators are built by the students in the frame of several experiments described in the following section.

Description of the teaching system

The proposed teaching system implements an interactive manner in experiments' progress. These experiments allow master students to learn about biochemical reactions, reaction schemes, kinetics, types of bioreactors, bioprocess models, bond graph methodology, etc. The exercises allow the students to modify the kinetic parameters, choose the desired type of bioreactor, plot time evolution of some biological variables (biomass, substrates, products), and compare the obtained results.

In order to help the students, the experiments comprise a short tutorial (in electronic form), which must be read on the beginning of an experiment, and a small quiz, useful for checking the students' knowledge after the experiment.

First, a set of experiments with 20-sim software package is designed; the final task is to obtain bond graph prototype simulators, which can be combined in order to obtain simulators for complex bioprocesses:

- Experiment no. 1: Basics of 20-sim modeling and simulation environment
- Experiment no. 2: Bond graph elements in 20-sim—implementation and connectivity
- Experiment no. 3: Prototype batch bioprocess simulator in 20-sim
- Experiment no. 4: Prototype continuous bioprocess simulator in 20-sim
- Experiment no. 5: Two interconnected bioprocesses simulator

Second, a set of modeling exercises is designed via bond graph, which comprises procedures for the achievement of mathematical models:

- Exercise no. 1: Mass balances and accumulation of species in bond graph terms
- Exercise no. 2: Constitutive equations and modeling of reaction rates
- Exercise no. 3: Mathematical model of the prototype batch bioprocess acquired via bond graph approach
- Exercise no. 4: Mathematical model of the prototype continuous bioprocess obtained via bond graph
- Exercise no. 5: Mathematical model of two interconnected bioprocesses

Simulation experiments: Prototype simulators

Twenty-sim is an advanced modeling and simulation program (Controllab Products B.V., Netherlands) that runs under Microsoft Windows. Using 20-sim, the behavior of systems, such as electric, mechanical, hydraulic, and chemical systems or any combination of these systems can be simulated. Twenty-sim fully supports graphical modeling, allowing the design of dynamic systems in an intuitive and user-friendly way. The 20-sim software package can be used by the students for the simulation of bioprocesses modeled by bond graphs. These simulators are organized in libraries that exploit the modularity of the method, which is very useful for the students, who will be able finally to understand and to simulate complex bioprocesses. Next, the core issues of experiments 3, 4 and 5 will be shortly presented.

Prototype simulators for batch and continuous bioprocesses

After they read short tutorials, the students start each experiment that consists in the implementation in 20-sim of bond graph elements (Sf, C, TF, etc.) by using libraries, tools and interactive menus. The prototype bond graph simulators are obtaining starting from the scheme (1) and by taking into consideration the bioprocess type.

In the case of the batch bioreactor (experiment no. 3), there is no influent into or effluent stream from bioreactor, and the biomass X is periodically collected. For the development of bond graph model of this bioprocess, the reaction scheme (1), and the mass transfer through the bioreactor are taken into account. The prototype is obtained and placed into a special implementation window of 20-sim environment (see Fig. 1). The directions of half arrows correspond

to the run of reaction, going out from the substrate S towards biomass X . The mass balances of the components involved in the bioreactor are represented by 0-junctions. Thus, we will have two 0-junctions corresponding to substrate S and biomass X . The accumulation of components S and X in the bioreactor is represented by bonds 1 and 7 and are modeled using capacitive elements C . For the modeling of yield coefficients, TF elements were used (Roman & Selișteanu, 2012). A difficult task is the modeling of reaction kinetics. The form of kinetics is complex, nonlinear and, in many cases, unknown. A general assumption is that a reaction can take place only if all reactants are presented in the bioreactor. Therefore, the reaction rates are necessarily zero whenever the concentration of one of the reactants is zero. In order to model the rate of reaction φ , a modulated two-port R element, denoted $MR_{4,5}$, was used.

For the case of continuous bioprocess (experiment no. 4), the substrate is fed to CSTB continuously, and an effluent stream is continuously withdrawn such that the culture volume is constant. From the reaction scheme (1) and taking into account the mass transfer, using the bond graph modeling procedure, the pseudo bond graph model is achieved and is given in Figure 2. The mass balances of components are represented by two 0-junctions: $0_{1,2,3,4}$ (mass balance for S), and $0_{8,9,10}$ (mass balance for biomass X).

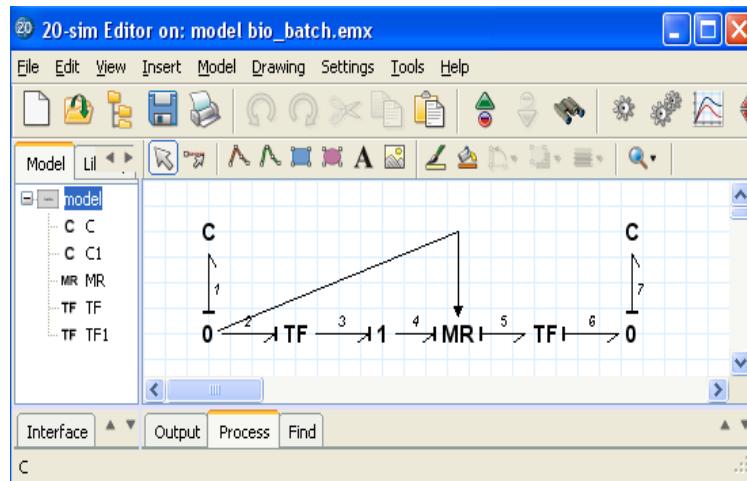


Figure 1. The 20-sim simulator of the batch prototype biotechnological process

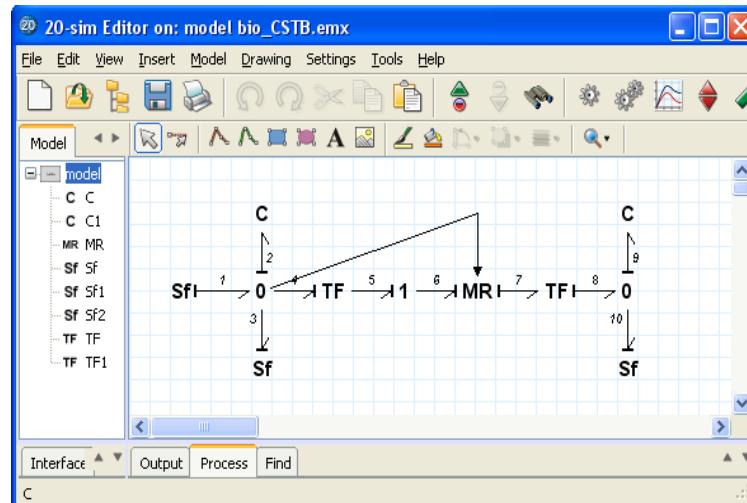


Figure 2. The 20-sim simulator of the continuous prototype biotechnological process

A modulated two-port resistive element $MR_{6,7}$ was used to model the kinetics. Mass flow of the component entering the reaction is modeled using a source flow element SF_1 . The output flows of the reaction components are modeled by using flow sources represented by bonds 3 and 10: SF_3, SF_{10} . The accumulation of substrate and biomass in CSTB is represented by bonds 2 and 9, and they are modeled using capacitive elements C (Roman & Selișteanu, 2012).

After the implementation of bond graphs, the students can use all the facilities of 20-sim environment to add or to remove elements, to run simulations, to modify various parameters, to obtain and to analyze the evolution of biological variables (also, the dynamical state-space models can be obtained according to the procedures described in next subsections).

A simulator for two interconnected bioprocesses

In order to exploit the modularity of bond graph approach, embedded in the 20-sim package, the students can realize more complex simulators by using the prototypes. Next, an example of such simulator is shortly described (experiment no. 5).

The activated sludge bioprocess is an aerobic process of biological wastewater treatment (Dochain, 2008; Roman & Selîsteanu, 2012). In practice, this bioprocess takes place inside CSTBs or in the so-called sequencing batch reactors. Usually, the activated sludge bioprocesses operate in at least two interconnected tanks, as in Figure 3: an aerator in which degradation of pollutants takes place and a sedimentation tank (settler) in which the liquid is clarified. That is, the biomass is separated from the treated wastewater. Part of the settled biomass is fed back to bioreactor, while the surplus biomass is removed. The reaction may be described by a simple autocatalytic aerobic microbial growth that can be represented by the reaction scheme:



where S , X and C are respectively the pollutant, biomass and dissolved oxygen, φ is the reaction rate and k_1 and k_2 are yield coefficients.

In bond graph terms, the mass balances of components involved in the aerator are represented by three 0-junctions: $0_{1,2,3,4}$ (mass balance for S), $0_{6,7,8,9}$ (mass balance for C), and $0_{12,13,14}$ (mass balance for X), and the mass balance of component involved in the settler is given by one 0-junction: $0_{16,17,18}$. The accumulations of species S , C , and X in bioreactor are represented by bonds 3, 8, 14, and 17, they are modeled using capacitive elements C . For the modeling of the reaction rate a two-port modulated R element, $MR_{11,12}$, was used. Mass flows of the components entering the reaction are modeled using flow source elements SF_1 and SF_6 . Also, the mass flow of recycled biomass is modeled using SF_{16} . The transformer elements $TF_{4,5}$, and $TF_{9,10}$ were introduced to model the yield coefficients. The output flows of the components exiting from the reaction are modeled using flow sources elements SF represented by bonds 2, 7, 15, 18. The output flow of component X from Aerator is an input flow for Settler (Roman & Selîsteanu, 2012).

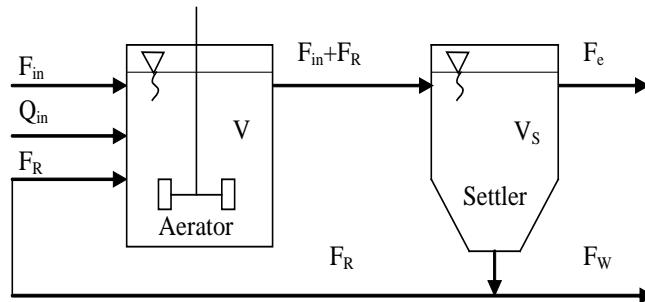


Figure 3. Schema of the activated sludge wastewater treatment bioprocess

The simulator presented in Figure 4 can be implemented by the students either by using the whole bond graph step-by-step procedure or by connecting the corresponding libraries for two continuous prototype processes (as in Fig. 2) interconnected into a cascade structure as in the schema from Figure 3.

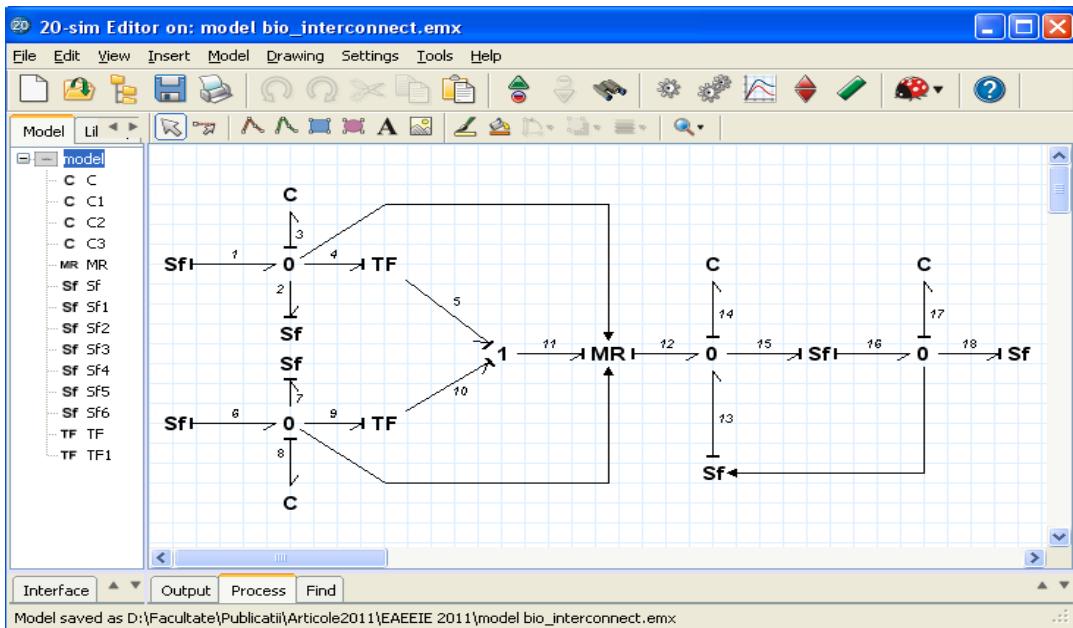


Figure 4. 20-sim simulator of two interconnected bioprocesses

Bond graph models of prototype bioprocesses and modeling exercises

In the second set of exercises, students can use the simulators obtained in the first set to develop dynamical models of bioprocesses. The exercises structure is the same as in the case of 20-sim experiments: short tutorials, main, and questions. The mathematical models are obtained via bond graph by writing the characteristic equations for both elements and junction structure and taking into account the constructive and process characteristics in mathematical terms. All the ingredients required for the design of mathematical models are studied by the students within exercises 1 and 2. After that, in the exercises 3, 4, and 5 the students learn how to build the mathematical models for the prototype bioprocesses and the activated sludge bioprocess (interconnected bioprocesses), respectively. To illustrate the procedure, in the following the main body of exercises 3 and 4 will be shortly described.

The mathematical model of batch bioprocess

By using the next procedure, the students obtain the model of batch bioprocess (in the frame of exercise 3).

(i) The constitutive equations of C-elements are as follows:

$$e_1 = \frac{1}{C_1} q_1 = \frac{1}{C_1} \int (-f_2) dt, \quad e_7 = \frac{1}{C_7} q_7 = \frac{1}{C_7} \int (f_6) dt. \quad (3)$$

(ii) From the constitutive relations of 1-junction (1_{3,4}) and MR element, we obtain: $f_3 = f_4$, f_4 being proportional to the reaction rate φ and V .

(iii) Using the constitutive relations of transformer elements and taking into account the signification of bond graph elements, the dynamical model is obtained:

$$V \frac{dS}{dt} = V \cdot \dot{S}(t) = -\varphi V, \quad V \frac{dX}{dt} = V \cdot \dot{X}(t) = \varphi V. \quad (4)$$

(iv) The model (4) expresses the equations of mass balance for (1). The dynamical behavior of the concentrations can be easily obtained from the system (4):

$$\frac{dS}{dt} = -\varphi, \quad \frac{dX}{dt} = \varphi. \quad (5)$$

Even if this system seems to be a simple one, the kinetics given by reaction rate φ can be very complex. The behavior of mathematical model (in the form (4) or in the form of concentrations' dynamics (5)) is studied by the students, who can use the 20-sim facilities to plot and to analyze the time evolution of main biological variables. As an example, in Figure 5, the profiles of biomass and substrate concentrations are presented as they are obtained from 20-sim. The students can observe the typical behavior of this process: the consumption of substrate associated with biomass production. They can change the form of kinetics, the values of some parameters, and the solver of differential equations (the type of solver can be crucial for stiff systems. See, for example, Figure 6).

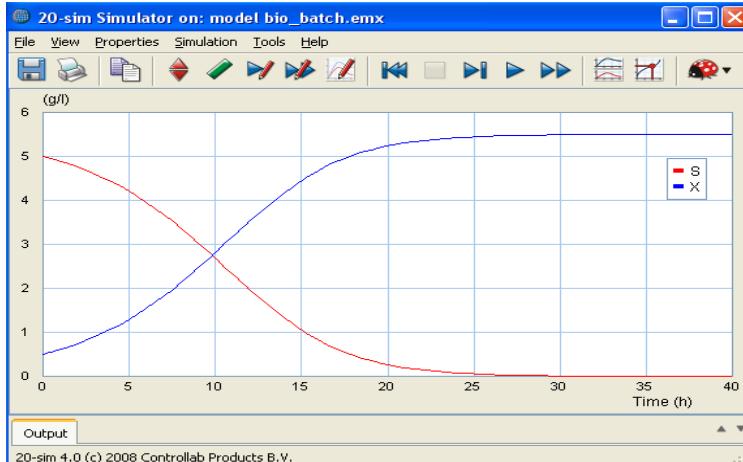


Figure 5. Evolution of concentrations in the case of the batch prototype bioprocess

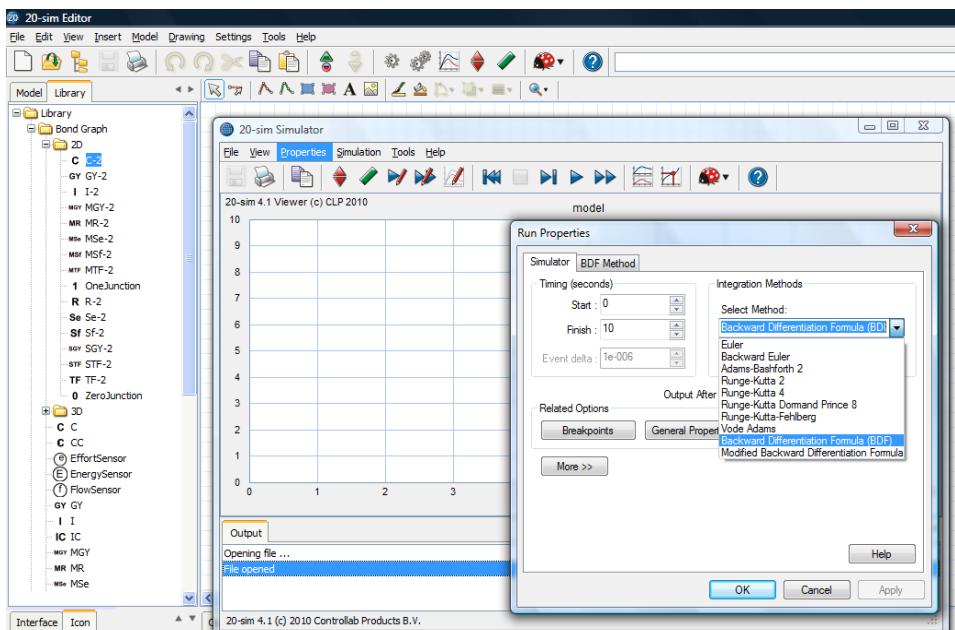


Figure 6. Setting the solver in 20-sim

The mathematical model of continuous bioprocess

In the frame of exercise 4, the students obtain the mathematical model of continuous bioprocess, by using the same modeling procedure as in the batch case.

(i) The accumulations of substrate and biomass represented by bonds 2 and 9, and modeled using capacitive elements C, give the following constitutive relations:

$$e_2 = \frac{1}{C_2} q_2 = \frac{1}{C_2} \int (f_1 - f_3 - f_4) dt, \quad e_9 = \frac{1}{C_9} q_9 = \frac{1}{C_9} \int (f_8 - f_{10}) dt. \quad (6)$$

(ii) The significance of bond graph elements is as follows: e_2 is the substrate concentration S (g/l), e_9 the biomass concentration X (g/l), f_6 is $\varphi \cdot V$, $C_2 = C_9 = V$ (l) is the reactor volume, $Sf_3 = Sf_{10} = F_0$, with F_0 the output flow (l/h), and $f_1 = F_{in}S_{in}$, where F_{in} is the influent substrate flow (l/h) and S_{in} the influent substrate concentration (g/l).

(iii) Therefore, from (6) and taking into account the constitutive relations of junction elements, the dynamical model can be obtained:

$$V \cdot \frac{dS}{dt} = F_{in}S_{in} - F_0S - \varphi V, \quad V \cdot \frac{dX}{dt} = -F_0X + \varphi V. \quad (7)$$

(iv) The model (7) expresses the equations of mass balance for (1). The dynamical behavior of concentrations can be easily obtained from (7). From the equation of continuity $F_{in} = F_0$ and using the so-called dilution rate $D = F_{in}/V = 1/t_r$, where t_r is the medium residence time, equations (7) become:

$$\frac{dS}{dt} = DS_{in} - DS - \varphi, \quad \frac{dX}{dt} = -DX + \varphi. \quad (8)$$

The behavior of mathematical model (in the form [7] or in the form of concentrations' dynamics [8]) is studied by the students. By using the 20-sim capabilities, the evolution of main biological variables can be analyzed. As an example, in Figure 7 the profiles of biomass and substrate concentrations are presented as they are obtained from 20-sim. The students can change the form of kinetics, the values of some biological and simulation parameters, etc.

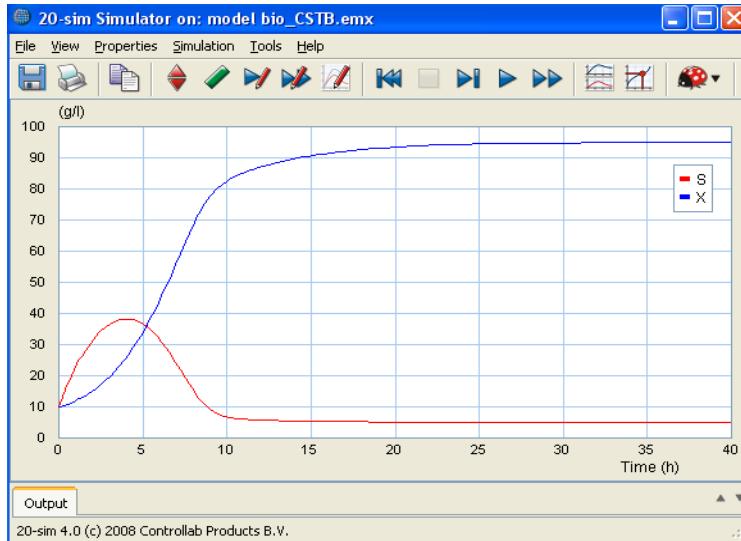


Figure 7. Time profiles of concentrations: The continuous prototype bioprocess

Analysis of learning performance

Participants and experimental condition

To evaluate the impact of the teaching system, we compared the learning performance by using two learning conditions: (i) a traditional theoretical set of lessons, which includes classical text descriptions, static images,

mathematical issues, etc., and (ii) the proposed computer-based interactive teaching system that covers the same learning content. The so-called null hypothesis would be that the different learning conditions do not imply different learning performance (Holzinger et al., 2009). The comparison was achieved with a procedure based on pre-tests and post-tests. The learning performance was measured using a multiple-choice test. To accomplish this study, 44 master students from Automation of Complex Systems master program (second year of study, 2010–2011, bioengineering) at the University of Craiova were used. Thirty-one men and thirteen women participated.

To assess knowledge and learning performance, a pre-test/post-test scenario was used, with a multiple-choice knowledge test, including twenty questions about the modeling of bioprocesses. Each of these questions represented a significant aspect of the discipline and demanded a systematic understanding to ensure choosing the correct answer. Every question included five possible answers; checking none, one, or more alternatives could be correct. The minimum score was 0 and the maximum score was 20. The pre-test and post-test used the same questions, but presented in different order. Because the complexity of the full teaching system, the tests focused only on a pair of experiment/modeling exercise. For example, one of these pairs contains Experiment 3: “Prototype batch bioprocess simulator in 20-sim” and Exercise 3: “Mathematical model of the prototype batch bioprocess acquired via bond graph.” These tests can be seen as a kind of pre-laboratory training, useful for the students in order to deal more easily with the real equipment, such as laboratory or pilot bioreactors (in our case, the bioengineering laboratory is equipped with a BIORSTAT Sartorius bioreactor [Nisipeanu, Bunciu, & Stănică, 2011]).

Procedure

The students were requested to provide biographical data and to complete the pre-tests to assess the prior knowledge in bioprocess modeling field. Then, the students were randomly divided into two groups, one denoted T (for the first learning condition, traditional) and one by C (the second learning condition, computer-based). Each group consists of 22 students (group T: 17 men and 5 women, and group C: 14 men and 8 women). Group T was provided with hard copies of the lessons set, and the participants from group C used the PCs from the classroom, with full access to the interactive teaching system. Both groups were given the same amount of time to learn. After a short pause, the students were asked to complete the post-tests. The entire procedure took about 110 min, which is a standard time period.

The use of computer-based simulators as pre-laboratory training is in accordance with cognitive load theory and constructivism (Kirschner, 2001; Kirschner, 2002; Limniou et al, 2009; Shiland, 1999). The entire procedure implies that the master students: (a) do not receive a massive amount of information at the same time, (b) have enough time to handle the useful information, (c) construct their new information based on the previous knowledge, (d) confirm or reject their initial hypothesis, and (e) think on bond graph method related to biochemical phenomena.

Additionally, we distributed some questionnaires to the entire group of 44 students, providing a number of statements about traditional/computer-based teaching approach, their interest in bioengineering, understanding of theoretical and practical problems previously studied (pre-requirements), their interest in real/simulated experiments before and after bioengineering course and so on.

Results and discussion

First, the results concerning the pre-tests are presented in Table 1. The mean scores and standard deviations were calculated by using simple routines provided in Matlab (The MathWorks, Inc., USA). As was expected, no significant differences were found between the two groups (T and C). In group T, the mean score in pre-test was $M = 11.63$, and the standard deviation $SD = 1.43$. In group C, the results were: $M = 11.95$, $SD = 1.64$. As reported in various references, the gender issues related to learning conditions and learning performance are interesting (Caspi, Chajut, & Saporta, 2008; Franzoni & Assar, 2009). The results obtained in the frame of our pre-test show that the women from both T and C groups scored better than the men from the two groups. See Table 1.

However, the results obtained at the post-test were quite different with respect to pre-test (Table 2). For the group T, the mean score was $M = 15.13$, $SD = 1.28$, while for the group C we have $M = 16.77$, $SD = 1.50$. As expected, the results obtained by both groups are higher than in pre-tests. It is interesting that the results obtained by the men from

group C are much better than the results obtained by the men from group T, which can mean that male students are more comfortable with computer-based training than they are with the traditional theoretical approach. As a conclusion, we can see that in the post-test, the group C resulted in a higher mean score than group T. Also, an interesting interaction of learning condition and gender was found for the post-tests.

Table 1. Results obtained in pre-test related to learning conditions and gender

Test type	Group	Mean score M	Standard deviation SD
Pre-test	T	11.6364	1.4325
	C	11.9545	1.6469
	T – women	12.8000	1.9235
	T – men	11.2941	1.1048
	C – women	12.1250	1.2464
	C – men	11.8571	1.8752

Table 2. Results obtained in post-test related to learning conditions and gender

Test type	Group	Mean score M	Standard deviation SD
Post-test	T	15.1364	1.2834
	C	16.7727	1.5097
	T – women	16.2000	1.4832
	T – men	14.8235	1.0744
	C – women	16.7500	1.3887
	C – men	16.7857	1.6257

In order to achieve a more appropriate statistical analysis, we apply the univariate analysis of variance (ANOVA), by using Statistics Toolbox, provided by Matlab. First, we computed the learning performance (i.e., the score in post-test compared with the score in pre-test), for both groups T and C. The results are presented in Figures 8 and 9, where the standard one-way ANOVA tables are given. The columns represent: SS (the sums of squares), df (degrees of freedom), MS (mean squares: SS/df), F statistic, and prob>F (the p value). ANOVA revealed a significant effect for both groups, ($F = 72.85$, $p \approx 0$, and $F = 102.32$, $p \approx 0$), as expected.

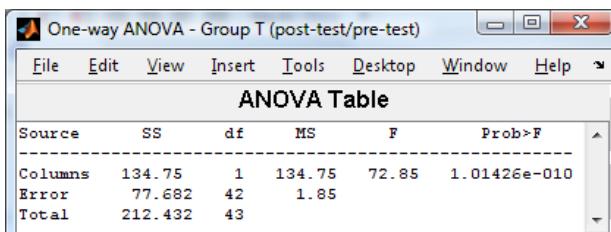


Figure 8. Statistics for group T (post-test/pre-test)

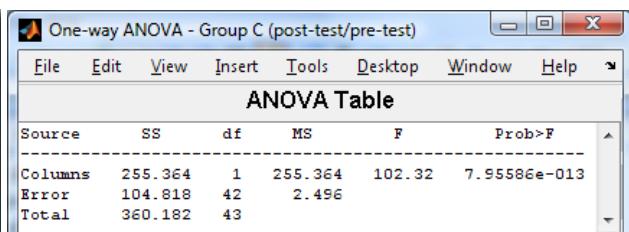


Figure 9. Statistics for group C (post-test/pre-test)

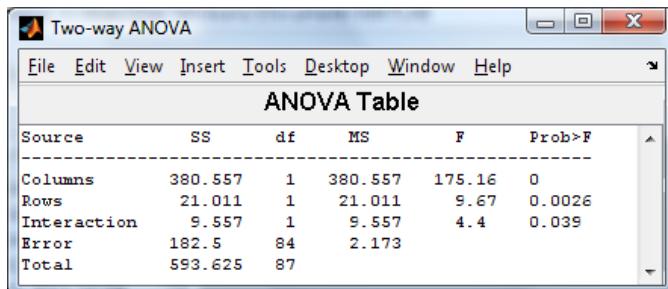


Figure 10. Two-way ANOVA results (Matlab)

Tests of Within-Subjects Contrasts—SPSS							
Measure:	MEASURE_1		Type III Sum of Squares	df	Mean Square	F	Sig.
Learning	Linear		21,011	1	21,011	5,238	,033
Error (Learning)	Linear		84,239	21	4,011		
TestType	Linear		380,557	1	380,557	1403,731	,000
Error (TestType)	Linear		5,693	21	,271		
Learning * TestType	Linear	Linear	9,557	1	9,557	74,519	,000
Error (Learning * TestType)	Linear	Linear	2,693	21	,128		

Figure 11. Two-way ANOVA results: Tests of within-subjects contrasts (SPSS)

	Test Value					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
T - pre	38,102	21	,000	11,63636	11,0012	12,2715
T - post	55,317	21	,000	15,13636	14,5673	15,7054
C - pre	34,048	21	,000	11,95455	11,2244	12,6847
C - post	52,110	21	,000	16,77273	16,1034	17,4421

Figure 12. Confidence intervals: results obtained with SPSS

However, the repeated single factor analysis of variance is not quite suitable for this experiment because this kind of analysis can miss possible interaction effects. Because here we have a repeated measurements design, repeated measurements are taken of the same individuals, and it is necessary to establish a within-subject effect. More precisely, averaging over all individuals as if they were independent may give misleading results. Therefore, a two-way ANOVA was performed by using the Matlab environment. The results are plotted in Figure 10. The purpose of two-way ANOVA is to find out whether data from several groups have a common mean.

One-way ANOVA and two-way ANOVA differ in that the groups in two-way ANOVA have two categories of defining characteristics instead of one. In Figure 10, the columns in the source represent the effects related to the pre-test and post-test, and the rows represents the effects related to the learning condition (T and C groups). As can be observed, the p-value for the pre-test/post-test effect is zero (to four decimal places). This is a strong indication that the scores obtained by the students differ from the pre-test to the post-test. The p-value for the learning condition effect is 0.0026, which is also highly significant. This indicates that the C group is out-performing the T group in the obtained scores. There does not appear to be strong interaction between learning condition and test type.

In order to compare these results with another statistical computing environment, we also used the SPSS package (general linear model—repeated measurements). The tests of within-subjects contrasts are given in Figure 11. As you can see the results are similar. The confidence intervals computed with SPSS are presented in Figure 12.

The ANOVA can be performed if the homoscedasticity and normality of the data is checked. The data normality was tested by using an adaptation of the Kolmogorov-Smirnov test—more precisely, the Lilliefors test—provided by the Matlab. Also, the homogeneity of variance was checked by using the Breusch-Pagan test.

It is interesting to check whether the effect of learning method treatment depends on gender. This approach calls for a two-way factorial with repeated measures in a mixed model. However, this kind of analysis is more complex for our particular experiment, because the data concerning the gender are unbalanced for the considered groups. Therefore, the analysis for gender issues is based only on the descriptive statistics presented in Tables 1 and 2.

Concerning the assessment of learning technique, the results obtained from the questionnaires completed by the students are presented in Table 3. The highest interest is in real bioreactor experiments, but the difference between

real experiments and simulators is quite small. Once the new methods of bioengineering training were used, the students' results were better, both during the semester and at the exam.

Table 3. Assessment of learning technique and interest in bioengineering

	Before bioengineering course and experiments			After bioengineering course and experiments		
	High	Medium	Low	High	Medium	Low
Interest in bioengineering	39%	54%	7%	74%	22%	4%
Understanding of theoretical problems previously studied	35%	44%	21%	73%	20%	7%
Understanding of practical problems previously studied	29%	40%	31%	70%	24%	6%
Interest in traditional theoretical methods	28%	53%	19%	32%	54%	14%
Interest in 20-sim simulators	40%	43%	17%	74%	21%	5%
Interest in real bioprocess experiments	71%	23%	6%	84%	14%	2%

Conclusions

Nowadays, the advances in information technology provide new means for improvement of learning technologies. The presented computer-based teaching system allows an improvement in bioengineering education and training. The experiments touch on the important problems for bioprocesses. The system has didactic properties such as modularity of the package, friendly graphical user interfaces and so on.

This study confirmed the results of previous research on exploratory learning using interactive simulations. Still, it is necessary to offer additional assistance on the correct use of a simulation before beginning to learn with the computer-based teaching system. In future research, the evaluation of proposed teaching tool can be further improved. The implementation of the proposed bioengineering teaching system resulted in significantly higher learning performance than traditional learning conditions. The results pointed out that, with some exceptions, these effects are independent of individual learning strategies but not necessarily of gender.

As the use of real bioreactors is expensive and even dangerous, the exploitation of software simulators constitutes a good alternative. The interactive system helps master students to understand different bioprocess modeling and simulation issues. The package can be extended with new experiments, and can be seen as a pre-laboratory training system.

Acknowledgments

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Designing and implementing a personalized remedial learning system for enhancing the programming learning

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ABSTRACT

In recent years, the demand for computer programming professionals has increased rapidly. These computer engineers not only play a key role in the national development of the computing and software industries, they also have a significant influence on the broader national knowledge industry. Therefore, one of the objectives of information education in Taiwan is to cultivate elite talents specializing in computer programming so as to improve Taiwan's national competitiveness. Although programming is a major fundamental subject for students in information sciences, learning to master programming languages is far from easy. Accordingly, this study aimed to establish a personalized remedial learning system to assist learners in remedial learning after an online assessment. The proposed system adopted the fuzzy logic theory to construct an appropriate learning path based on the learners' misconceptions found in a preceding quiz. With concepts of each course constructed in a learning path, the proposed system will select the most suitable remedial materials for a learner in terms of learner preference to facilitate more efficient remedial learning. Finally, the system, proven by several conducted experiments, can offer a comprehensive and stable remedial learning environment for any e-learning programs. The analysis of learners' achievements confirmed that the method of this study has achieved the effects of remedial learning and adaptive learning.

Keywords

Remedial learning, Intelligent tutoring systems, Fuzzy logic, Learning style

Introduction

Programming is an important fundamental skill in the fields of information science, engineering, management and education. It is also a basic prerequisite required of students majoring in the disciplines of natural sciences, mathematics, and engineering. Foreman (1988) notes that programming contains knowledge and skills required for the development of computer expertise and is also a key prerequisite for a comprehensive understanding of computer science. Although programming is a major fundamental subject for students in information sciences, learning to master programming languages is far from easy. Winslow (1996) observes that it takes more than ten years of training and experience for a beginning student to become a well-versed programmer. At present, programming languages are taught primarily via a teacher-centered approach, which fails to allow the instructor to identify problems encountered by individual students. A learner who cannot solve problems instantly in the course of learning gradually tends to lose interest in learning. Hence, it is important to find ways of teaching students to solve their own problems in learning a programming language.

In recent years, the learning environment has been changing due to the rapid development of the Internet and information technology. Zhang et al. (2004) note that the Internet and multimedia technologies are reshaping the way knowledge is delivered and that e-learning is becoming a real alternative to traditional classroom learning. The focus of learning has shifted over the past 20 years from an emphasis on traditional classroom learning and paper examinations to greater focus on e-learning and assessment environments, i.e., learning conducted or supported over the Internet. The Internet allows learners to access their learning tools easily at any time and at any place. In addition, e-learning can be used to support teaching in the classroom and also can offer a virtual classroom in which learners can complete their course work. Although several studies have suggested the benefits of developing an e-learning system for instruction, these systems still pose some problems for learners, including learner control, disorientation and cognitive overload (Ausubel, 1968; Conklin, 1987; Alomyan, 2004).

Learner Control: Individual learners are able to study independently on the Internet at home or in other places without instructors. Online learning enables a learner to download the learning materials related to a concept that he/she has to learn and to choose or arrange the learning sequence from the collected learning materials. However, some of the learning materials can be too difficult for students who have little prior knowledge or background knowledge. Ausubel (1968) notes that prior knowledge is the most important factor determining the achievements of learners during the learning process. As a result, learners without sufficient prior knowledge may not comprehend the concepts that they need to learn and enhance their learning performance (Gagne & Brown, 1961). **Disorientation:** With a faster, more accessible Internet, people these days tend to search and learn from the Internet for fragmented knowledge. Although they are versatile, these web sites generally follow no standards for content organization and presentation order. When these are posted on the Internet, collected and indexed by robots using keywords, and returned by powerful search engines, a vast number of homepages or learning objects is returned directly to a learner in no particular order. Chiou et al. (2010) note that all the learning materials in a curriculum are sequenced by hyper links in most web-based learning systems, but there is no concrete sequence without navigation support. Even if certain topics are related, a learner who may have little or no experience in the specific domain of study must still move forward and backward among the materials and figure out which page to read first. Thus, an effective way of organizing collected material into systematic and sequenced learning contents would be a great help for learners who are new to a specific domain. **Cognitive Overload:** The most popular tools today for seeking knowledge are the Google or Yahoo keywords-based search engines on the Internet. Learners can easily obtain the information or learning materials they need, but they still have to read and organize those learning materials by themselves. For this reason, learners have to spend a lot of time in browsing and sorting through the information they find. Tsai (2009) notes that the abundance of online information resource could result in anxiety on the part of individual learners over the vast amount of online information. As a result, it is an important challenge to offer the most appropriate learning materials directly to each learner in the online learning environment.

Therefore, in this paper, we have proposed a Moodle-based Personalized Remedial Learning System (MPRLS) that uses fuzzy logic theory to construct an appropriate learning path based on the learners' misconceptions and then to recommend the most suitable materials from the Internet according to the learners' own preferences, to facilitate more efficient remedial learning for the learners.

Related works

Adaptive learning environment

In traditional hypermedia education systems, the “one-size-fits-all” approach causes confusion among learners. For example, those traditional education systems provide the same content and the same set of links to all learners. Consequently, the materials may not suit the learners' needs in the learning process (Qu, Wang, & Zhong, 2009). Over the last decade, many e-learning systems have been developed to assist learners in a variety of areas because e-learning systems can be addressed to a maximum number of participants with a maximum diversity of learning style, needs, and preferences (Beldagli & Adiguzel, 2010). There are many advantages of e-learning activities. One of them is the importance of “Adaptive Learning”. The learning content can be adapted to each learner's strengths and weaknesses to achieve the most efficient learning experience. That is, by assessing a learner's initial knowledge of a topic and preferred learning style, an e-learning system can decide what learning content should be offered next (Papanikolaou et al., 2002). By offering adaptive content or learning paths, the system enables the learners to study more quickly and more effectively (Bra, Brusilovsky, & Houben, 1999).

Many researchers have developed adaptive e-learning methodologies and platforms. Phobun & Vicheanpanya (2010) proposed an adaptive intelligent tutoring system that combines adaptive hypermedia with an intelligent tutoring system to improving learners' learning achievements. Romero, Ventura, Zafra, & Bra (2009) proposed a web-based adaptive educational system to suggest personalized links based on other students with similar characteristics, using different recommendation techniques and web mining tools. Carchiolo, Longheu, & Malgeri (2002) designed a prototype of a web-based learning environment to provide learners with a dynamically adaptive formative path according to their needs and capabilities. Chen (2008) developed a genetic-based personalized e-learning system to provide a learning path based on the difficulty of the courseware and the results of pre-tests for individual learners.

Learning style

The concept of learning style can be traced back to the 1970s and has been widely acknowledged in recent years. It is assumed that each learner's personal learning style can enable him/her to achieve optimal learning effectiveness and interest. Though most people learn through a combination of the three primary styles (auditory, visual, and kinesthetic), everyone has a preferred style that works the best for him/her. A learning style is an individual repertoire of preferred learning methods and strategies that are used during the learning process (Beldagli & Adiguzel, 2010).

With the extensive application of adaptive teaching to the digital education in recent years, learning style has drawn a great deal of academic attention, and much relevant research has been published. Keefe (1979) holds that learning style plays a crucial role in learning and enables an instructor to provide an individualized education. An analysis of learning style helps an instructor to understand messages delivered by a learner in response to an external learning situation. Thus, an instructor can provide learners with proper instruction to solve their learning difficulties. Dunn, Dunn, & Perrin (1994) propose that learners will improve their learning performance and attitude when the instruction and resources are compatible with their learning style. Accordingly, helping students develop their learning style and providing proper instruction and teaching materials will improve their learning effectiveness. This paper employs Kolb's theory to evaluate the learning style of each student (Kolb, 1984). Kolb views a human learning activity as a series of processes in which a human being successively acquires a practical concrete experience, form an abstract concept by reflective observation, transform the abstract concept into a general one, apply the general concept to a new situation for verification, and develop a new individual experience and a distinctive learning style.

The methodology and the system architecture

In this section, several approaches are used to automatically construct a suitable learning path and recommend suitable remedial materials out of a collection of learning materials according to the learners' preferences.

System modules depiction

The architecture of the proposed system is shown in Figure 1. The four major components of the system are the *Learner Testing Component*, *Inference Module*, *Learning Style Analysis* and *Learning Path and Remedial Materials Recommender*.

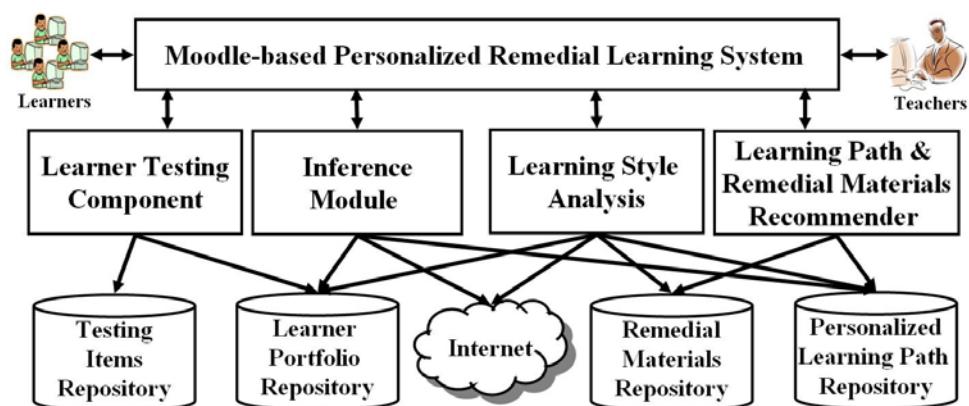


Figure 1. The architecture of the Moodle-based personalized remedial learning system

At first, teachers are able to edit the learning style questionnaire and test items in the testing items repository via the MPRLS interface. Then, a learner logs into the proposed system for learning and testing. For the beginner, the proposed system will provide the learning style questionnaire for the learners to analyze their own learning style. After the learners complete the entire testing process, the proposed system analyzes each of the learners' examination results to identify their misconceptions, and stores them in the learner portfolio repository. The *Inference Module*

uses fuzzy logic to infer an appropriate learning path for each of the learners' misconceptions based on the collected learning material from the Internet. Based on the generated learning path, the *Learning Style Analysis* then retrieves the related remedial materials that satisfy the learners' preferences from the Internet and stores them in the remedial materials repository. Finally, the purpose of the *Learning Path and Remedial Materials Recommender* is to recommend both the most suitable learning paths and the most suitable learning materials for each course unit based on the learners' misconceptions and preferences to facilitate more efficient learning for all the learners. The details of the system components are described as follows.

Learning testing component

Two major roles are played by the Learner Testing Component. The first role is to support an editor interface that enables instructors to edit the learning style questionnaire and test items. The second role is to analyze the results after the learners complete the entire testing process. Moreover, after the learners complete the entire testing process, the system analyzes the testing results and stores them in the learner portfolio repository. Figure 2 shows the interface of the assisted instruction system on Moodle. The teachers and learners can register for accounts and passwords by hitting the “登入” hyperlink denoted by ①. After they fill in the relevant form with their personal information, the system automatically sends them an e-mail to confirm their registration. As shown in ②, the teachers can design a curriculum that includes the course description, the goals of the course, the test sheets, etc.



Figure 2. The interface of the assisted instruction system

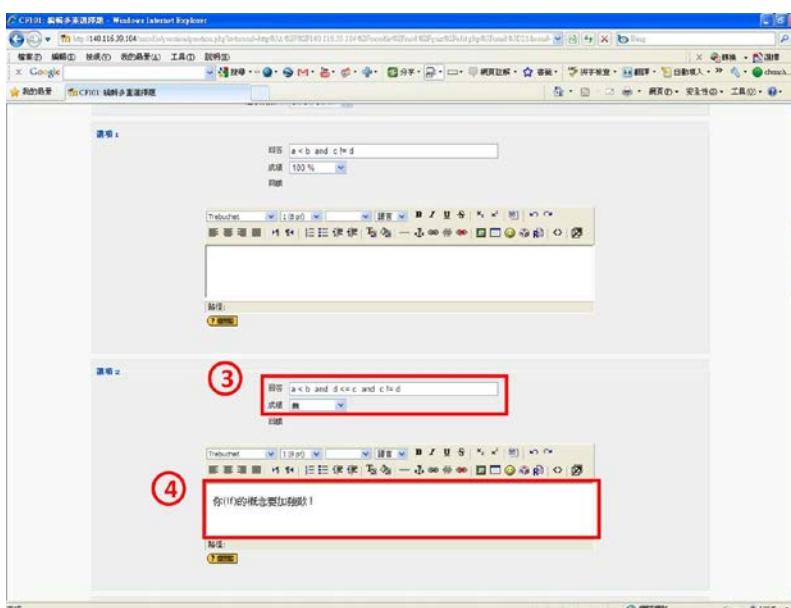


Figure 3. The edit interface of test items and feedback for teachers

Figure 3 shows the test items and feedback edit interface. In ③, teachers can edit the test items, the answers and the score. Furthermore, to help learners to identify which concepts require remedial learning, the teachers edit the feedback message for each test item in ④. After the testing process, the teachers can use the interface to assess learners' learning performances and store the results into the learner portfolio repository. The proposed system also analyzes the testing results to identify the students' misconceptions according to the feedback messages.

Inference module

The concept of fuzzy logic appeared following the definition of fuzzy sets by Zadeh in 1965. The aim of fuzzy logic is to emulate the human reasoning process and to help us make decisions based on imprecise data (Hajek, 2006). The purpose of the Inference Module is to construct a suitable learning path based on the learner's testing results. To identify a suitable learning path according to the learner's misconceptions, we need to consider the degree of relation between two different concepts; if the degree is high, the concept should be recommended as the next one for learning. Hence, the fuzzy inference mechanism computes the relationship degree of each concept pair out of all the candidate concept units by the means of four steps, the *Input*, the *Fuzzifier*, the *Inference* and the *Defuzzifier* (Zimmermann, 1991).

Step 1: The input phase

The first step is the formation of Input Linguistic Features, which involves computing the three feature values for each concept pair for processing in the next step of the algorithm. The three feature values include the *Concepts' Extension* (*CsE*), the *Concepts' Similarity* (*CsS*) and the *Concepts' Coherence* (*CsC*).

- **Concepts' Extension:** In the field of text mining, one of the basic ideas is that two terms that appear together frequently in the same text are likely correlated or connected. In this study, if a document with a theme of Concept C_a has frequent references to Concept C_b , it is implied that the two concepts are correlated and that Concept C_b is likely to be a prerequisite of Concept C_a . The reason is that any learning is gradually progressive. The concepts frequently appearing in the learning process tend to be those already learned. Accordingly, we adopt a probability model to explore the correlation between the two concepts through a large quantity of online materials. The *CsE* is shown in formula 1.

$$CsE_{A,B} = \frac{Concept_A \cap Concept_B}{Concept_A \cup Concept_B} = \frac{N_{A,B}}{N_A + N_B - N_{A,B}} \quad (1)$$

where N_A represents the number of search results obtained by querying the candidate concept A on the Google search engine, N_B denotes the number of search results by querying the candidate concept B , and $N_{A,B}$ represents the number of search results containing both candidate concept A and candidate concept B .

- **Concepts' Similarity:** The *CsS* represents the similarity between a given article and the articles already read by a learner. If the value is high, then presumably the topic of the article is already familiar to the learner, and it should be easy for the learner to comprehend the article. In other words, a concept with a content that is highly correlated to what a learner has already been learning should be more likely to be recommended to the learner. Therefore, a cosine measure is employed to compute the similarity weighting between each article pair. Finally, to calculate the similarity of each concept pair, we sum the similarity weightings of each article for each individual candidate concept by using formula 2.

$$CsS_{A,B} = \frac{\sum_{i=1}^x \sum_{j=1}^y SW_{A_i, B_j}}{x \times y} \quad (2)$$

where $CsS_{A,B}$ denotes the similarity between candidate concept A and candidate concept B , and the parameters x and y are constant, where the number of articles chosen out of the search results is set to 10. $SW_{i,j}$ represents the similarity weighting between article i and article j , again with values lying between 0 and 1. The higher the value of $SW_{i,j}$, the closer the similarity.

- **Concepts' Coherence:** When recommending a course to a learner with a sequence of learning objects, the continuity between the contents of these articles is very important for the learner to successfully understand the course. To automatically construct suitable learning paths with better content continuity, coherences between articles have must be identified, which are called the coherence weightings and computed from the generated concept lattice derived in (Hsieh & Wang, 2010). After that, we sum up the coherence weights of each article for individual candidate concept, as in the CsC , by using formula 3.

$$CsC_{A,B} = \frac{\sum_{p=1}^x \sum_{q=1}^y CW_{A_p, B_q}}{x \times y} \quad (3)$$

where $CW_{p,q}$ is the coherence between articles p and q , $CsC_{A,B}$ represents the coherence between candidate concept A and candidate concept B , and the constants x and y , which denote the number of articles selected out of the search results, are set to 10.

Step 2: The fuzzifier phase

This step computes the degree of membership for the linguistic feature values, i.e., the CsE , CsS and CsC of each concept pair. We use both the trapezoidal membership function and the triangular membership function for each linguistic term. Each fuzzy input variable has three linguistic terms, namely, *Low*, *Medium*, and *High*, each of which has a membership function to represent its degree of membership.

Step 3: The inference phase

The third step is the inference step, which contains the *AND* operation and the *OR* operation. It employs a total of 3^3 or 27 rules, which are based on the possible combinations of the three linguistic terms and the three fuzzy input variables. All of the fuzzy inference rules are defined by the domain expert's prior knowledge. The output variable of each rule is defined as a fuzzy output variable DCR , the *Degree of Concept Relationship*, which includes DCR_Low , DCR_Medium and DCR_High as its three associated linguistic terms. The final three values of the output variable DCR represent the *Degree of Concept Relationship* between two different concept units; the candidate concept unit with the highest value should be recommended next to the learner.

Step 4: The defuzzifier phase

This final step involves defuzzification. In this dissertation, we use the discrete *center of area (COA)* computation method, as shown in formula 4. The final step is to perform the defuzzification process to get the DCR of the concept pair, where L is the number of quantization levels, such that the finer the level, the more precise the result and the higher the computational complexity.

$$DCR = \frac{\sum_{i=1}^L \sum_{d=1}^D \mu_d(y_i) \times y_i}{\sum_{i=1}^L \sum_{d=1}^D \mu_d(y_i)} \quad (4)$$

In formula 4, y_i is the i -th quantization value, and D is the number of linguistic terms of DCR . $\mu_d(y_i)$ is the degree of membership of y_i in d . The result of the computation is the degree of relationship between two different concept units based on a quantization value between 0 and 1. The larger the value, the more likely a suitable concept is recommended next to the learner. All of the values of the concept relationship for each concept pair are calculated by formula 4 and are arranged in a *Degree of Concept Relationship Matrix*, the $DCRM$, as in formula 5 (Hsieh & Wang, 2010).

$$DCRM = \begin{bmatrix} dcr_{1,1} & dcr_{1,2} & \cdots & dcr_{1,v} \\ dcr_{2,1} & dcr_{2,2} & \cdots & dcr_{2,v} \\ \vdots & \vdots & \vdots & \vdots \\ dcr_{u,1} & dcr_{u,2} & \cdots & dcr_{u,v} \end{bmatrix} \quad (5)$$

For an example of the detail process of inference module, assume a learner's misconception is the “*For-statements*” in the C++ programming language. By using the Apriori algorithm, two candidate concepts, “*For-statements*” and “*Data types*” are identified (Hsieh & Wang, 2010). The *input phase* then computes the three feature values include the *CsE*, *CsS* and *CsC*, respectively. After that, the *fuzzifier phase* computes the degree of membership for the linguistic feature values. Suppose candidate concept “*For-statements*” and candidate concept “*Data types*” have the following degrees of membership of the linguistic terms low, medium, and high for the three fuzzy variables: {(0,0.4,0.6), (0.3,0.7,0), (0,0.55,0.45)}, as shown in Table 1.

Table 1. Membership degree of linguistic terms of each fuzzy variable.

				Linguistic terms			
				Low	Medium	High	
				<i>CsE</i>	0	0.4	0.6
Fuzzy Variables	<i>CsS</i>		0.3		0.7	0	
	<i>CsC</i>		0		0.55	0.45	

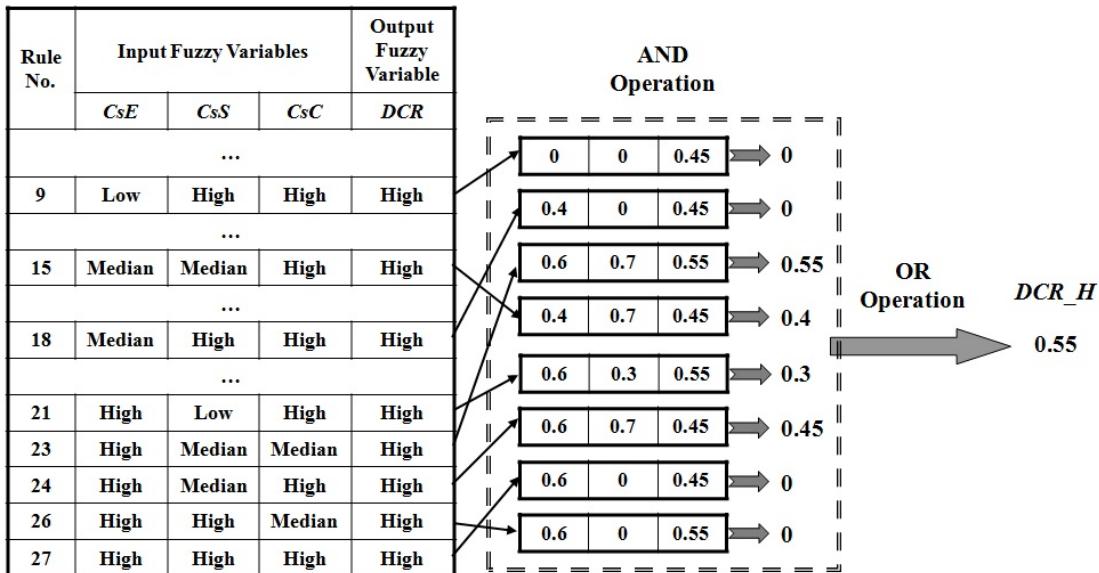


Figure 4. Calculation of the fuzzy rule inference.

Suppose there are eight related rules. The degrees of membership of their linguistic term *DCRs* are the *Hs* in the last column of the left box in Figure 4. The *AND* operation operates on these rules, taking the minimum value of the degrees of membership of fuzzy variables in each rule, and in Figure 4, the values farthest to the right in the middle box comprise the output. The *OR* operation then takes the maximum value of the results of the *AND* operation, and in Figure 4, the value farthest to the right is the final result of *DCR_H* of *DCR*, which is 0.55. The final values of the other linguistic terms are computed in the same way. Finally, the *defuzzifier phase* computes the relationship degree of each concept pair and the results are in Table 2.

Table 2. An example of the degree of concept relationship matrix.

		For-statements	Data types
For-statements			0.66
Data types		0.11	

Learning style analysis

To analyze learners' learning styles, this study adopted the Learning Style Inventory as modified by Kolb (Kolb, 1984). It is composed of 12 questions describing the four learning stages and serves to measure four types of learning styles, namely, Diverger, Accommodator, Assimilator and Converger. The details of four types of learning styles can be described as follows:

- **Converger:** Those with highest scores in Abstract Conceptualization and Active Experimentation. The greatest strength of a person with a converging learning style is the practical application of ideas. They do best in situations where there is a single correct answer or solution to a problem and they can focus on specific problems or situations. They would rather deal with technical tasks than social and interpersonal issues.
- **Diverger:** Those with highest scores in Concrete Experience and Reflective Observation. The greatest strength of a person with this style is creativity and imaginative ability. They are sensitive. They excel in the ability to view concrete situations from many perspectives and generate many ideas, as in a brain-storming session.
- **Assimilator:** Those with highest scores in Abstract Conceptualization and Reflective Observation. The greatest strength of a person with this style is the ability to understand and create theories. They excel in inductive reasoning and in synthesizing various ideas and observations into an integrated whole.
- **Accommodator:** Those with highest scores in Concrete Experience and Active Experimentation. The greatest strength of people with an accommodating learning style is in constructing plans and experiments and involving themselves in new experiences. They often solve problems and learn by trial-and-error, relying heavily on other people for information.

According to the distinctive characteristics shown by each of the four types of learning style, this study used its system to search online for suitable remedial materials for each type of learners. It has found four sources of remedial materials: Teaching Website, Comprehensive Website, Discussion Website and Applied Website, which can be described respectively as follows:

- **Teaching Website:** A teaching website contains teaching materials focused on instruction in basic syntax and concepts. It is suitable for learners emphasizing theoretical logic with the learning style of Assimilators. The system acquired a portion of the contents of C++ Programming at the website of "Liang-Ge-Ge Learning Notebook" (Lin Hsin-Liang, 2003) for students to learn their desired concepts. This website, constructed with an abundance of information, is recognized in Taiwan as a high-quality teaching website for computer programming.
- **Comprehensive Website:** A comprehensive website contains a variety of teaching materials concerning computer programming and reference documents for relevant techniques. It is suitable for learners who prefer to work on technical problems with the learning style of Convergers. The system has found the website of the MSDN Library for students to learn their desired concepts. The "MSDN Library" website, designed by Microsoft, offers a full spectrum of programming information, including the development of web services, reference documentation, technical articles, software development kits and sample code.
- **Discussion Website:** A discussion website contains discussions on experience sharing and program code and is suitable for learners who prefer to learn actively by brainstorming in an open learning activity with the style of Divergers. Accordingly, the system has found the articles on C/C++ programming on the discussion section of the website of "Study-Area" for learners to learn their desired concepts. This website is a highly interactive discussion website for experience sharing and programming.
- **Applied Website:** An applied website contains application-centered teaching materials that are suitable for learners who prefer practical applications with the learning style of Accommodators. Accordingly, the system has found for students the materials at the website of "YAHOO Knowledge" that receive more than 60% positive ratings from a minimum number of three commentators. YAHOO Knowledge is a social networking website rather than a discussion website. It contains much more information focused on technical exchanges and applications. The website is constructed with a rating function for replies to rule out errors or repetitions and to achieve a high degree of accuracy for its information.

In this study, the system searched and provided suitable teaching materials according to the learning styles of learners. It intended to enable learners to find remedial materials that are interesting to them and to increase their learning effectiveness.

Learning path and remedial materials recommender

To provide remedial learning resources for a learner, e.g., to satisfy a learner's desire to understand a specific terminology in a given domain, usually requires prerequisite knowledge of the relevant terminology. Some of the concept units associated to the prerequisite knowledge must be prepared for such a learning activity, and they must be taught at the beginning of the learning path, if necessary. This paper constructs a suitable learning path for a learner according to the *Degree of Concept Relationship Matrix*. To build a learning path to correct the learner's misconceptions in a continuous manner, the concept unit that most closely matches the misconception is chosen as the main subject of learning, the candidate concept unit with the highest weight of relationship to the misconception is selected for the prerequisite knowledge, and all the other units are found and arranged subsequently according to their relationship weights. The following algorithm describes the learning path construction.

Learning Path Generation Algorithm

Input: Misconception (*MC*), large themeset size (*LTS*) and degree of concept relationship matrix (*DCRM_{ij}*).

Output: A suitable learning path (*LP*).

Procedure:

1: *LP* = {0}

2: Find a concept unit (*CU*) that meets the *MC* from the candidate concept unit set. Add *CU* to *LP*, i.e., *LP* = {→ *CU*}.

3: While (length of *LP* < *LTS*) {

 Find the *CU_X* with the highest relation weighting to the Head of *LP* in *DCRM_{ij}*

 If (*CU_X* ∈ *LP*)

 Do {

 Find the *CU_X* with the next highest relation weighting to the Head of *LP* in *DCRM_{ij}*

 in *DCRM_{ij}*

 } until (*CU_X* ∉ *LP*) }

 else Add *CU_X* to *LP*

4: Return *LP*.

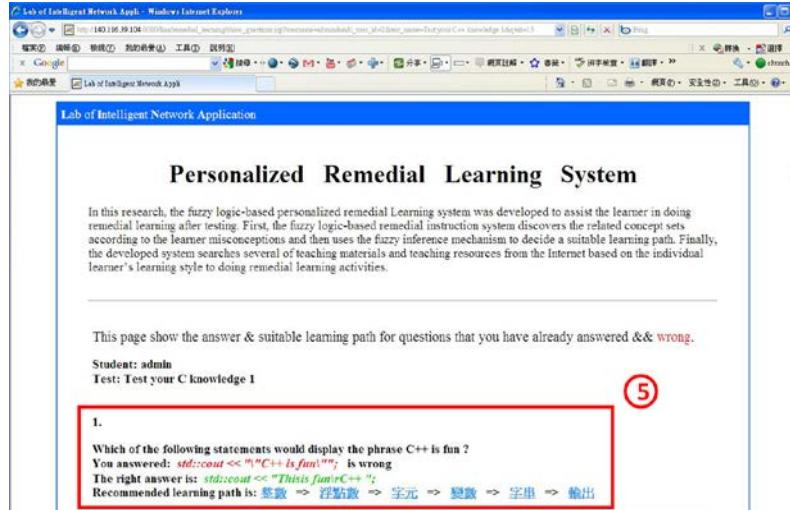


Figure 5. The interface of the constructed learning path for an individual misconception

Figure 5 shows the interface of the constructed learning path with the related remedial materials for an individual misconception. As shown in ⑤, each test item for which the learners chose the wrong answer contains the right

answer and the recommended learning path. A recommended learning path, composed of several concept units, is the suitable learning sequence for the individual learner according to his/her specific misconception. Each concept unit also includes the recommended remedial materials.

After the learner chooses a concept unit to learn, the proposed system then automatically provides the remedial materials extracted from the Internet based on their learning style. As shown in ⑥, those remedial materials that contain four kinds of resources, i.e., teaching websites, comprehensive websites, discussion websites and applied websites, are exhibited in sequence according to the learner's preferences, from top to bottom. Finally, when the learner completes the entire remedial learning process, the proposed system automatically provides a questionnaire to identify their preferences among the different recommended remedial materials, as shown in ⑦.

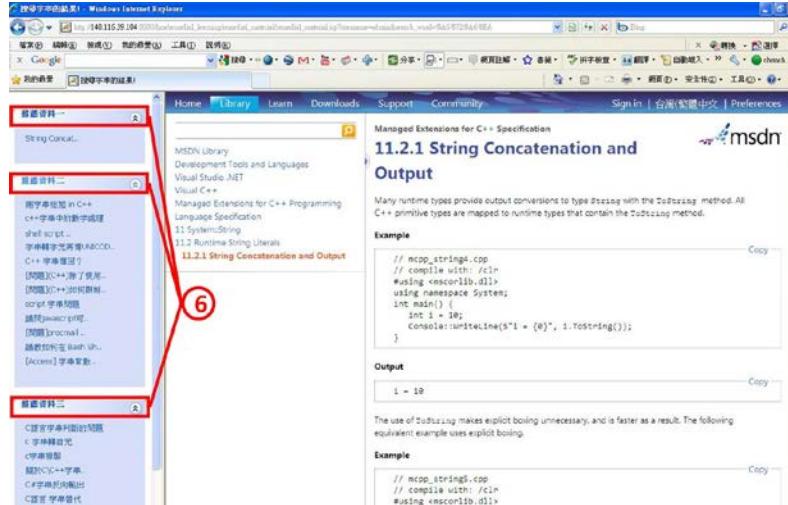


Figure 6. The interface of material contents for an individual concept unit



Figure 7. The interface for a learner's preference feedback after learning

Experiment results

Experiment design

Experiments were conducted to evaluate the effectiveness of the method proposed in this paper. A total of 55 sophomore students, 9 females and 46 males, from the Engineering Science Departments of the Nation Cheng Kung University, Taiwan, were involved in the experiments over two months. The C ++ programming language is a basic

and important skill for students majoring in the discipline of engineering. It is a required programming language curriculum in the Engineering Science departments of the Nation Cheng Kung University. Therefore, this study uses the C++ programming language as an example. Additionally, most of the participants had no or even minimal prior computer programming knowledge before learning.

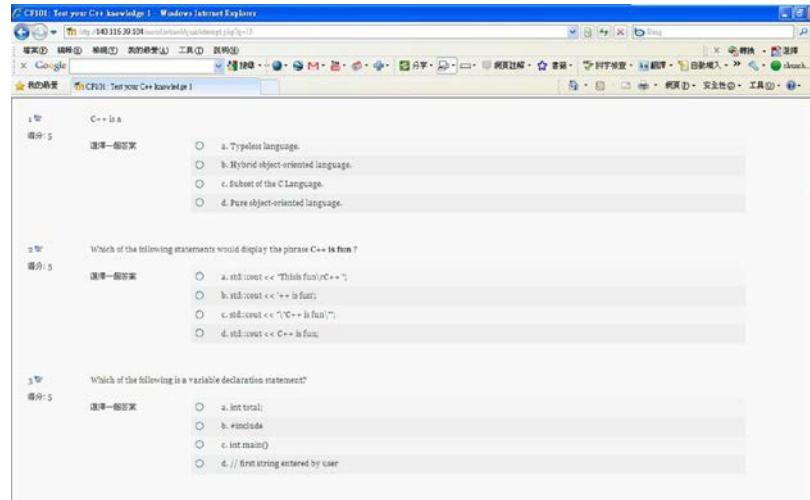


Figure 8. The testing interface for an individual learner

A randomized pre-test-post-test control group design was employed in this paper. The experiments primarily measure the effectiveness of the adaptive remedial learning. All participants were randomly assigned to two groups. A control group ($N = 28$) used the MPRLS without the recommended learning paths and adaptive learning materials. An experimental group ($N=27$) used the recommended learning paths and adaptive learning materials for remedial learning. In this study, the testing sheets, which are composed of multiple-choice questions, were designed by the teachers for both the pre-test and post-test. The pre-test items are different from the post-test items. Besides, the five experts on the C++ programming language also participate in evaluating the reliability and validity of the measurements. The figure 8 displays the testing interface for the learners. After randomized grouping and pre-testing, participants were engaged in remedial learning processes for two months. The performance of learners in the experimental group, who used the proposed system for remedial learning, was measured. The performance of learners in the control group, who selected learning materials to read on their own, was also measured in the same way. To evaluate their learning performance after the experimental procedure, the participating students were asked to take a post-test.

Experiment results

This section presents two evaluation results based on the learning performance of learners and the learners' learning style analysis.

Learning performance of learners

An independent sample test was used to verify the differences between the experimental group and control group after the participants finished the pre-test. Table 3 shows the average scores on the pre-test for the experimental group and the control group. According to the analysis results, Table 4 shows that there are no significant differences in pre-test results ($t = .011$, ${}^*p = .991 > .05$) between the experimental group and the control group. In other words, the two groups' abilities in C++ programming were very close. After the two months of remedial learning, the paired samples t-test was used here to assess whether there were statistically significant differences between the performance of the experimental group and control group on the post-test. Table 5 shows the difference in the mean pre-test and mean post-test scores both the experimental group and the control group. The results indicate that there is no significant improvement in learners' abilities after the learning process for the control group ($t = .657$, ${}^{**}p = .517 > .05$), whereas the improvement for the experimental group is significant ($t = -2.550$, ${}^*p = .017 < .05$). The

results indicate that the participants in the experimental group made significant improvements compared to those in the control group.

To explore whether the remedial system was more helpful to a specific type of learners (low-achieving or high-achieving), students in the experimental group were divided into two categories in terms of their pre-test grades (students with a failing grade and those with a passing grade). The results of the experiment indicated that after using the system, low-achieving students made significant progress ($t = -5.133, p = .000 < .05$) as shown in Table 6, whereas high-achieving students made no significant improvement in learners' abilities ($t = 1.242, p = .236 > .05$) as shown in Table 7.

Table 3. The evaluation results of the pre-test for the experimental group and control group.

Group		N	Mean	Std. Deviation	Std. Error Mean
Pre-test	Experimental Group	27	55.93	11.688	2.249
	Control Group	28	55.89	10.891	2.058

Table 4. The *t*-test of the pre-test of learning performance.

Equal variances assumed	Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
	F-test	Sig.	t-test	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
	.097	.756	.011	53	.991	.033	3.045	-6.074	6.140
Equal variances not assumed			.011	52.395	.991*	.033	3.049	-6.084	6.150

* $p > .05$ (confidence interval: 95%)

Table 5. The paired samples *t*-test of the pre-test and post-test for experimental group and control group.

Pair	Paired differences						t-test	df	Sig. (2-tailed)			
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference								
				Lower	Upper							
Experimental group (N = 27)	Pre-test and Post-test	-6.667	13.587	2.615	-12.042	-1.292	-2.550	26	.017*			
Control group (N = 28)	Pre-test and Post-test	1.964	15.831	2.992	-4.174	8.103	.657	27	.517**			

* $p < .05$ (confidence interval: 95%)

** $p > .05$ (confidence interval: 95%)

Table 6. The paired samples *t*-test of the pre-test and post-test for the learners who failed the exam in the experimental group.

Pair	Paired differences						t-test	df	Sig. (2-tailed)			
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference								
				Lower	Upper							
The learners who failed the exam in the experimental group (N = 13)	Pre-test and Post-test	-16.538	11.616	3.222	-23.558	-9.519	-5.133	12	.000*			

* $p < .05$ (confidence interval: 95%)

Table 7. The paired samples *t*-test of the pre-test and post-test for the learners who passed the exam in the experimental group.

The learners who passed the exam in the experimental group (N = 14)	Pair	Paired differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper	t-test	df	Sig. (2-tailed)
	Pre-test and Post-test	2.500	7.532	2.013	-1.849	6.849	1.242	13	.236*

* $p > .05$ (confidence interval: 95%)

Learners' learning style analysis

Based on the learning style theory of Kolb, this study has classified learners into four types: Accommodators, Assimilators, Convergers and Divergers. For each of the learning styles, the system has found suitable teaching materials from a variety of websites, including discussion websites, applied websites, comprehensive websites, and teaching websites. For instance, for a student identified as a Diverger, the system will have the most suitable teaching materials (from a discussion website) placed at the top of the recommendation list, followed randomly by those from the other three websites. To evaluate whether the teaching materials offered by the system are suitable for each learner, the system conducted a questionnaire survey asking learners to choose the teaching materials in which they were most interested. A total of 27 learners using the system were placed in an experimental group. The analyzed results are as follows:

- Divergers: A learner with the learning style of Divergers is presupposed to have a higher preference for discussion websites. The results showed that six of the nine Diverger-style learners in the experimental group preferred a discussion website.
- Accommodator: A learner with the learning style of Accommodators is presupposed to have a higher preference for an applied website. The results showed that only one of the three Accommodator-style learners in the experimental group preferred an applied website.
- Assimilator: A learner with the learning style of Assimilators is presupposed to have a higher preference for a teaching website. The results showed that seven of the ten Assimilator-style learners in the experimental group preferred a teaching website.
- Converger: A learner with the learning style of Convergers is presupposed to have a higher preference for a comprehensive website. The results showed that three of the five Converger-style learners in the experimental group preferred a comprehensive website.

Conclusion

This study provides an online learning system that automatically searches for relevant learning concepts and remedial teaching materials for learners to engage in remedial education. Providing guidelines and adaptive teaching materials through a system can help learners improve their learning conditions such as learner control, disorientation and cognitive overload in an online environment and thus improve their learning effectiveness. According to the results of the experiment, this study has the following conclusions:

- There was no significant difference between the experimental group and the control group in the pre-test comparison. Specifically, both groups had the same level of programming ability before the experiment. After using a personalized remedial learning system, the students in the experimental group were able to raise their learning effectiveness and achieve a significant difference in their programming ability. However, low-achieving students could be less effective or less knowledgeable learners who needed to learn gradually and progressively with proper guidance. Hence, given a learning path, low-achieving students progressed to a significantly greater extent.

- With the exception of Accommodator-style learners, more than 50 percent of each type of learners considered that the teaching materials matched learner preference, indicating that the system can provide learners with suitable teaching materials according to their learning styles. However, the results of the evaluation fail to reflect the reality of Accommodator-style learners, with far fewer samples.

The contributions of this study can be described as follows. Many teaching materials are compiled and edited manually. A manually-produced teaching material costs a lot of time and manpower. This study analyzed the characteristics of teaching websites, considered the styles of learners, and obtained online teaching materials automatically. It can provide learners with suitable, diverse teaching materials instantly. Moreover, the questionnaire survey verified that learners take greater interest in the teaching materials recommended by the system. On the other side, the adaptive remedial teaching system developed by this study helps to provide suitable learning access to remedial materials for learners to engage in progressive remedial learning at all times. Therefore, we believe that our research results would support more researchers to follow up such studies in the future.

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Learning by Designing Instruction in the Context of Simulation-based Inquiry Learning

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ABSTRACT

This study compares learning from designing instruction in the context of simulation-based inquiry learning with learning from expository teaching. The domain of instruction was the electricity domain of high-pass and low-pass filters. Participants were students from a technical vocational school. In the experimental condition ($N = 21$) students created assignments for an imaginary student to help this student to learn from a computer simulation. The LOOK-EXPERIMENT-DESIGN (LED) approach was developed to support students in designing these assignments. This support structure scaffolded students in orienting themselves in the simulation (LOOK), in performing experiments to gain more insight into the simulated domain (EXPERIMENT), and in designing assignments (DESIGN) about the simulated domain. Students in the control condition ($N = 28$) received traditional instruction. Students came from two different classes and were divided over the two conditions. After 3 two-hour lessons, all students completed a test measuring conceptual and procedural knowledge. Results showed that, in one class, students who learned by designing assignments performed significantly better on test items measuring conceptual knowledge than students who learned from traditional instruction. This was not replicated in the other class. No differences between the conditions were found for procedural knowledge.

Keywords

Inquiry learning, Simulations, Learning by teaching, Physics teaching

Introduction

Currently there is a general consensus that inquiry-based approaches to learning science that incorporate students' active investigation and experimentation are necessary to motivate students for science (Osborne & Dillon, 2008). Inquiry is the process in which students engage in the investigation of scientifically oriented questions, perform active experimentation, formulate explanations from evidence, evaluate their explanations in light of alternative explanations, and communicate and justify their proposed explanations (National Research Council, 2000). Beyond the motivational benefit, inquiry learning and its associated processes also have value of their own; inquiry learning generates knowledge and, if well supported, can be more effective than direct forms of instruction (Furtak, Seidel, Iverson, & Briggs, 2012). For these reasons, it is held that inquiry should be part of the science curriculum (e.g., National Research Council, 2000).

Contemporary technology-based approaches to science learning provide students with ample opportunities for inquiry. Technology-based environments offer simulations, games, data sets, and/or remote and virtual laboratories for students' inquiry-related use. Inquiry calls for non-linear and interactive content that these technology-based environments are able to provide, so that their technological affordances are directly used for pedagogical purposes (de Jong, 2006). Evidence is accumulating that technology-enhanced learning environments for inquiry provide students with genuinely effective learning opportunities, and large-scale studies show that these inquiry environments outperform more direct approaches to instruction on a variety of outcome measures (e.g., Deslauriers & Wieman, 2011; Eysink et al., 2009; Marusić & Slisko, 2012).

However, these promising results only materialize when the inquiry process is structured and scaffolded (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011). Effective scaffolds come in many forms. Examples include tools for creating hypotheses, data analysis tools, and tools for saving and monitoring experiments (see e.g., de Jong, 2005; Quintana et al., 2004; Zhang, Chen, Sun, & Reid, 2004). A growing number of computer-based inquiry environments have emerged that provide students with inquiry facilities together with an integrated supportive structure and scaffolds. Examples of such learning environments are: Inquiry Island (White et al., 2002); GenScope (Hickey, Kindfield, Horwitz, & Christie, 2003); SimQuest-based environments (de Jong et al., 1998); Co-Lab (van Joolingen, de Jong,

Lazonder, Savelsbergh, & Manlove, 2005); WISE (Linn, Davis, & Bell, 2004); STOCHASMOS (Kyza, Constantinou, & Spanoudis, 2011); and SCY (de Jong et al., 2012).

One approach that has not as yet been explored is to encourage learning from simulations by having students create scaffolds for other learners. This method is based on the idea of “learning by teaching”, which assumes that in aiming to teach others tutors are encouraged to learn the domain very thoroughly themselves. From research on peer tutoring, we know that tutors gain knowledge from their teaching experience; due to their need to explain to and question the tutee, tutors engage in processes requiring reflection about or summarization of their own knowledge (Roscoe & Chi, 2007). This “learning by teaching” approach has been used in technology-enhanced learning in the “Betty’s brain” software (e.g., Leelawong & Biswas, 2008). Here students learn by instructing a teachable agent, a graphical computer character equipped with artificial intelligence. Studies with Betty’s brain show that teaching another is highly motivating and leads to better learning results than learning for yourself (Chase, Chin, Oppezzo, & Schwartz, 2009), and also that learning by teaching the agent leads to higher performance compared to traditional teaching methods (Biswas, Leelawong, Schwartz, Vye, & Teachable Agents Grp, 2005).

Another example is SimStudent; in SimStudent students learn by instructing a simulated student (Matsuda et al., 2010). Recent work has shown that students who teach SimStudent can achieve considerable and efficient knowledge gains, specifically if they have to reflect about their own teaching actions (Matsuda et al., 2012). However, there is also research that indicates that learning by teaching can hinder learning. Atkinson, Derry, Renkl, and Wortham (2000), for example, summarize a number of studies in which creating explanations for another learner was compared to creating explanations for oneself, with the overall finding that the students who prepared for teaching someone else scored lower on knowledge tests. These authors attribute this result to higher levels of anxiety and lower intrinsic motivation. They also indicate that having experience with tutoring beforehand may yield greater benefits from creating explanations for others. In other recent work the importance of preparing students for their tutoring role is also emphasized (Matsuda et al., 2011).

These lines of research are further explored in the current study, in which we compared learning by designing assignments for another (fictitious) student to complete in a computer simulation with learning from expository teaching. Within the present study an assignment is a question, the correct answer and an explanation of the answer. An example of a question in such assignment would be: *What happens to the output voltage of the filter if you double the frequency?* Normally, the question, the alternative(s), and the feedback for an assignment are designed by an instructional designer or teacher. In the current study the assignments were designed by students themselves, with the idea that they could learn from the design process.

In a previous study (Vreman-de Olde & de Jong, 2004) students designed assignments related to a computer simulation on electrical circuits. Two-thirds of the designed assignments were about calculations and definitions. One-third of the designed assignments were about the discoveries students made with the simulation, but these assignments were rather superficial and mainly described simple effects. To support students in designing assignments, we developed a paper-and-pencil design sheet, that prompted student to generate an idea, transform the idea into an assignment, and evaluate the assignment (by running it in the software environment). Students using this design sheet designed more assignments about the relations in the simulated domain than non-scaffolded students. In addition, scaffolded students more precisely described relations and provided more explanations than the non-scaffolded students. However, no differences between the two groups were found on a knowledge test (Vreman-de Olde & de Jong, 2006). These results, the review by Atkinson et al. (2000), and recent work on peer tutoring (e.g., Tsivitanidou, Zacharia, & Hovardas, 2011) suggest that students need (more) detailed scaffolding for their assignment designing activities.

In the present study, we compared an *experimental condition*, in which students designed assignments for a simulation on electrical circuits and were supported by a detailed design scaffold that guided the students through different steps (described more fully in the Method section), with a *control condition*. In the control condition students worked on the same learning content but followed traditional instruction in which the teacher used the blackboard for explanations and students completed calculation exercises. To assess students’ learning outcomes a knowledge test with different types of test items was administered. We expected that the experimental group would perform better than the control group on conceptual test items measuring insight into the cause-effect relations of the examined domain because they would gain insight into those relations by designing assignments. Second, we expected that students in the control condition would perform better than the experimental group on procedural (calculation) items because of their greater amount of practice in performing calculations. Although these predictions

seem straightforward, recent work shows that a focus on enhancing conceptual knowledge may also lead to an improvement in procedural knowledge (Kolloffel & de Jong, 2013). This result is explained by the phenomenon of bootstrapping (Schauble, 1996) or iterative knowledge development (Rittle-Johnson, Siegler, & Alibali, 2001), which refers to the idea that the acquisition of conceptual understanding and of procedural knowledge can in some cases mutually support and stimulate each other.

Method

Participants

Participants were 50 students from an intermediate level vocational engineering training program, average age 17 years. Students were from two intact classes coming from two different educational paths within technical vocational training, namely, Electronic Engineering (Class 1) and Automotive Engineering (Class 2). For their regular “practical lessons” the teachers had already split up each of the classes into two groups. In each class one of these pre-defined groups was assigned to the experimental condition, and the other to the control condition. The experimental condition consisted of 22 students, 12 students from class 1 and 10 from class 2. The control condition consisted of 28 students, 13 from class 1 and 15 from class 2. One student from the experimental condition (class 1) was absent during the test. As a result, the total experimental group consisted of 21 students. Students participated in the experiment with their own class and were instructed by their own teacher.

Materials

The domain and computer simulation learning environment

In this study, a SIMQUEST (van Joolingen & de Jong, 2003) application was used. One electrical high-pass filter and two low-pass filters were simulated. A low-pass filter is a circuit offering easy passage to low-frequency signals and difficult passage to high frequency signals, while a high-pass filter's task is just the opposite. Filters are built with two elements: A resistor (R) and a coil (L), or a resistor and a capacitor (C). In general, the theme of filters and the passage of signals is a difficult subject.

In designing the application, we used a series of four simulation interfaces for each of the three filters, presented in the same order for each filter. Complexity of the interfaces in the simulation was increased gradually, (see, e.g., White & Frederiksen, 1990). Each series started with a simple interface presenting the elements of the filter, so that students could learn how the individual elements react to frequency changes. The second interface is shown in the left window of Figure 1. In the “Change variables” box the values of one or more variables can be changed. The output variables are visible in the “Results” box, in the “resistance diagram” and in the graph. The third interface focused on U_{out} and the current I for the whole frequency range. The fourth interface showed a graphical representation of the transfer function, plotting U_{out}/U_{in} as a function of the frequency.

The support

Students in the experimental condition were asked to design assignments so that an “imaginary” fellow student could learn from the simulation. For this task we created a support structure that guided the students through three consecutive steps: LOOK (orientation on the simulation), EXPERIMENT (experimentation with the simulation), and DESIGN (designing assignments). The rationale behind these steps, which we called LED, is that we want to focus students’ attention on the relations that are important in the domain (Swaak, van Joolingen, & de Jong, 1998). After students have acquired knowledge, they are asked to make this knowledge explicit in developing a question, the correct answer and the explanation of that answer.

The support was presented in the simulation environment together with a set of paper-and-pencil worksheets (called LED-sheet hereafter). The online-support in the simulation consisted of assignments, tips, and overviews. This support was available in a window next to the simulation interface (Figure 1). The LED-sheets matched the structure of the on-line support; for example, if on-line support asked students to investigate a certain relation, instructions on the associated sheet supported students in making notes about their investigations.

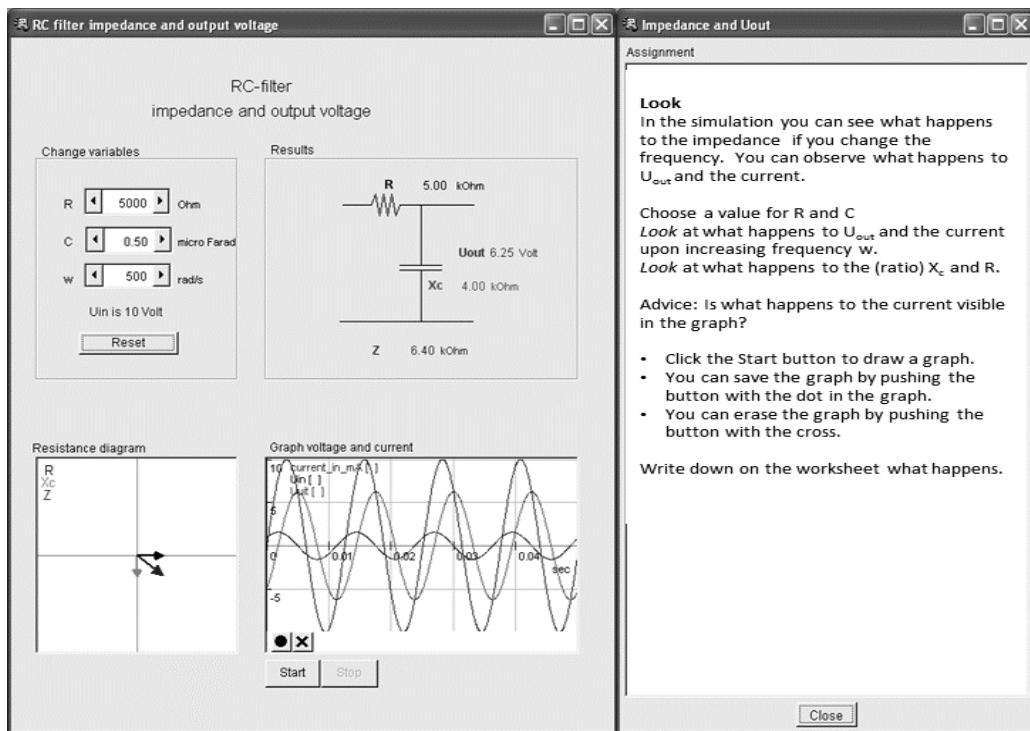


Figure 1. Screen shot of simulation interface and support from the LOOK phase.

First phase: LOOK

In the LOOK-phase, the main goal was to explore the domain. The on-line support started with an overview of the learning goals for the specific interface, followed by investigation tasks that provided students with concrete targets, so that they could perform specific inquiries in the computer environment. Students also received hints for performing experiments correctly. On the related LED-sheet, "observation starters" supported students in making notes of their observations. An observation starter is a semi-structured sentence, starting with a given focus of observation and ending with dots to be filled in. An example is: "If R increases, then.....". By giving students this starter, observations are structured (change only R), focused (it is important to change R), and note-taking is assured (the sentence must be completed).

Second phase: EXPERIMENT

In the Experiment phase, the main goal was to transform the qualitative observations from the Look-phase into more exact descriptions. Students were supported by several detailed scaffolds.

First, students had to perform a series of systematic experiments and keep a record of the data from those measurements. To support them in this process, we included a "partly-filled-in-table" (presented in Table 1) on a LED-sheet. In this table, the (increasing) values of the independent variable and a number of the dependent variables were already given. Students had to complete this table.

Table 1. Example of the "Partly-filled-in-table"

ω (in rad/s)	X_C (in kOhm)	R (in kOhm)	U_{out} (in V)	Z (in kOhm)	I (in mA)
50					
100					
500					
1000					

5000					
Conclusion: If ω increases then:	Xc will	R will	U _{out} will	Z will	I will

The last row of the table contained what we called “conclusion starters”. These sentences were added to support students in drawing conclusions from the table. Compared with the LOOK phase the students’ statements were more precise.

Second, students were prompted to take a careful look at representations from the simulation such as formulae and diagrams. They were, e.g., asked to calculate the impedance X_C for two values of the frequency ω_1 and ω_2 (with $\omega_2 = 2\omega_1$). Students were also asked to draw diagrams (e.g., the resistance diagram in Figure 1) for different values of the frequency and draw conclusions.

Third, students were given “prediction-starters” to support them in thinking deliberately about the consequences of a change, e.g., “when the frequency becomes higher, I think the output voltage will....”

Third phase: DESIGN

In this phase, the main goal was to design an assignment about the observations made and the knowledge acquired during previous phases. Students were supported in using this knowledge and making it explicit in their design. In generating a question, they were instructed to pose a question about the observations they had made. In formulating the answer, they were advised to check the correctness of the answer with the help of the simulation. In generating the explanation for their assignment, they were advised to explain the answer in detail, and to make use of calculations, representations, and observations. For each interface, except for the fourth one, students went through the three LED phases.

Knowledge test

Knowledge was assessed using a paper-and-pencil (post-)test. The knowledge test consisted of two parts: one set of items intended to measure conceptual (insight) knowledge, and a second set of items focused on measuring procedural (calculation) knowledge. All items were scored by a rater who was blind to the condition of the participant who had taken the test. Both the test and the answering key were developed together with the teacher.

Conceptual knowledge (insight into the cause-effect relations in the domain) was measured by items in which students were asked to predict or explain the effect of a change. Students received points for correct answers and for their reasoning. In the example shown in Figure 2, the student not only had to choose a situation, but also had to give a reason for their choice. There were a total of 28 conceptual items, with a maximum total score of 50 points; the maximum point value per item depended on its complexity (13 items with a maximum of 1 point, 9 with a maximum of 2 points, 5 with 3 points and 1 with 4 points). Reliability analysis of the test resulted in a Cronbach's alpha of 0.80. Two judges independently scored the answers to the conceptual knowledge items for ten percent of the data, with inter-rater agreement reaching 0.70 (Cohen's kappa).

Procedural knowledge was measured by test items in which students were asked to perform calculations. Students received points for the calculation procedure and the correct answer. There were a total of 6 procedural items with a maximum total score of 15 points; the maximum point value per item depended on its complexity (1 item question with 1 point possible, 3 with a maximum of 2 points, 2 with a maximum of 4 points). An example of a procedural item is presented in Figure 3. Reliability analysis of the test resulted in a Cronbach's alpha of 0.64. Two judges independently scored the answers to the procedural knowledge items for ten percent of the data, with inter-rater agreement reaching 0.76 (Cohen's kappa).

There were a total of nine introductory items, that were used to “warm up” the students. These items referred to general domain knowledge and were not analyzed.

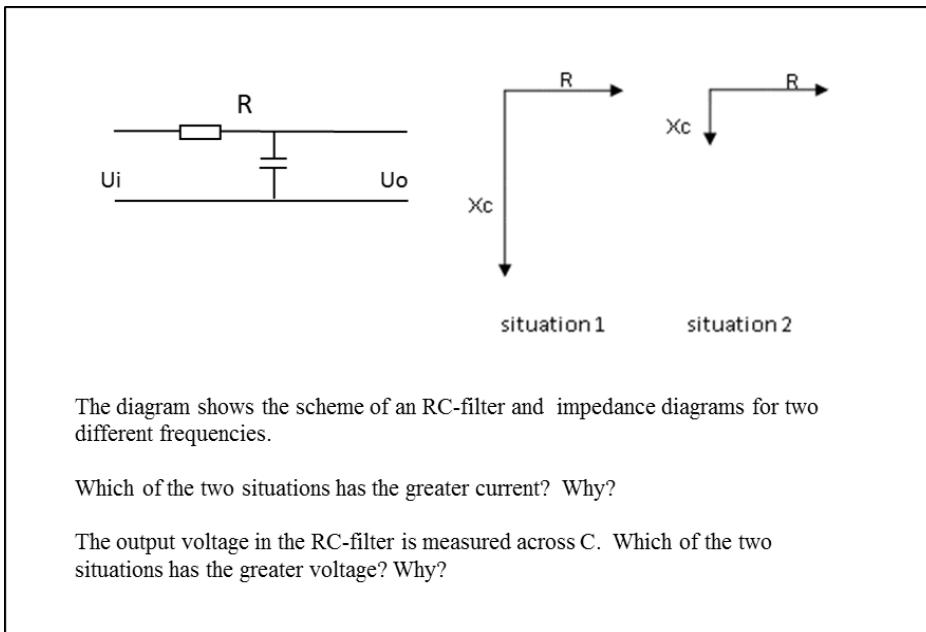


Figure 2. Example of a conceptual knowledge item

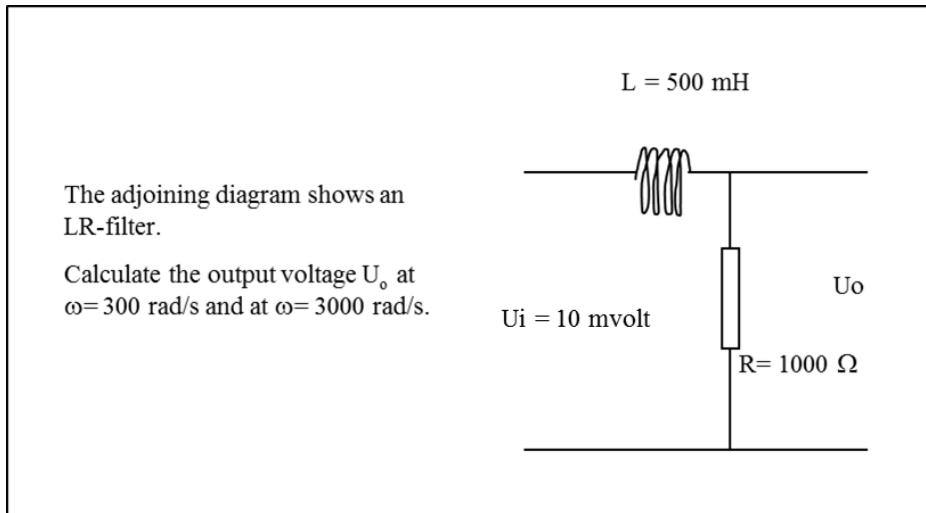


Figure 3. Example of a procedural knowledge item

Procedure

Students in both conditions had three weekly two-hour lessons on the subject of low-pass and high-pass filters, which was part of their regular curriculum. The fourth lesson was used to administer the knowledge test. Class 1 participated in the study first, and a few months later Class 2 participated. The same procedure was followed for both classes. The same domain content was covered in both conditions.

In three two-hour sessions, students in the *experimental condition* went through the simulations of each of the three filters. At the beginning of the first lesson, the experimenter introduced the students to the SIMQUEST learning environment. For the design task, the experimenter explained the three phases in the design approach and told the students how to use the LED-Sheets. During the first lesson, students worked with the simulation of the first filter. At the end of the lesson, all LED-sheets were collected. At the beginning of the second and the third lessons, the LED-sheets were returned to the students and students continued where they had stopped the lesson before. Near the end

of the third lesson, students were asked to have a look at the transfer functions of each filter (they were not supposed to design assignments about transfer functions). At the end of the third lesson, LED-sheets were collected. For both classes the students' own teacher was available during all lessons to answer students' questions.

In the *control condition*, students received three two-hour lessons, from their own teacher. They did not use a computer simulation but received conventional instruction. The teacher used the blackboard for explaining the domain and students completed calculation exercises from their textbook. Informal observations of activities in the class were made during all lessons by the experimenter.

Results

In the results section, we first present the exam scores for both conditions in each class, as a way to establish the comparability of the experimental and control groups in terms of prior domain knowledge. Next, we present the results of the knowledge post-tests. Finally, to gain understanding in the way the students used the scaffolds, we analyzed students' completed paper-and-pencil design sheets.

Exam scores

Table 2 gives an overview of the mean exam scores on the subject of electricity for both conditions and for each class. The exam scores (which could range from 1-10) for this subject were made up of the scores on a number of tests from the students' regular curriculum that they had taken before the experiment began. The way these exam scores were determined in both classes was not similar (both followed a different curriculum) but data for each condition were normally distributed for both Class 1 (Experimental: Shapiro-Wilk $W = 0.959$, $df = 11$, $p = .754$; Control: Shapiro-Wilk $W = 0.969$, $df = 13$, $p = .754$) and Class 2 (Experimental: Shapiro-Wilk $W = 0.915$, $df = 10$, $p = .316$; Control: Shapiro-Wilk $W = 0.928$, $df = 15$, $p = .252$). No difference between the experimental and control condition was found (Class 1: $F(1,22) = .623$, $p = .438$ Class 2: $F(1,23) = .439$, $p = .514$). From this we may conclude that the experimental and control condition entered the experiment with comparable prior knowledge.

Table 2. Mean exam scores for the two classes; control and experimental condition

Condition	Experimental	Control
	M (SD) n (min-max)	M (SD) n (min-max)
Class 1	5.9 (1.2) 11 (3.7 – 7.8)	5.4 (1.9) 13 (2.2 – 8.4)
Class 2	6.4 (1.6) 10 (4.1 – 8.9)	6.8 (1.5) 15 (4.1 – 8.6)

The knowledge test

Table 3 shows the mean scores on the conceptual items and the procedural items from the post-test for both conditions. Shapiro-Wilk tests showed that the test scores were normally distributed for both conditions for both the conceptual items (Experimental: Shapiro-Wilk $W = .972$, $df = 21$, $p = .611$; Control: Shapiro-Wilk $W = .971$, $df = 28$, $p = .611$) and the procedural items (Experimental: Shapiro-Wilk $W = .908$, $df = 21$, $p = .051$; Control: Shapiro-Wilk $W = .947$, $df = 28$, $p = .165$). The results of a MANOVA on students' scores on conceptual and procedural items showed no significant effect of condition ($F(2, 46) = 2.552$, $p = .089$).

Table 3. Mean scores for the two conditions (all students) on the knowledge test

Condition	Experimental (n = 21)	Control (n = 28)
Knowledge items	M (SD)	M (SD)
Conceptual items (max = 50)	29.7 (8.5)	26.7 (8.0)
Procedural items (max = 15)	7.2 (4.1)	8.4 (4.4)

Because students came from two different classes with different backgrounds, we performed an analysis of the results on the knowledge tests for the two classes separately.

Class 1. Table 4 shows the results of the knowledge tests for the two conditions in Class 1. Statistical tests for detection of outliers showed that one student in the experimental condition appeared to be an outlier for the conceptual items (with a score greater than 2 SD below the mean score). This student was removed from further analyses. In both conditions results on the conceptual test remained normally distributed after the removal of the outlier (Experimental condition: Shapiro-Wilk $W = 0.939$, $df = 10$, $p = .542$; Control condition: Shapiro-Wilk $W = .899$, $df = 13$, $p = .129$). The test results for the procedural knowledge test were affected by the removal of the outlier (Experimental condition: Shapiro-Wilk $W = .790$, $df = 10$, $p = .011$; Control condition: Shapiro-Wilk $W = .950$, $df = 13$, $p = .597$). Therefore, the non-parametric Kruskal-Wallis test was used to examine the differences between conditions within Class 1. A significant difference between the two conditions was found on conceptual items ($H(1) = 5.044$, $p = .025$) but not on procedural items ($H(1) = -.117$, $p = .732$).

Table 4. Mean scores for the two conditions of Class 1 on the knowledge test

Condition	Experimental (n = 10)	Control (n = 13)
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
Knowledge items		
Conceptual items (max = 50)	33.9 (7.8)	25.2 (6.5)
Procedural items (max = 15)	8.5 (4.6)	8.0 (4.9)

Class 2. Table 5 shows the results of the knowledge test for the two conditions in Class 2. Statistical tests for detection of outliers showed that one student in the experimental condition appeared to be an outlier for the conceptual items (with a score greater than 2 SD above the mean score). This student was removed from further analysis. The distribution of results remained normal for both the conceptual test (Experimental condition: Shapiro-Wilk $W = 0.972$, $df = 9$, $p = .913$; Control condition: Shapiro-Wilk $W = .937$, $df = 15$, $p = .341$) and the procedural knowledge test (Experimental condition: Shapiro-Wilk $W = .970$, $df = 9$, $p = .899$; Control condition: Shapiro-Wilk $W = .935$, $df = 15$, $p = .318$). A one-way MANOVA showed no significant differences ($F(2, 21) = 2.099$, $p = .148$) between the two conditions on the knowledge test (conceptual and procedural items). This implies that the significant difference found in Class 1 on conceptual knowledge items is not duplicated in Class 2.

Table 5. Mean scores for the two conditions of Class 2 on the knowledge test

Condition	Experimental (n = 9)	Control (n = 15)
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
Knowledge items		
Conceptual items (max = 50)	26.1 (4.3)	28.0 (9.1)
Procedural items (max = 15)	5.7 (2.9)	8.8 (4.0)

Qualitative analysis of the support structure

The goal of our intervention was that students would create assignments with answers and explanations that would help them better understand the domain themselves. Two examples of assignments that were created by students are given in Figure 4. To gain insight into the effect of scaffolds used (see also Method section), we examined the correctness and performed a qualitative and informal analysis of the students' notes students on the LED-sheets. The results of this analysis are presented in this section.

RC-filter	
Question:	What happens to U_{out} upon increasing R?
Answer:	U_{out} becomes smaller.
Explanation:	U_{out} becomes smaller because the voltage across R becomes larger and C 'gets' less voltage.
CR filter	
Question:	Is this a high-pass or low-pass filter?
Answer:	High-pass
Explanation:	The higher the frequency, the lower the 'resistance of C', so the voltage across R becomes larger. So, this is a high-pass filter.

Figure 4. Two examples of assignments created by students

Observation starters

We hypothesized that observation starters would support students in making careful observations in the simulation and in taking notes about their observations. The answers to the observation starters were generally correct, implying that students changed the correct independent variable and observed the dependent variables we wanted them to study. In addition, we saw that some students went beyond the focus of the observation starters and described their own observations. For example, they expressed their surprise about the effect of the frequency on the impedance diagram.

Partly-filled-in-table and conclusion starters

Our assumption was that the partly-filled-in-tables would support students in performing systematic experiments, keeping an overview of their data and drawing conclusions about the relations examined. Analysis of the filled in tables shows that students filled in correct measurements of the dependent variables and that conclusions concerning the examined relations were generally correct.

Representations (1): Calculations and conclusion starter

We hypothesized that the combination of calculations on the LED sheet and conclusion starters would help students to gain a more quantitative understanding of a causal relation (see example in Method section). We found that students' answers to the calculations were mostly correct, as well as the quantitative relations they formulated.

Representations (2): Diagrams and conclusion starter

We hypothesized that drawing diagrams on the LED sheet would support students in gaining a deeper understanding of the represented concepts. Regarding the resistance diagram (see Figure 1) students were asked to draw the diagram for two values of the frequency ω . For increasing frequencies, all students drew a shorter arrow for X_C and Z (both are correct). Some students added notes about the Pythagorean formula - this formula can be used to calculate Z from X_C and R . In addition, we saw that students started to draw representations on the LED-sheets when they made their own observations. Students also drew representations when explaining their assignment answer.

Prediction starters

Lastly, we hypothesized that prediction starters would support students in thinking about effects of changes in e.g., the frequency, and in reflecting on the correctness of their predictions. In analyzing the notes made on the LED-sheets, we found that students' predictions often were not correct. We also found no reflections about the correctness of the predictions.

Discussion

In this study, we compared two version of the same learning environments. In the *experimental condition*, students designed assignments for fictitious students in a simulation based inquiry learning environment. In their design task, students went through the three design phases LOOK-EXPERIMENT-DESIGN. This sequence may not be novel to inquiry learning in general, but it is novel when used in combination with designing assignments for a computer simulation for (fictitious) other students. Along the way, students were supported such that they could gain more insight into the simulated domain. In the *control condition*, students did not use a computer simulation but received conventional instruction. The teacher used the blackboard for explaining the domain and students completed calculation exercises from their textbook. A knowledge test was administered to measure learning differences between conditions. This test contained procedural items, measuring knowledge of calculation procedures, and conceptual items, measuring insight into causal relations. The two classes that participated in our study were each

divided into two groups; one group in each class participated in the experimental condition and the other group in the control condition.

Overall, we found no differences on the conceptual and procedural knowledge test items between the two conditions. Looking at the two classes separately, we found that students in the experimental condition of Class 1 performed significantly better on the conceptual items than students in the control condition. However, this result was not repeated for Class 2. This might have been caused by the difference in prior computer simulation experience between the two classes. During their regular lessons, students in Class 1, who came from a different educational program (Electronic Engineering) than students from Class 2 (Automotive Engineering), had used the program Multisim to build and simulate circuits. Experience with the Multisim simulations might have helped the students from Class 1 in learning from a simulation. For students in Class 2 this was their first encounter with computer simulations and we know from research that it takes students a bit of time to have enough experience in inquiry learning (Hickey et al., 2003; Ketelhut, 2007).

To guide the students in the experimental condition we developed a support structure. Asking students to design assignments already structures students' inquiry process. Additional scaffolds were added to support the design process so that students would be able to explore the domain, perform experiments, gather data for the design of their assignments and formulate assignments based on their newly acquired knowledge. During the whole process, students made notes on their LED-sheets. An informal qualitative analysis of these notes and the observations we made during the lessons showed that the effects of these scaffolds look promising.

First, the scaffolds "observation starter" and "drawing representations" seemed to assist students in starting an investigation, as was reflected in students' notes LED-sheets and observations made during the lessons. In addition, the representations assisted students in formulating explanations for their assignments. Drawing representations of the total impedance in the circuit helped students remember the Pythagorean formula used to calculate the total impedance. Second, the "partly-filled-in table" (developed to support students in planning and monitoring a series of experiments) assisted students in performing a series of measurements and drawing conclusions about the collected data. It seems that this relatively straightforward table helped students to keep an overview of their data and enabled them to focus on the relations being investigated. This is in line with studies that have emphasized the importance of monitoring support (Veermans, van Joolingen, & de Jong, 2006). Third, in complying with the scaffold telling them to "perform calculations", students performed two calculations with a formula and used the outcomes to describe the relation between the variables. With hindsight, we could have exploited this scaffold more by linking the calculations and its resulting quantitative relation from the EXPERIMENT phase more explicitly with the (qualitative) observations of the same relation in the LOOK phase. In this way, students might have realized that careful observations in a simulation can be used to check their understanding of a formula. A point of concern, however, is that, as our qualitative analysis showed, many predictions as formulated in the "prediction starters" were not correct. Students were not inclined to reflect on the correctness of their predictions - a process which might have given rise to interesting learning moments. Students might need extra support in reflecting on their work. This is important because reflection on one's own knowledge is a pivotal aspect of learning with computer simulations (Smetana & Bell, 2012).

The current study had limitations in the small number of participants involved and the unfamiliarity of working with simulation software for a number of the participants. This study therefore is only a first step towards designing effective "learning by design" instruction (see also de Jong et al., 2012) . The current work indicates that designing assignments for a simulation with the LOOK-EXPERIMENT-DESIGN approach opens opportunities for students to gain insight into the simulated domain. Prior experience in working with simulations seems to be a potential facilitating condition in this learning process. With respect to the scaffolds, we found that these straightforward types of support were relatively easy to use and seemed to assist our students in focusing on important relations in the domain, learning from the simulation and in using the knowledge they had acquired in designing their assignments.

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Digital Peers to Help Children's Text Comprehension and Perceptions

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ABSTRACT

Affable Reading Tutor (ART) is an online reading lesson designed for children who are starting to comprehend reading. A digital, human-like character (virtual peer) in ART serves as a peer model that demonstrates the use of the reading comprehension strategy called *questioning* to help improve the learners' comprehension of expository texts. This study, with 141 boys and girls in the fourth and fifth grades in the United States, examined the effects of virtual-peer presence (presence, absence, and control) on learners' text comprehension and also the effects of learner gender and virtual-peer attributes (human-like male, human-like female, robot still image) on learners' perceptions of their peer and on their text comprehension. The results revealed that the virtual-peer presence group outperformed both the absence group and the control group in the immediate and delayed posttests text comprehension. There were mixed results in the impacts of learner gender and virtual-peer attributes on text comprehension. The learners' perceptions of their agent were not differentiated by neither learner gender nor virtual-peer attributes. The findings are discussed with virtual-peer design implications.

Keywords

Interactive learning environment, Virtual peers, Pedagogical agents, Computer-assisted language learning, Reading strategy instruction

Introduction

Researchers in literacy education argue that social interaction fosters students' comprehension of texts while they are reading. That is, personal connection with peers and teachers enhances students' curiosity towards reading, their engagement in reading, and their preference for reading challenge (Guthrie, 2002). At the same time, the National Reading Panel in the United States (National Reading Panel, 2000) has issued a strong recommendation that young readers be directly taught reading strategies to increase their comprehension of expository texts.

Children at the early stages of reading to comprehend seem to need more direct individualized instruction and guidance through supportive relationships. This type of individual support, however, has been a big challenge in a conventional classroom setting, which typically has one teacher and dozens of children. As an alternative, computer-assisted language learning (CALL) might be explored as a way to provide young learners with direct and self-paced strategy instruction. With recent advances in interface technology, in particular, it is possible to simulate social and affective interactions in CALL, through animated digital peers or tutors (Kim & Wei, 2011; McQuiggan, Robinson, & Lester, 2010). The author developed Affable Reading Tutor (ART), a CALL environment embedded with a digital peer, to help elementary-school students learn questioning strategy to comprehend cause-and-effect relationships in expository texts. This paper presents a classroom-based experiment that has examined the effectiveness of peer presence on learners' text comprehension and their perceptions of their peer in ART.

Theoretical Backgrounds

Effective reading comprehension instruction

Social interaction is considered critical in learning and intellectual development. In particular, reading researchers have established that social interactions with peers and teachers can foster motivation to read and enhance text comprehension (Palinscar & Brown, 1984; Gambrell, 2001; Guthrie, 2002). Guthrie (2002) argues that situational interest is easily aroused in a shared reading context where individuals naturally expand themselves through interaction with their peers and teachers. Traditionally, well-known reading-comprehension instruction approaches like reciprocal teaching (Spörer, Brunsteina, & Kieschke, 2009), interactive read-aloud (Barrentine, 1996), dialogical-thinking reading lessons (Commeyras, 1993), and guided reading (Pinnell, 2002) are all interactive in nature and emphasize the provision of social context for enhanced engagement in reading and comprehension.

In addition, children who start reading to comprehend expository texts are very likely to benefit from direct, self-paced strategy instruction that helps them grapple with new texts (Almasi, Garas-York, & Shanahan, 2006; Guthrie et al., 2004; Leopold & Leutner, 2012; Pressley, 2002). For many young readers, reading comprehension strategies are not acquired naturally; rather, strategy use is a specific and learned procedure that promotes active and intentional reading (Trabasso & Bouchard, 2002). Readers who are not explicitly taught this cognitive procedure are less likely to learn, develop, or use the strategies spontaneously (Andreassena & Bråtenb, 2011; Wharton-McDonald, Pressley, & Hampston, 1998). Reading comprehension strategy, therefore, must be taught by way of direct instruction that uses explicit and repeated demonstration and modeling of strategy use (National Reading Panel, 2000). Moreover, it seems that a young reader benefits from individualized guidance, with which he/she can learn at his/her own pace to build the habit of strategy use gradually. One challenge is that this kind of individualized and direct strategy instruction is not always offered in conventional classrooms due to limited resources (i.e., a single teacher with a multitude of children) (Pearson & Dole, 1987). One promising area to explore could be work done in computer-assisted language learning.

Computer-Assisted Language Learning (CALL)

In recent decades, CALL researchers have explored a range of technologies and pedagogical approaches such as interface design and authoring, data management and access, intelligent tutoring systems, speech recognition technologies, and natural language (Stockwell, 2007). The areas most extensively studied in CALL research over time include grammar, vocabulary, speaking, and writing. Also, CALL has been applied and studied more actively in the context of second-language learning than in first-language learning. For example, in a study with 122 Korean tenth-graders who learn English as a foreign language, Yun and colleagues (2008) found that constructed-response (fill-in-the-blank) questions with explicit feedback in CALL were effective for improving the learners' recall of vocabulary and transfer. Chen and Wang (2008) tested several of Ellis's language learning principles in collaborative cyber-community-based learning, with seven Chinese EFL learners in a college and found that the use of text chat and joint web browsing helped foster communicative language skills in synchronous online classes.

In contrast to the growing amount of CALL research, the use of CALL to teach reading has been relatively limited and has even shown a consistently decreasing trend over the last decade (Stockwell, 2007). Furthermore, among the existent CALL applications for reading, the majority deals with discrete skills development like vocabulary building and word recognition. A meta-analysis of CALL research in reading indicates that most research has focused on developing phonemic awareness, letter identification, word identification, and speed and fluency in reading words (Blok, Oostdam, Otter, & Overmaat, 2002). There has been a dearth of CALL research to examine the effectiveness of CALL for reading comprehension instruction. Reading comprehension could be better taught in social and interactive contexts, as recommended by many reading researchers.

Although CALL applications afford individualized instruction conventionally, they often fall short of integrating social interaction. Therefore, the author explored animated, digital peer technology to see if the technology would expand the capacity of CALL by rendering a social context that might benefit young readers.

Virtual peer

The term virtual peer refers to an animated, digital character, a subset of a more broadly used term *pedagogical agents* (animated life-like characters embedded in educational applications). It is well acknowledged that people, consciously or unconsciously, tend to ascribe mental states to computers and interact with computers socially (Kim, 2007; (Reeves & Nass, 1996). Virtual peer technology seems to broaden the communication bandwidth between a learner and a computer. It has been used to render social presence and enrich learning experiences in computer-based learning (Gulz, 2005; Iacobelli & Cassell, 2007; Johnson, Rickel, & Lester, 2000). A number of researchers in pedagogical agents support consistently that the social presence produces positive gains in learner affect and engagement (Atkinson, 2002; Dempsey & van Eck, 2003; Gulz, 2004; Johnson, et al., 2000; Kim & Wei, 2011; Mayer, Johnson, Shaw, & Sandhu, 2006; Moreno & Mayer, 2000; Plant, Baylor, Doerr, & Rosenberg-Kima, 2009). Moreover, some studies argue for the modeling effect (Kim & Baylor, 2007; Ryokai, Vauelle, & Cassell, 2003). Kim and Baylor (2007) claimed that the use of virtual peers as role models for learners could be viable for enhanced motivation and learning, in that a virtual peer playing as a coping or mastery model could motivate the learner toward challenging and less popular domains of learning.

Embedded in computer-based reading instruction, a virtual peer could be designed to explicitly demonstrate reading strategy use and encourage a young reader to use the strategy. Through the peer's modeling (Bandura, 2001; Schunk & Hanson, 1989), the learner might vicariously learn the strategy use and improve their text comprehension. Further, the peer's visual and verbal demonstration is likely to lessen young readers' burden to read through explanations in text or graphics (i.e., reducing cognitive load) and, thereby, improve the efficacy of strategy instruction. Ryokai and colleagues' study (2003) hinted this modeling effect. In their study, children who played with the virtual peer *Sam* listened to Sam's stories carefully and mimicked Sam's linguistic styles in their speech. It seemed that Sam played a social role for the children. The children might feel affiliated with Sam, which, presumably, induced their behavioral changes. A similar modeling impact was implied in an online tutoring game teaching phonemic decoding skills, where children's skills increased only when the program included a digital tutor that gave oral feedback to the children (Kegel & Bus, 2012).

Given the lack of computer-based reading-comprehension instruction, the author developed a reading lesson, Affable Reading Tutor (ART) to model the use of comprehension strategy for children who just started reading to comprehend. In the lesson, the children studied finding cause-and-effect relationship in expository texts, observing a virtual peer's strategy use. The young readers might be able to develop social relations and interact socially with the peer, which would be beneficial for their motivation and text comprehension. The author investigated the impact of the peer serving as a peer model that demonstrated strategy use to increase the learners' text comprehension.

This study was focused on how effectively a virtual peer's modeling of reading strategy use would improve children's text comprehension, compared to the strategy instruction without virtual-peer presence. The primary research question asked 1) *Will the presence of a virtual peer influence learners' text comprehension?* Also, referring to the current literature in virtual peers (or pedagogical agents), two additional questions were asked. The second question was about learner gender because learner gender was often a factor determining the effectiveness of agent presence (Baylor & Kim, 2005; Kim, Baylor, & Shen, 2007). The second question asked 2) *Will learner gender and virtual-peer presence interact to influence text comprehension?* The third question was about learners' perceptions of virtual-peer attributes. Researchers in agent technology emphasize a learner's building social relations with their agent in order to maximize its instructional effectiveness (Dautenhahn, Bond, Canamero, & Edmonds, 2002). How a learner would perceive their virtual peer seems to be a meaningful factor for the efficacy of the learning environment. At the same time, much of agent research indicates learners' sensitive reactions to agent attributes, such as gender and appearance (Baylor & Plant, 2005; Haake & Gulz, 2008; Kim, Wei, Xu, & Ko, 2007). In particular, Haake and Gulz (2008) argue that an agent's visual appearance carries social baggage that could activate a learner's expectations of the agent. The third question asked 3) *Will learner gender and virtual-peer attributes interact to influence learners' perceptions of a virtual peer?*

Method

Participants

Participants were 141 children in the fourth and fifth grades (68 boys and 73 girls) in an elementary school located in a mountain-west state in the United States. Access to the participants was achieved by collaborating with classroom teachers who volunteered to use the intervention environment in their classes. The study was implemented as a mandatory class activity. The participants were randomly assigned to experimental conditions by the system programming.

Learning environment

Curriculum content

The intervention was an online strategy lesson named Affable Reading Tutor (ART), which was delivered via the Internet. The curriculum included reading comprehension of science texts, combining language arts and science education in keeping with the Benchmarks for Science Literacy set by the American Association for the Advancement of Science (<http://www.aaas.org>) in the USA. Comprehending expository texts is challenging because of the texts' abstract nature and complicated and varied sentence structures (Gersten, Fuchs, Williams, & Baker, 2001). It is particularly difficult for young learners, whose limited background knowledge inhibits their ability to inferentially connect ideas into a coherent

mental representation of the texts (Cote, 1998; McNamara & Kintsch, 1996). Reading strategy must be taught directly to assist those learners.

The specific content identified cause-and-effect relationships using questioning strategy. Questioning strategy was chosen because it was most broadly recommended in the literature on reading strategy instruction (Cerdána, Vidal-Abarcab, Martínez, Gilabert, & Gilb, 2009; Rosenshine, 1986; Spörera, et al., 2009). The National Institute for Literacy (2007) highlights questioning strategy as a way to support struggling readers in the publication *What Content-Area Teachers Should Know About Adolescent Literacy*. To deal with expository texts, readers should “generate questions before, during, and after reading . . . (p. 20).” Questioning thoughtfully while reading helps a reader to gain more information from unfamiliar texts.

In the ART lesson, children read a story about a boy named Ian who set up a weekly training schedule to condition himself to run a marathon. The virtual peer, Chris, demonstrated the questioning strategy and encouraged the learners to use the strategy. Before the learners started reading, Chris explained both cause and effect and how to use the questioning strategy to find the cause-and-effect relationship in sentences. During the reading, Chris demonstrated using the strategy by asking the learners questions about what they have read. He also presented verbal encouragement for the learners to build a habit of questioning while reading. The learners practised identifying causes and effects, guided by Chris’s questioning. The practice problems were presented in different formats, e.g., multiple choice, short answer, and open-ended.

Based on the literature (Guthrie, Wigfield, & Humenick, 2006; van Keer & Verhaeghe, 2005), the author developed Chris’s questions in seven categories: (1) Questions to activate students’ prior knowledge: e.g., *Do you like sports? What’s your favorite sport?* (2) Summarizing questions: e.g., *If you were to summarize the first paragraph in one or two sentences, what information would you include?* (3) Direct questions: e.g., *Why does Ian need regularly scheduled days of rest? What will happen if Ian doesn’t rest his muscles and joints?* (4) Questions to guide writing: e.g., *If you could exercise regularly, what kind of exercise would you do? Why?* (5) Comprehension questions: e.g., *If you can make a title for the story, what would you choose for the title?* (6) Inference questions: e.g., *What would happen if Ian didn’t practise running before he runs a marathon?* (7) Inferential-comprehension questions: e.g., *What is this passage mainly about?* Figure 1 presents example screens of the ART environment, with two variations of Chris (male and female) and without Chris (a still image of a robot as a space filler).



Figure 1. Virtual peer variations in ART

Virtual peer design

Male and female peer images were designed using Curious Labs’ Poser, as shown in Figure 1. Voices of a similar-aged boy and girl were recorded and synchronized with the images. To stimulate a learner’s sense of being related to the virtual peer, the talking style was matched with the target learner group’s style. Facial expressions, blinking, and pointing gestures were added to make Chris look believable and natural.

Independent variables

Virtual-peer presence

Virtual-peer presence had three levels (presence, absence, and control). In Presence, a peer (either male or female, randomly assigned) was present. In absence, students worked in ART without a peer. Instead, a still image of a robot filled the space, and a computer-generated voice-over presented instructional messages. The control group did not take ART and performed the learning task individually with paper-based material. This material presented exactly the same strategy instruction in text and graphics, without a virtual-peer image. Except for the described differences, all three conditions presented the identical instructional content.

Learner gender

Based on the previous agent studies and the preliminary interviews with boys and girls from the target group, learner gender (male versus female) was included as a variable to understand if there would be gender differences in text comprehension and in student perceptions of a virtual peer (research questions 2 and 3).

Virtual-peer attributes

There were three virtual-peer attributes (human-like male, human-like female, and robot image).

Dependent measures

Text comprehension

To measure the students' text comprehension, paper-based pre- and posttests were administered. The pretest included six short-answer questions about a passage on Ian's sunburn after swimming at the beach, e.g., *What caused Ian's sunburn? What was the effect of the sunburn?* The test was administered the day before the intervention and later used as a covariate to control for learners' prior comprehension skills. Two posttests were implemented, one the day after the intervention (immediate posttest) and the other one week after the intervention (delayed posttest). In a short-answer format, each test asked two recall questions on the information presented in the intervention and eight comprehension questions (four questions per passage). Two recall questions asked (1) *What keywords help you identify a cause?* (2) *What keywords help you identify an effect?* Each was awarded three points. The comprehension questions were similar to the pretest. For example, in a passage about rainbows, students were asked questions such as the following: *Let's find the effect, what happens after rainbows occur? What causes the colors to arc across the sky?* The maximum possible score in a posttest was fourteen.

Perceptions of a virtual peer

Learners' perceptions of a virtual peer were measured by a fourteen-item questionnaire, modified from Agent Affability Measures (Kim, Baylor, et al., 2007; Kim, Wei, et al., 2007). At the end of the lesson, learners were asked to express the degree to which they agreed with each item, on a scale from 1 (not at all) to 7 (very much). The statements were as follows: (1) *Chris was friendly*, (2) *Chris was smart*, (3) *Chris was interesting*, (4) *Chris made me feel comfortable*, (5) *Chris was dependable*, (6) *Chris was intelligent*, (7) *Chris was easy to understand*, (8) *Chris was approachable*, (9) *Chris cared about my learning*, (10) *Chris made the lesson interesting*, (11) *Chris made me excited about reading*, (12) *Chris helped me understand better*, (13) *I felt like Chris understood me*, and (14) *I'd like to learn reading skills from Chris again*. Inter-item reliability, evaluated as Coefficient α , was .95.

Procedures

The researcher implemented the ART lesson, assisted by the teachers, to control for teacher influence. Both computer- and paper-based (control group) lessons were entirely self-contained. The learners completed all the tasks individually, depending solely on the information presented in the material. The overall procedures were as follows:

1. The children took a paper-based pretest a day prior to the intervention.
2. On the intervention day, they were randomly assigned to the groups and briefly introduced to the materials.
3. They performed the learning task for one class.
4. They took a paper-based posttest the day after the lesson and another posttest a week after the intervention.

Design and analysis

For research question 1, the independent variable was virtual-peer presence (agent presence, absence, and control), and the dependent variable was text comprehension. This question was answered using one-way ANCOVAs, with a pretest text comprehension set as a covariate, respectively for the immediate posttest and for the delayed posttest.

For research question 2, the independent variables were virtual-peer presence and learner gender (male vs. female), and the dependent variable was text comprehension. Question 2 was answered using two-way ANCOVAs, with a pretest set as a covariate, respectively for the immediate posttest and for the delayed posttest.

For question 3, the independent variables were virtual-peer attributes (human-like male, human-like female and robot image) and learner gender (male vs. female), and the dependent variable was learners' perceptions of their peer. Question 3 was answered using a two-way ANOVA. For all the analyses, the significance level was set at $\alpha < .05$.

Results

Table 1 presents the descriptive statistics of three text-comprehension tests. The pretest was analyzed using a one-way ANOVA, which revealed no statistically significant difference among the groups.

Table 1. Means and standard deviations of text comprehension tests

Tests	Peer presence	Peer absence	Control
Pretest	2.85 (1.12)	2.85 (1.35)	2.18 (1.18)
Immediate posttest	7.86 (.36)	6.36 (.62)	6.46 (.60)
Delayed posttest	8.65 (.23)	8.16 (.38)	7.26 (.35)

Research question 1: The effect of virtual peer presence on text comprehension

For the immediate posttest, the one-way ANCOVA revealed a significant main effect for virtual-peer presence, $F(2, 98) = 3.36, p < .05, \eta^2 = .06$ (a medium effect, according to Cohen's guidelines) (Cohen, 1988). The virtual-peer presence group outperformed the absence group and also the control group.

For the delayed posttest, the one-way ANCOVA revealed a significant main effect for virtual-peer presence, $F(2, 87) = 5.53, p < .01$. The effect size of this difference was evaluated as $\eta^2 = .11$, indicating a medium effect. The Bonferroni post hoc revealed that the virtual-peer presence group significantly outperformed the control group. In conclusion, both immediate and delayed posttests results supported the effectiveness of virtual-peer presence on learners' text comprehension.

Research question 2: The interaction effect of learner gender and peer presence on text comprehension

The two-way ANCOVA revealed neither statistically significant interaction of learner gender and virtual-peer presence nor main effect of learner gender on text comprehension in immediate and delayed posttests. However, as shown in Figure 2, a visual representation suggested an interaction trend that separated boys' and girls' text comprehension by virtual-peer conditions in the two tests. That is, girls' text comprehension was ranked in the order of virtual peer presence

highest, robot image next, and control least whereas boys' text comprehension was in the order of virtual peer (highest), then control, then robot image.

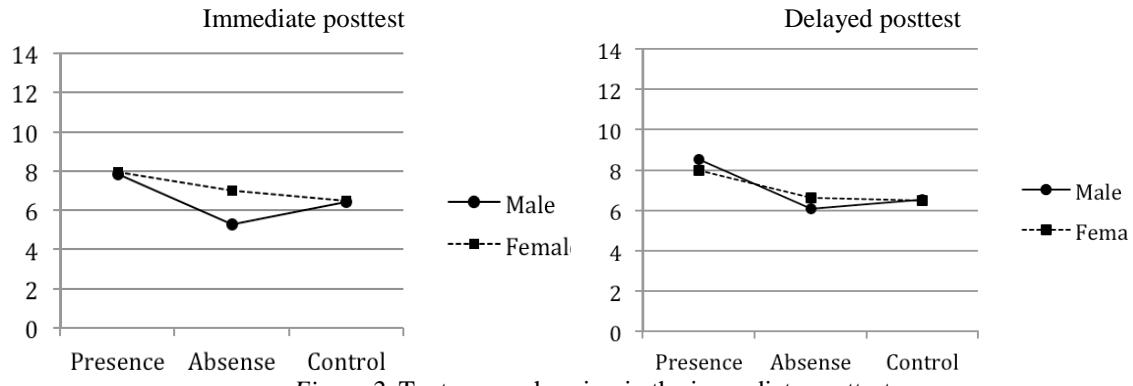


Figure 2. Text comprehension in the immediate posttest

Therefore, one-way ANCOVAs with boys and with girls separately were further conducted to examine statistical differences in each group's text comprehension by virtual-peer presence. The results revealed a significant difference only in the girls' text comprehension in the delayed posttest, $F(2, 46) = 3.62, p < .05$. The Bonferroni post hoc revealed that the girls in virtual peer presence significantly outperformed the control group. The effect size of this difference was evaluated as $\eta^2 = .14$, indicating a medium effect.

Research question 3: The effect of learner gender and peer attributes on peer perceptions

The two-way ANOVA revealed neither statistically significant interaction effects nor main effects of learner gender and virtual-peer attributes on learners' perceptions of their peers. However, a visual representation of the data suggested an interaction trend, as shown in Figure 3. Boys tended to perceive the robot image most favorably whereas girls perceived it least favorably. Therefore, one-way ANOVAs with boys and girls separately were further conducted to examine statistical differences in each group's perception of their peer by virtual-peer attributes. The results did not reveal statistical significance of virtual-peer attributes on the boys' perceptions of the agent nor on the girls' perceptions.

Incidentally, the author tested boys' and girls' text comprehension by virtual-peer attributes. The results revealed a significant difference on the boys' text comprehension in the immediate posttest, $F(2, 35) = 8.65, p < .001$. The effect size of this difference was evaluated as $\eta^2 = .33$, indicating a strong effect. The boys in the male-peer condition outperformed the female-peer group ($p < .001$) and also the robot image group ($p < .01$). This difference was not observed among the girls.

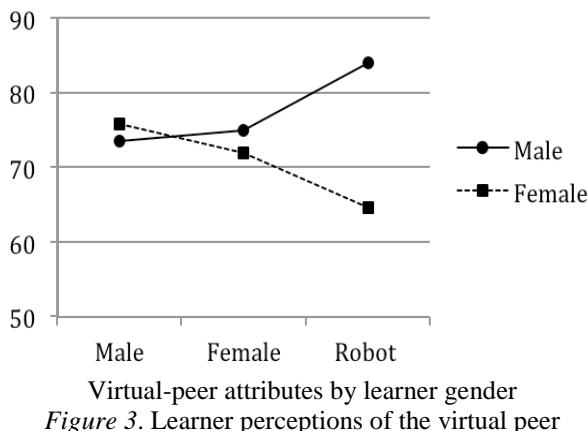


Figure 3. Learner perceptions of the virtual peer

Discussion

This study explored whether a virtual peer would be able to simulate the role of a peer model in conventional settings so as to effect computer-based reading-strategy instruction. Although direct and individualized reading strategy instruction is essential for children who start reading to comprehend, reading strategy instruction has not been actively applied in CALL. Also, some conventional reading programs present the concepts, examples, and strategies in text or at best in images. This manner of information presentation seems untenable, particularly for young readers who start reading to comprehend. First, children might be less engaged in learning reading strategies because of the impersonal nature of written texts presented on the screen. Text may not be sufficiently motivating to promote strategy use. Second, learners need constant reminders and encouragement to use the learned strategy. The author examined the use of the social and affective affordance of virtual-peer technology to provide more engaging strategy instruction for young children. The results of the study, in general, supported the benefit of virtual peer technology as a viable tool to offer effective strategy instruction in CALL.

Regarding the effectiveness of virtual-peer presence on text comprehension, the results supported the effectiveness of virtual-peer technology on learning. This study, implemented in natural classrooms, added evidence for the positive impact on learning gains that have been inconclusive in the virtual-peer (or pedagogical-agent) literature. A number of empirical studies in agent technology conducted over the last decade have supported agent technology's effectiveness on learner affect, including interest, motivation, attitudes, or engagement, with different age groups. There is a consensus among the researchers on the effectiveness of agent presence on learner affect and motivation. However, only a few studies have shown the effectiveness on learning gains (Atkinson, 2002; Graesser, Moreno, & Marineau, 2003; Moreno, Mayer, Spires, & Lester, 2001). In this study, the fourth- and fifth-grade boys and girls more effectively increased their comprehension of expository texts after working with a human-like virtual peer, compared to the peer absence groups. One reason is that the virtual peer might play a social role as a peer model to motivate the learners to engage. More important, the peer was equipped with solid pedagogy for strategy instruction recommended by the reading research community. Designers often seem to focus on maximizing the affordance of a technology and overlook the importance of content pedagogy. To be effective, however, technological affordance should be orchestrated integrally with subject-matter pedagogy. This might be analogous to a capable human teacher or peer in classroom. Teacher presence alone might not be sufficient to produce increased learning. The teacher must be well versed in the content and in pedagogical approaches to foster successful learning. Also, the social and affective dynamic seems to play a pivotal role in reading instruction for a learner's willingness to try. Just as the virtual peer's supportive demeanor might facilitate the learner's engagement, so do the supportive relationships with the teacher or peer help inspire a learner to read in a classroom.

Regarding the impact of learner gender, this study resulted in somewhat mixed findings. When both learner gender and virtual-peer presence were included in the analysis, there was no statistically significant gender difference. However, when the impact of peer presence was examined with boys only and with girls only, the results revealed different patterns of gender difference in text comprehension. The girls' text comprehension in the delayed posttest was significantly higher in the virtual-peer presence condition, compared to the peer-absence group, who used ART without a peer, and also to the control group, who used a paper-based material. The boys' text comprehension was significantly higher in the immediate posttest in the male-peer condition than the female-peer condition and the robot-image condition.

These findings seem to be in line with agent literature. First, female students show more positive attitudes toward agent presence and perform better after working with an agent or at computing applications supporting social interactions (Cooper & Weaver, 2003; Hakkarainen & Palonen, 2003; Kim et al., 2007; Passig & Levin, 2000; Weber & Custer, 2005). Second, studies revealed the superior effectiveness of a male agent to that of a female agent, regardless of learner gender (Baylor & Kim, 2004; Kim, Baylor, et al., 2007). The authors in these studies attributed the differential effectiveness to the influence of gender-related social biases (Carli, 1999, 2001). The current study revealed a similar pattern in learner and agent gender, but less strongly, possibly due to the developmental stage of the boys and girls. Literature in social psychology indicates that students over the age of thirteen are considered typically imbued with gender-related stereotypes (Dunham, 1990). The learners in this study did not seem to possess established gender-based biases for their learning, or perhaps these biases still remained at a subliminal level.

Debriefing with the learners also revealed a consistent pattern. The author asked the learners about their preferences for virtual-peer gender in future applications. Although several boys and girls articulated their preferences, the majority looked uninterested in the issue. This might also explain why the learners' perceptions of their peer were not differentiated by virtual-peer attributes, in contrast to previous agent studies with adolescents and college students.

Third, regarding the impact of virtual-peer attributes, the study did not produce sufficient evidence for the boys' and girls' differential reactions to virtual-peer attributes. This result might be related to the second point. The learners did not seem to have developed stereotypical expectations for agent appearance (Haake & Gulz, 2008). This age group might be at the stage where we can effectively intervene to prevent from undesirable gender- or race-related stereotypes, using agent technology. As Haake and Gulz suggested, virtual peers could be flexibly designed to have a range of identities and styles for educational purposes and counter negative social influences in the real world.

One thing to note is a trend that girls' perceptions of their virtual peer were ranked consistently with their learning gains. They perceived a human-like virtual peer—regardless of its gender—most favorably and comprehended text highest in the peer condition. On the other hand, boys' perceptions of the virtual peer were ranked opposite to their learning gains. The boys perceived a robot image with synthetic voice-over most favorably, but performed poorest in that condition. Perhaps the boys perceived the robot as fun, which, in turn, triggered a play mood and made the boys less serious about the learning task. Learners' readiness must be a consideration in the design of virtual-peer attributes. Careful analysis of learners, immediate and long-term learning goals, and learning contexts should be warranted prior to launching the design.

A few recommendations are made to expand and confirm the findings. First, subsequent research should examine learners' strategy use. The frequency of their strategy use in the following reading task will better inform us of the effectiveness of virtual-peer modeling and the relational bond between a learner and the peer. Second, it would be worth examining the relationship between fun learning experience and actual learning gains in technology-based learning (e.g., virtual-peer-based learning, simulations, and games). Third, the findings provide only initial evidence for the potential of a virtual peer for effective strategy instruction and should be generalized judiciously. Because virtual-peer technology was new to the learners, we cannot exclude the possibility of the novelty effect. Future research should confirm the finding over the long term.

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Design of a Dual-Mapping Learning Approach for Problem Solving and Knowledge Construction in Ill-Structured Domains

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ABSTRACT

Problem solving has been increasingly used as an important approach to learning especially in ill-structured domains. It is assumed that knowledge can be better consolidated and extended through problem-solving experience. However, many learners do not have the ability to separate general knowledge from specific cases, which inhibits successful transfer of knowledge to new situations. This study addressed the challenge by proposing a dual-mapping learning approach that involves argument mapping and concept mapping to externalize and integrate problem-solving and knowledge-construction processes in problem-based learning. A preliminary study of the design and effects of the approach is reported. Findings show its effectiveness in improving both problem-solving and knowledge-construction performance.

Keywords

Problem-based learning, Problem solving, knowledge construction, Educational technology

Introduction

A critical element of fostering learning is to have learners to carry out tasks or solve problems in an environment that reflects the use of knowledge into practice (Brown, Collins & Duguid, 1989). It is assumed that learning can be better acquired through problem-solving experience. However, many learners do not have the ability to separate general knowledge from specific cases as they focus on surface features of problems rather than on the development of an understanding of the problem domain (Kirschner et al., 2006). This problem inhibits the likelihood of successful transfer of knowledge to new situations. While problem-based learning (PBL) is increasingly used in medical education and other ill-structured domains, there is a concern about its impact on learners' knowledge base (Albanese & Mitchell, 1993; Gijbels et al., 2005; Hartling et al., 2010).

It is crucial to reveal what is entailed in PBL experience and examine how knowledge construction can be better supported in PBL. However, both problem solving and knowledge construction are complex cognitive processes that cannot be easily captured and mastered. Knowledge gained from practice is found difficult to retain and reuse as a result of contextualization and dynamic aspects of actual problem-solving practice (Patel et al., 2009a). Although situated learning and cognitive apprenticeship (Collins, Brown & Holum, 1991) theories offered guidelines and strategies to facilitate learning in problem contexts, how practice and knowledge reciprocate each other has been overlooked in existing studies.

This study aims to address the challenge by proposing a dual-mapping learning (DML) approach for externalizing and integrating complex problem-solving and knowledge-construction processes. Medical education was selected as the domain for this study, as problem-solving experience is regarded as crucial to learning and expertise development in this field. Moreover, computer-based technology is increasingly used in various aspects of medical education (Kushiniruk, 2011). The DML approach focused on a computer-based dual-mapping cognitive tool and implementation of the tool into an online environment for PBL.

The objective of the study was to design, implement, and evaluate the DML approach. A design-based research paradigm was therefore adopted for the study. Design-based research is a systematic methodology that creates, builds, and evaluates innovative artifacts or interventions to deal with identified problems in educational practices (Reeves,

2006). Although PBL has advantages of promoting active and reflective learning, there are concerns about its weakness in general study design, and careful research is needed to understand whether and how potentials of PBL might be realized (Hmelo-Silver, 2004). Design-based research is particularly important in such kind of situations that complex and ambitious educational reforms are ill-specified and the implementation process is uncertain (Wang, Vogel & Ran, 2011). Design-based research contains two key components: design and evaluation of the proposed artifact or intervention. Accordingly, the research questions of the study include: (1) how can the DML approach be designed to externalize and integrate problem-solving and knowledge-construction processes? and (2) how effectiveness is the DML approach in PBL?

Design-based research usually involves four steps: problem analysis, solution development, solution testing and refinement, and reflection on design principles (Reeves, 2006). In this study, the requirement of constructing systemic knowledge in PBL is analyzed in the introduction and related work sections; a theory-driven design of the DML approach is discussed in the theoretical framework, conceptual design, and implementation sections; testing of the DML approach is reported in the evaluation section; and findings of the study in terms of answers to the two research questions are summarized in the discussion section, followed by conclusions at the end.

Related work

Problem-based learning (PBL)

PBL is a pedagogical approach that situates learning in complex problem-solving contexts. In view of its emphasis on active, transferable learning and its potential for motivating students, PBL has been increasingly adopted in ill-structured domains such as medicine education, and widely used in a variety of settings from school to professional education. For effective learning through practical experience, problem solving and knowledge construction should reciprocally reinforce (DeGrave, Boshuizen & Schmidt 1996). However, many studies have tackled problem solving and knowledge construction separately, failing to see them as an integrated two-way process. In the medical domain, many studies examined the novice-expert difference in problem-solving behaviors including data identification, hypothesis generation, and reasoning and justification, while other studies investigated structures or models used by experts to organize their knowledge (Patel et al., 2009b), with little connections between the two themes.

Interactions between problem solving and knowledge construction

While there is no doubt that problem solving requires well-organized knowledge in addition to general problem-solving skills and strategies, it remains somewhat opaque how an expert's knowledge base is successfully constructed (Wu & Wang, 2012). Practical experience is found to train more routine experts than adaptive experts who continually learn and update their knowledge based on experiences with novel problems and situations (Mylopoulos & Regehr, 2007). Similar views can be found from the study on mind-practice dualism in professional skills development (Dall'Alba & Sandberg, 2006). In response to the challenge, there are a few studies to investigate the transformation from practice to knowledge. Studies on cognitive apprenticeship claimed that masters often have difficulties instructing novices by failing to take into account the implicit processes involved in carrying out complex skills, and teachers are therefore encouraged to identify the processes of abstract tasks and make thinking involved in these tasks visible to learners (Collins et al., 1991). Jonassen (2011) emphasized the problem representation as a key to problem-centered learning. Ericsson (2009) and Dall'Alba and Sandberg (2006) highlighted the importance of revealing mental processes and mechanisms involved in problem-solving activities to understand learning from practical experience. Kinchin, Cabot and Hay (2008) suggested to routinize the interactions between practice and underlying understanding to improve expertise development in higher education. However, these views and suggestions are limited to initial conceptions, lacking investigations on viable methods to realize the ideas and their effects on PBL practice.

Computer-based cognitive tools

Computer-based cognitive tools are recommended to facilitate learning in problem contexts (Jonassen, 2005). By reflecting human cognition through visual representations on the screen, computer-based cognitive tools have been

increasingly used to augment cognition, foster thinking, and facilitate inquiry and self-directed learning (Wang et al., 2011). Two types of cognitive tools are directly relevant to this study. *First*, argument mapping can be used to represent reasoning and decision making processes in problem solving (Fox et al., 2007). It is a visual representation of an argument's structure in informal logic involving fact, claims, explanations, evidence, and rebuttals (Kirschner et al., 2003). *Second*, concept mapping can be used to represent conceptual understanding underlying problems. It is a visual representation of concepts and their relationships, mainly for representing and organizing domain knowledge (Novak & Canas, 2008) and is increasingly used to facilitate and assess in-depth understanding and critical thinking in complex situations (Spector, 2006). However, most studies on cognitive tools have been limited to the use of the tools in specific teaching or learning activities, rather than the design of systemic teaching or learning strategies or environment.

Theoretical framework

The proposed DML approach was underpinned by the cognitive apprenticeship model (Collins et al., 1991), an instructional paradigm based on situated cognition and directly aligned with PBL. Based on the cognitive apprenticeship model, learning in problem contexts should consider: (a) situating abstract tasks in authentic contexts, (b) making complex tasks and thinking processes visible, and (c) providing necessary help to learners. Different from traditional schooling methods, the cognitive apprenticeship model emphasizes that abstract tasks and thinking processes must be made visible, i.e., making expert knowledge and practice explicit for learners to observe, enact, and finally practice. Further, six cognitive strategies including articulation, reflection, exploration, modeling, coaching, and scaffolding are proposed in the cognitive apprenticeship model.

In addition to the cognitive apprenticeship model, the DML approach was proposed based on the need for integrating problem-solving and knowledge-construction processes and the potential of computer-based cognitive tools in facilitating cognitive processes. Accordingly, the DML approach was featured by a dual-mapping cognitive tool designed based on two models for problem solving and knowledge construction, respectively. *First*, the SOI (selecting, organizing, and integrating) model proposed by Mayer (1996) describes the *knowledge-construction* process and mechanism. The model involves three sequential cognitive steps: (a) selecting relevant information for further processing in working memory (WM), (b) organizing incoming information into a coherent representation in WM, and (c) integrating incoming information with prior knowledge in long-term memory (LTM). To externalize these mental activities in knowledge construction, *concept mapping* can be directly applied to conceptualize knowledge and extend it into a progressively more complex network of understanding.

Second, a computational model proposed by Dougherty, Thomas and Lange (2010) outlines the hypothesis-led *problem-solving* process and mechanism. The model focuses on the relationships among the environment (e.g., perceptual information), memory system (including exemplar/episodic memory and semantic memory), and problem-solving behaviors (including hypothesis generation, probability judgment, and hypothesis testing). While solving a problem, the observed data trigger traces from the exemplar memory, which, in turn, matches the known hypotheses from the semantic memory. During the matching process, possible hypotheses are generated and tested before making a judgment. The process is iterative and dynamic, where hypotheses can be updated when new data are encountered. To make such complex, dynamic processes visible to learners, argument mapping can be directly applied to represent and justify problem-solving activities.

Conceptual design

The DML environment was design to consist of (a) an exploratory problem context for interaction with problems, (b) a dual-mapping cognitive tool for articulation and integration of problem-solving and knowledge-construction processes, and (c) expert support to facilitate the learning process. The dual-mapping tool is the core of the DML environment. It involves concept mapping and argument mapping for externalizing and integrating problem-solving and knowledge-construction processes. The learner starts the learning process by selecting and exploring a problem case and representing problem-solving actions into hypothesis generation, hypothesis justification, and diagnostic conclusion in an argument map. While solving the problem, the learner needs to recall prior knowledge or derive

new understanding, which can be represented in a concept map for easy reference and update throughout the learning process.

Argument mapping and concept mapping play different roles in the DML approach (see Figure 1). Argument mapping helps to sharpen problem-solving skills through building coherent and well-grounded argumentation structure (Fox et al., 2007). Concept mapping helps to pull out domain knowledge and conceptualize contextual knowledge (Spector, 2006). More importantly, the two types of mapping processes are integrated so that (1) the argument map explicates problem-solving experience for generating new understanding for reuse; and (2) the concept map provides anchored points for solving problems based on relevant knowledge and for integrating new understanding with prior knowledge.

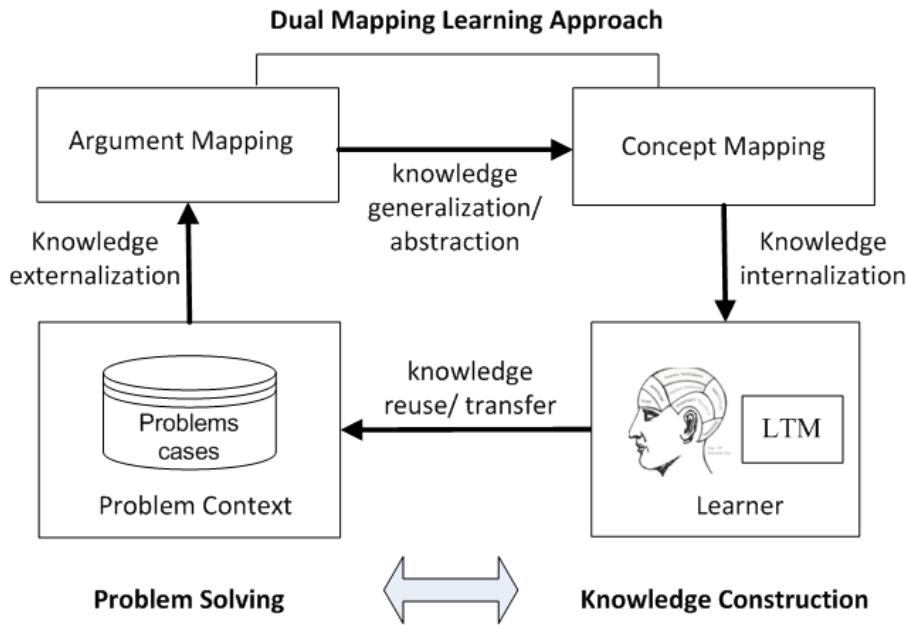


Figure 1. Conceptual framework of the DML approach

The six cognitive strategies rooted in the cognitive apprenticeship model are incorporated into the DML approach.

- *Exploration* refers to pushing learners into a mode of problem solving on their own. In this study, a problem context was set up to help learners to explore problems and solutions autonomously.
- *Articulation* refers to getting learners to articulate their knowledge, reasoning, or problem-solving processes. In this study, the dual-mapping cognitive tool was proposed to help learners to articulate their problem-solving and knowledge-construction processes.
- *Reflection* refers to enabling learners to compare their own problem-solving processes with those of others. In this study, learners could review their PBL processes presented in dual maps and compare them with feedback or advice from the expert.
- *Modeling* refers to providing learners with examples of desired performance usually from teachers or experts. In this study, the PBL process with a sample case using the DML environment was demonstrated to learners.
- *Coaching* refers to observing a learner's performance and providing feedback and advice on the performance. In this study, computer-generated adaptive feedback and hints were provided for individual learners throughout the learning process.
- *Scaffolding* refers to providing help to learners for tasks that learners are unable to complete autonomously. In PBL, learners may suffer from high cognitive load, and easily get lost and feel frustrated by a number of complex, dynamic tasks. In this study, the PBL process was decomposed into a set of tasks, the flowchart of which was provided to scaffold the complex learning process.

Implementation

Based on the conceptual framework, a web-based DML system for learning with clinical diagnostic problems was implemented. It consisted of the following key components.

Exploratory problem context

The learner could start the learning process by accessing a clinical case in the “exploratory problem context” window. The case information was represented in texts, charts, and images, as shown in Figure 2. The information was organized first by clinical date and then by content, categorized into patient history, physical examinations, lab tests, imaging records, patient state, and prescription history. The learner could check the initial information of the case and perform clinical actions to achieve additional information.

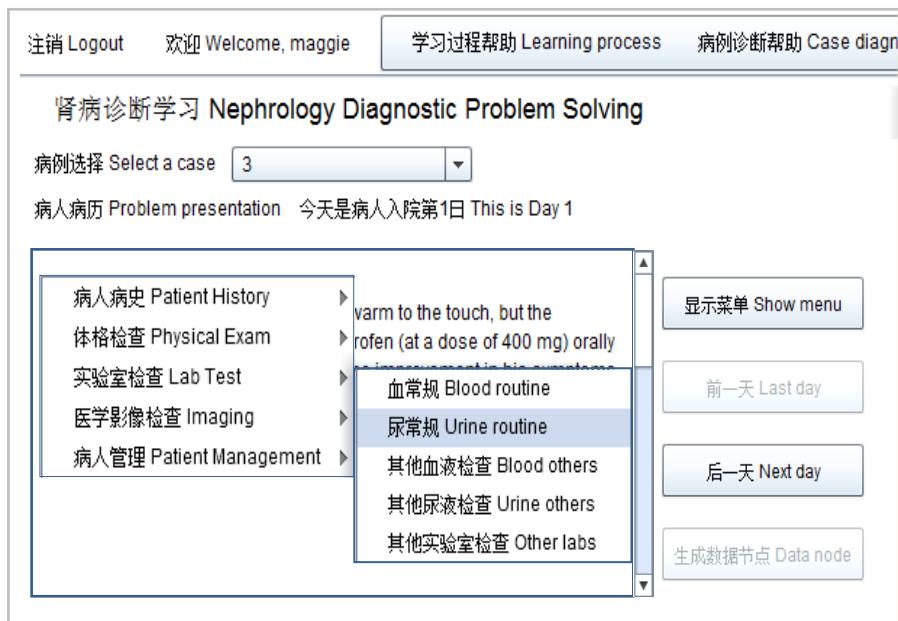


Figure 2. Exploratory problem context

Most clinical cases are progressive, in other words, a patient's information is not received in one snapshot. In the DML system, each piece of patient information was given a label starting with “Dx” to indicate the patient data for the x-th day. To obtain sufficient information of a case, the learner had to make hypothesis-led information search in a progressive way.

Dual-mapping cognitive tool

The dual-mapping cognitive tool was designed to visualize and integrate the problem-solving and knowledge-construction processes in PBL. As shown in Figure 3, the tool consisted of an argument mapping panel and a concept mapping panel. The learner could use the argument mapping panel to represent the diagnostic and reasoning processes in the argument map. In addition to data nodes, the learner could generate one or more hypothesis nodes in the argument map. The strength of a hypothesis was reflected by the border of the hypothesis node - the heavier the border the stronger the hypothesis, while the strongest one was the diagnosis node. Each hypothesis node could be linked with relevant data nodes based on two types of reasoning links, namely support and against. The strength of a reasoning link was reflected by the width of the arrow-line that linked the nodes, the wider the arrow-line the stronger the link. The learner could justify their reasoning actions by adding brief text to the reasoning links. Further,

the learner could generate one or more evidence nodes to support the justification, and each evidence node could be linked to external references such as journal articles and books.

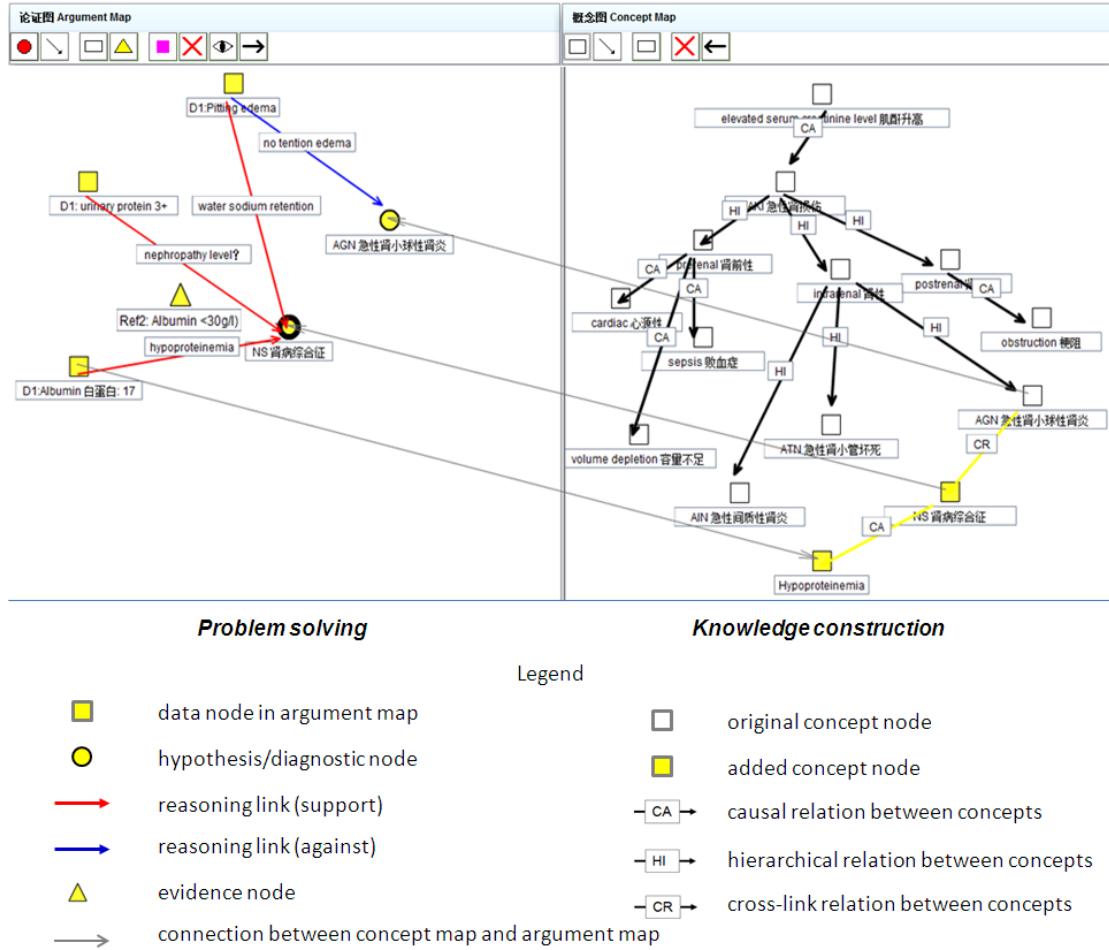


Figure 3. Dual-mapping cognitive tool

On the other hand, the learner could use the concept mapping panel to represent his/her understanding of the domain knowledge into concept nodes and their relations (including hierarchical, causal, and cross-link). An initial version of the concept map covering a few basic concepts with their relations was provided in the system. The learner was required to update the concept map by adding missing concepts and relations. New concept nodes could be generated by retrieving relevant terms or adding new terms from the system.

To capture interactions between problem solving and knowledge construction, the learner could connect nodes in the concept map with relevant nodes in the argument map to indicate the knowledge that supports the problem-solving process, or connect nodes in the argument map with relevant nodes in the concept map to explicate the knowledge generated from the problem-solving process. Moreover, the learner could use other features of the tool to zoom in/out the maps, show/hide explanations or evidence nodes, and adjust the display of hypothesis nodes according to its strength.

Figure 3 represents a part of the DML process for diagnosing a nephrotic syndrome case. First, pitting edema and urinary protein are generated as two data nodes in the argument map according to the patient's chief complaint. The captured data trigger the recall of knowledge about acute glomerulonephritis (AGN) and nephrotic syndrome (NS). The former is already represented in the concept map while the latter is not. Therefore, NS is added to the concept map and linked with AGN. Further, the two concepts are applied to generate two hypotheses in the argument map. The pitting edema symptom supports the NS hypothesis since renal retention of sodium and water may cause edema. However, this symptom does not support the AGN hypothesis as AGN is more likely to cause tension edema rather

than pitting edema. Moreover, the urinary protein sign corroborates the possibility of NS and raises the doubt of nephropathy-level protein in urine. A 24-hour urine protein test is then requested, and the low-level albumin (also called hypoproteinemia) confirms the NS hypothesis by the evidence of albumin less than 30g/L. Accordingly, hypoproteinemia is added to the concept map with a causal link to NS.

Scaffolding and coaching support

Problem solving usually contains a number of complex, dynamic, and interactive tasks, making learners easily get lost and feel frustrated. In this study, the PBL process is decomposed into a set of tasks to scaffold the complex learning with problems.

- *Perform clinical actions.* The learner accesses the initial information (e.g., chief complaint) of the case and performs clinical actions for further information.
- *Identify critical information.* After identifying the critical information of the case, the learner generates relevant data nodes in the argument map.
- *Recall and update knowledge.* While solving the problem, the learner recalls relevant knowledge, which can be represented in the concept map, and updates the concept map throughout the learning process.
- *Generate hypotheses.* Based on the case information and relevant knowledge, the learner generates one or more hypotheses in the argument map.
- *Justify hypotheses.* To reach a conclusion, the learner justifies the hypotheses by adding reasoning links and supporting evidence to the argument map.
- *Make a diagnostic conclusion.* After some iterative explorations and analyses, the learner makes a diagnostic conclusion in the argument map.

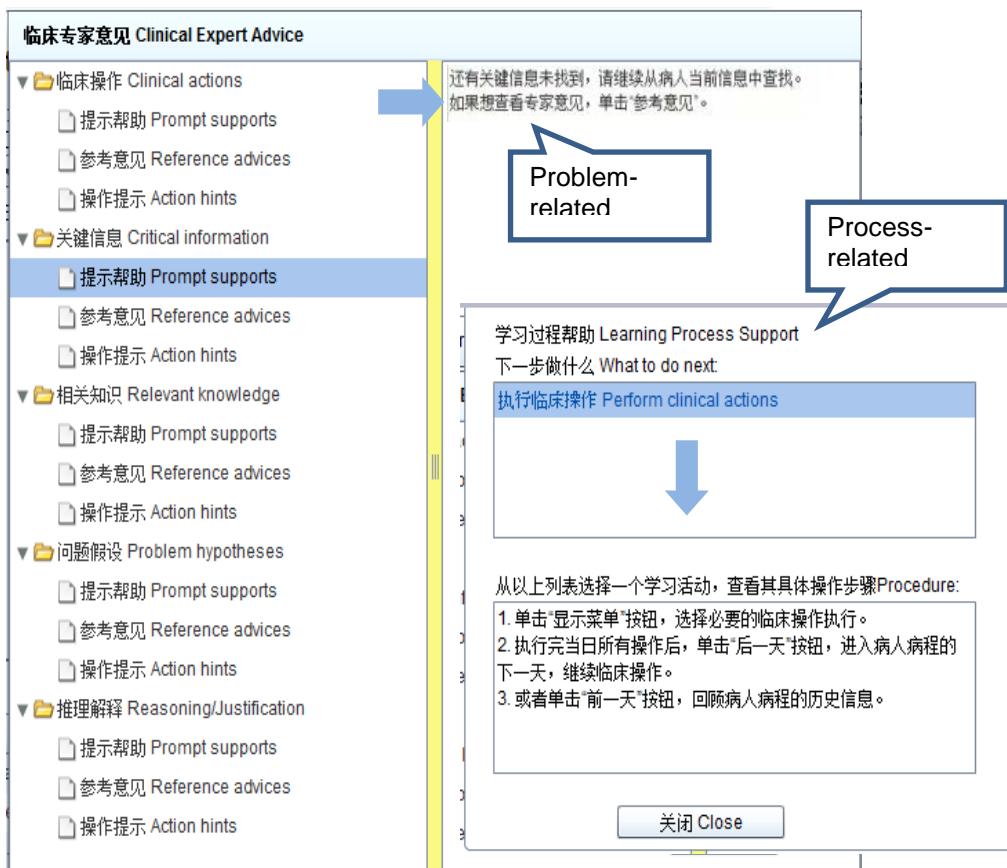


Figure 4. Coaching support

In addition to the scaffolding of the general learning process, individual coaching was provided to learners. The coaching support involved process- and problem-related guidance as shown in Figure 4. Both were generated by the system and adaptive to individuals. The process-related guidance involved suggestions on what to do next according to the learner's progress. The problem-related guidance was relevant to the solution of the case, categorized into clinical actions, critical information, relevant knowledge, problem hypotheses, and reasoning and justifications. In addition, a summative report of the solution to the case made by the expert could be accessed by the learner after he/she completed the learning with that case.

Evaluation

To examine the effectiveness of the proposed approach, the DML environment was used and evaluated by medical students. A preliminary evaluation was carried out with two first class medical schools in China, one at Tongji University and another at Southeast University. PBL had been adopted by both schools, but limited in scope. Two domain experts and one instructor from the two schools were invited to participate in the study. They provided support in selection of the clinical cases and assessment of students' learning outcomes. An online PBL program involving five clinical cases about the kidney disease was provided in the system. The cases were collected and adapted from clinical practice and academic references.

A combination of quantitative and qualitative methods including surveys, interviews, tests, and DML products were used for evaluation. Data triangulation was employed by using both survey and interviews to examine participants' perceptions of the DML system, and by using traditional tests, self-perceived learning gains, and DML products to assess the learning outcomes.

Participants

Twenty-nine students from the two schools participated in the preliminary use and evaluation of the DML environment. They had fundamental medical knowledge but little clinical experience. Their participation in this study was fully voluntary. 65.5% of the participants were females and 34.5% males. Most of them (65.5%) were in the fourth year of their seven-year medical curriculum (including five years of undergraduate study and two years of graduate study). Most of them reported to have intermediate (41.4%) and good (41.4%) computer skills. Their intention to use technology for learning was between neutral (41.4%) and positive (41.4%).

Procedure and instruments

Before using the DML system, participants were administered a survey to collect their demographic information. A face-to-face demonstration of how to use the system to perform PBL with a sample case was then provided to the participants. After some exercise with the sample case, the participants started to learn with other four cases in the system. They were required to complete the learning program in their free time within four weeks. During the learning period, the instructor helped to facilitate the learning process when needed.

A *pre-test* and *post-test* were used to assess the learning outcome. The questions of the tests were adapted from relevant text books (Clatworthy, 2010) for assessing problem-solving knowledge and skills in diagnosing the kidney disease. At the end of the learning program, learners' evaluations of the DML environment and their perceived learning gains were collected in a *survey*. The items measuring learners' perceptions (usefulness, ease of use, and intention to use) of the learning system were adopted from the information technology acceptance literature (Davis, 1989). The items measuring learners' perceived learning gains with regard to problem-solving and knowledge-construction abilities were adopted from the well established Student Assessment of their Learning Gains (SALG) instrument (WCER, 2011). These measures have been internationally validated and widely used. Internal consistency of these instruments was assessed in this study using Cronbach's α , and the reliability coefficients for all the subscales were higher than .70.

Semi-structured interviews were arranged with all the participants at the end of the program to collect their comments on the advantages and disadvantages of the DML system. The interview data were coded and analyzed by

two raters, and Cohen's Kappa was used to measure the agreement between the raters on the themes identified from raw interview responses. The result (Cohen's Kappa = .87) showed a high degree of consensus between the raters. Moreover, students' *DML products* generated in the learning system were assessed based on the criteria adapted from prior studies (Srinivasan et al., 2008; Facione & Facione, 2008; Jonassen, 2011). The rubrics involve quantity and quality of five items including data nodes, hypothesis nodes, and reasoning links in the argument map, and concept nodes and relations in the concept map. Each item was scored on a 5-point Likert scale and normalized to a scale between 0 and 1. The overall dual-mapping score of a case was the average of the scores of the five items. Moreover, the connections between the argument map and the concept map built by learners were analyzed to examine the interactions between the problem-solving and knowledge-construction processes.

Findings

Findings from evaluation survey

Learners' evaluations of the DML environment and its main functions collected from the survey questionnaire are summarized in Table 1. The overall system and its main functions were perceived to be useful. Regarding ease of use, learners' evaluations of the problem context and scaffolding and coaching support were found positive, while their evaluations of the overall system and the dual-mapping tool were weakly positive. Accordingly, learners' intention to use the system was weakly positive.

Table 1. Learners' evaluation

	OVER_USE	EPC_USE	DMT_USE	SCS_USE	OVER_ITU
<i>M</i>	2.62	2.68	2.57	2.55	2.47
<i>SD</i>	.81	.72	.84	.64	1.04
	OVER_EOU	EPC_EOU	DMT_EOU	SCS_EOU	
<i>M</i>	2.05	2.40	2.07	2.21	
<i>SD</i>	.99	.67	.92	.83	

Note. USE: usefulness; EOU: ease of use; ITU: intention to use; OVER: overall system; EPC: exploratory problem context; DMT: dual-mapping tool; SCS: scaffolding and coaching support (5-point Likert scale: 0 represented "strongly disagree" and 4 represented "strongly agree")

Learning outcomes

The learning outcomes were assessed based on the tests, self-perceived learning gains, and DML products. The test papers were graded by the instructor, and the scores were normalized to a scale between 0 and 1. The paired-sample *t* test indicated that there was no significant difference between the pre-test and post-test scores, albeit a slight increase in the mean score (pre-test *M* = .24; post-test *M* = .29, *p* > .05).

With regard to the self-perceived learning gains, participants reported nearly moderate level of progress in both problem-solving and knowledge-construction abilities (see Table 2).

Table 2. Self-perceived learning gains

	PSA	KCA
<i>M</i>	1.87	1.97
<i>SD</i>	.88	.98

Note. PSA: problem-solving abilities; KCA: knowledge-construction abilities (5-point Likert scale: 0 represented "no progress" and 4 represented "large progress")

On the other hand, the dual maps generated by learners from the first and last case were blindly assessed by the two domain experts based on the predefined rubrics. The inter-rater reliability of assessment by the two raters was .91, significant at the .01 level. The average of the two raters' ratings was used for further analysis. In addition, Pearson's correlation coefficient was calculated to test the consistency between the dual-mapping score and test result. The dual-mapping scores of the last case were found to be significantly correlated with the post-test scores (*r* = .73, *p* < .01).

Details of the descriptive statistics and paired-sample t tests to compare the dual-mapping performance between the first and last case were presented in Table 3. A significant improvement in overall performance was found from the first to the last case ($t(28) = 5.72, p = .000$). The effect size (Cohen, 1988) was 1.17, indicating large progress in dual-mapping performance from the first to last case. As the dual-mapping performance in the five items were concerned, there was a significant improvement from the first to the last case in all items except the “reasoning links.” When associating the five items with learners’ problem-solving and knowledge-construction performance, it was found that participants’ problem-solving performance (reflected in data nodes, hypothesis nodes, and reasoning links) was better than their knowledge-construction performance (reflected in concept nodes and concept relations) for both the first and last case. Furthermore, the knowledge-construction performance presented larger variations among the participants in the last case than in the first case.

Table 3. Dual-mapping scores for the first and last case (scores range from 0 to 1)

	First case		Last case		Paired-sample t tests		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>
DaN	.44	.16	.58	.12	3.92	28	.002**
HyN	.25	.15	.35	.13	2.80	28	.017*
ReL	.23	.17	.35	.20	1.73	28	.111
CoN	.17	.16	.35	.31	3.45	28	.005**
CoR	.13	.17	.23	.25	2.80	28	.017*
Overall	.24	.11	.38	.14	5.72	28	.000**

DaN: data nodes; HyN: hypothesis nodes; ReL: reasoning links; CoN: concept nodes; CoR: concept relations

* $p < .05$;

** $p < .01$

To further analyze the change of dual-mapping performance from the first to the last case, Table 4 presents the descriptive statistics and the paired-sample t test results regarding the numbers of connections between problem solving and knowledge construction. There was a significant improvement from the first to the last case ($t(28) = 2.67, p = .045$) in the number of connections from problem solving to knowledge construction (represented by the links from the argument map to the concept map), but no significant difference in the number of connections from knowledge construction to problem solving (represented by the links from the concept map to the argument map).

Table 4. Numbers of connections

	First case		Last case		Paired-sample t tests		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>
PS2KC	2.33	1.50	3.83	1.79	2.67	28	.045*
KC2PS	2.17	1.17	2.50	1.39	0.79	28	.465

Note. PS2KC: from problem solving to knowledge construction; KC2PS: from knowledge construction to problem solving.

* $p < .05$

Findings from interviews

All the participants were interviewed regarding their comments on the advantages and disadvantages of the DML system. Table 5 outlines the interview result.

Table 5. Summary of interview responses from learners (n = 29)

Positive comments	No. of hits
The DML environment is useful for knowledge construction.	20
The DML environment is useful for problem solving.	19
The expert support is helpful for learning.	10
The DML environment is innovative.	5
The problem cases are well-prepared.	5
The DML environment supports self-directed learning	3
Negative comments	No. of hits

The dual-mapping tool is somewhat complicated.	15
Some interfaces of the system are not very user-friendly.	7
More guidance on dual-mapping learning is needed.	6
Problems cases should cover different levels of difficulty	3

Most learners found the DML environment useful for both problem solving and knowledge construction. As one mentioned, “The system gives us a clear and systemic picture of main tasks involved in clinical problem solving. It is very helpful for developing logic thinking and reasoning skills.” Another participant commented, “It is usually difficult to manage complex and separate pieces of knowledge for clinical problems, but this system provides a useful approach to making knowledge well organized and connected.” Learners also felt the expert support provided by the system helpful for their self-directed learning, especially for checking missing points in their understanding and thinking. Some of them mentioned that the DML was innovative and the clinical cases were well-prepared, and they felt such kind of learning system could benefit a large number of learners for clinical professional development. On the other hand, many learners reported that the dual-mapping cognitive tool was somewhat complicated, and some interfaces that were perceived not very user-friendly. Some participants also felt DML challenging especially under the situation without immediate face-to-face instructions. They suggested more learning guidance provided for DML.

The instructor and domain experts were also interviewed for their comments on the DML system and its impact on teaching. They expressed their clear interest in the DML approach and positive comments on DML system with its ability to stimulate learners’ motivation and sense of autonomy for learning. As the instructor said, “Different from traditional spoon-fed learning, the proposed system is unique in activating learners’ curiosity for learning with real problems. It provides learners with valuable experience of learning with a high degree of autonomy.” Further, they commented that most medical schools in China did not allocate sufficient time and resources for teaching sophisticated skills of problem solving, and that there was a high demand to incorporate such kind of problem-centered learning system into the traditional classroom to benefit more learners from blended learning experiences.

Discussions

The findings of the study are discussed as the answers to the two research questions. With regard to the *first question*, a DML environment was designed and implemented for externalizing and integrating problem-solving and knowledge-construction processes. Based on the cognitive apprenticeship model and its cognitive strategies, the DML environment was designed to incorporate an exploratory problem context for *exploration* with problems and solutions, a dual-mapping cognitive tool for *articulation* and *reflection* of cognitive processes in problem solving and knowledge construction, and *scaffolding* and *coaching* support to facilitate the complex learning process. In particular, the computer-based dual-mapping cognitive tool, a core element of the DML environment, was designed by taking into account the hypothesis-led mechanism for problem solving and the SOI (selecting, organization, and integrating) model for knowledge construction. It involved argument mapping and concept mapping techniques to articulate and integrate key cognitive elements involved in problem-solving and knowledge-construction processes. In brief, the DML environment was designed to facilitate PBL by enabling learners to explore with problems in authentic situations, externalize and reflect on their problem-solving and knowledge-construction processes, and improve their knowledge by aligning new understanding from problems into existing knowledge structure; and, on the other hand, by providing learners with sufficient guidance to ensure effective learning experiences.

With respect to the *second question*, the DML system was evaluated based on learner perceptions and learning outcome. *In terms of learner perceptions*, the survey results show that the DML system was perceived to be useful, but not very easy to use. Interview results confirmed that many learners regarded the DML environment useful and innovative, but they suggested some interfaces of the dual-mapping cognitive tool to be improved and more guidance to be provided for DML. Moreover, the instructor and domain experts commented that the DML environment offered valuable learning experiences and stimulated students’ sense of autonomy in learning. They also indicated the need for incorporating such learning environment into regular teaching programs.

In terms of learning outcomes, learners reported to make moderate progress in problem-solving and knowledge-construction abilities, consistent with a significant improvement found in their DML products, although no

significant difference was found between the pre-test and post-test scores with the four-week period. The result is consistent with previous studies in that what students learn from PBL is mixed especially based on traditional examination scores (Gijbels et al., 2005; Hartling et al., 2010). Researchers have argued for more rigorous and authentic measures of knowledge and skills that are more sensitive to the effects of PBL (Patel et al., 2009a). In this study, learners' dual-mapping scores for the last case were found to be significantly correlated with their post-test scores, indicating that the proposed dual-mapping cognitive tool was consistent with the traditional paper-and-pencil-based test in assessing PBL outcome. This finding is in line with the current trend of using cognitive tools to assess knowledge and skill development especially in complex learning (Pirnay-Dummer, Ifenthaler & Spector, 2010).

More importantly, the dual-mapping scores were found to provide more formative assessment of PBL performance than traditional tests in the following aspects: learners made a significant improvement from the first to the last case in both problem solving and knowledge construction; learners performed better in problem solving than in knowledge construction for the first and last case; learners improved in directing problem solving to knowledge construction from the first to the last case; and the knowledge-construction performance varied more than the problem-solving performance among learners in the last case. These results further demonstrated the effectiveness of the DML approach in improving problem solving and knowledge construction as well as in building connections between the two. Moreover, by comparison with problem solving, knowledge construction was found to be more challenging to most learners and more difficult to be improved in a short period of time.

Conclusions

Learning through problem solving has been increasingly adopted as an important approach to education and expertise development especially in complex domains. However, the effect of PBL on construction of systemic knowledge is not found satisfactory. Many learners do not have the ability to separate general knowledge from specific cases and apply it to new situations. There is a clear need to reveal how practice and knowledge reciprocate each other. This study addressed the challenge by proposing a dual-mapping learning approach for externalizing and integrating complex cognitive processes in problem solving and knowledge construction.

The findings of the study have implications for research and practice in PBL. While PBL has become a critical strategy of curriculum reforms and pedagogical innovations in many disciplines, more studies are needed to enrich design principles and assessment methods of PBL, especially with technology support. This study contributes to the instructional design, technology, and assessment for learning in complex problem contexts. In the meantime, the proposed DML environment provides a platform for further studies on how problem solving and knowledge construction interact and reinforce each other in PBL.

The limitations of the study should be noted that the design in a local context may not easily generate valid design principles and preliminary findings from a small number of participants may not be sufficient enough to claim the effectiveness of the approach for a broader population. Future work will address these limitations. Meanwhile, by its nature of design-based research, this study needs iterative analysis, design, and implementation to test and refine the proposed approach as well as to develop relevant design principles and theories for a better understand of and better approaches to support learning in problem contexts.

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Affordances and Constraints of a Wiki for Primary-school Students' Group Projects

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ABSTRACT

This study examined a wiki as a computer-supported collaborative learning (CSCL) environment at upper primary level. A total of 388 Hong Kong Primary-five (P5) students in four Chinese primary schools used a wiki platform within the context of their group projects in General Studies (GS) classes. Adopting a mixed-methods design, qualitative and quantitative data were collected from focus group interviews, survey and wiki entries. Findings showed that the wiki platform provided educational, technological, and social affordances for the P5 students' collaborative learning. At the same time, constraints were found to be related to technological factors and users' dispositions, which may be counterbalanced by providing scaffolding and selecting wiki variants. Students' attitudes towards the pedagogical value of the wiki were found to be strongly positive after the group project implementation. Overall, this research contributes to the literature on the use of wikis in primary education.

Keywords

Wiki, Affordances, Constraints, Collaborative learning, Primary school, Group project

Introduction

The potential of social software in facilitating positive changes in educational processes has been articulated. Wiki technology is one of the widely explored social software in schools, colleges and universities (Parker & Chao, 2007). Recent years have witnessed a rapid increase in the use of wikis as a computer-supported collaborative (CSCL) environment. CSCL emphasizes how technology can support collaborative learning to enhance members' interaction (Lipponen, 2002).

Research suggests that wiki technology is a useful tool for information sharing and knowledge construction (Chu, 2008; Elgort, Smith, & Toland, 2008). Research also shows that wiki technology helps improve the level of students' collaboration and their quality of work (Chu, 2008; Hughes & Narayan, 2009). However, a few studies have reported that the use of wikis has little impact on student's interaction, the problem of which has been identified as being associated with poorly supported integration of the wiki into the teaching format of a particular course (Cole, 2009). This suggests that the wiki, used as a CSCL environment needs to be examined in terms of not only technological capacities, but also the educational and social factors that facilitate collaborative activities (Kirschner, Strijbos, Kreijns, & Beers, 2004). Therefore, a better understanding of wikis in education will be developed if we examine the specific learning activities that are afforded by this technology.

Although the simplicity of wikis makes them a good tool for young learners in collaborative tasks, research regarding the use of wikis at primary level is scarce and in its infancy. Recent studies demonstrate that wikis is a useful tool for primary-school students' collaborative writing (Désilets & Paquet, 2005; Li, Chu, Ki, & Woo, 2012; Woo, Chu, Ho, & Li, 2011). However, there is limited information on the nature of the interaction between the students and the wiki (Elgort et al., 2008). Thus, this study aimed to present a systematic study of the affordances, constraints and students' attitudes towards a wiki for primary-school group projects.

Based on the objective, three specific research questions (RQ) were posed:

RQ1: What are the technological, educational and social affordances perceived by students when using a wiki for their group project work? And how do these affordances be utilized?

RQ2: What are the constraints perceived by students when using a wiki for their group project work? And how can these constraints be counterbalanced?

RQ3: What are the students' attitudes towards the pedagogical value of the wiki?

Literature review

Originally coined by Gibson (1977), the term “affordance” refers to a relation naturally existing between the attributes of an object and the characteristics of the user. It provides a direct approach to perceiving the value and meaning of objects or environments that afford users to perform particular actions. Norman defines this term as “the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used” (1988, p. 9). The difference between the two definitions is that Gibson’s definition refers to utility, while Norman’s refers to usability (Bower, 2008). As distinguished by Nielsen (1994), utility represents the functionality that a system provides a user, while usability concerns how well the user can actually use the functionality in order to achieving a task. Therefore, Gibson’s perspective focuses upon the fundamental characteristics of the object in relation to the user, which is more suitable in discriminating how technologies can be applied to design learning tasks. Norman places more emphasis on how an object is perceived, which is a better way to evaluate learning technologies.

The concept of “affordance” is adopted in the field of CSCL as a framework for the purpose of designing and evaluating CSCL environments that involve the unanticipated interactions between members during collaborative learning, such that affordances are classified as educational, technological and social affordances (Kirschner et al., 2004). Educational affordance refers to characteristics of the learning environment that facilitate collaborative learning behavior; social affordance to characteristics that offer social-contextual facilitation in relation to students’ social interaction; and technological affordance to characteristics that enable learners to accomplish learning tasks in an efficient and effective way. This classification is developed from the understanding that CSCL represents a learning situation “where the education context is collaborative, the social context is the group, and the technological context is the computer-mediated setting” (Kirschner et al., 2004, p. 50). When evaluating technology as a CSCL environment, we should analyze the combination of educational, social, and technological affordances for collaborative learning. In describing a methodology to support technology selection for the learning process, Bower (2008) puts forward a functional category of technological affordances. However, a classification of educational and social affordance has not been identified in previous studies. Studies must attempt to extend our understanding of affordances as they emerge from classroom practitioners’ efforts to utilize this technology with a combination of these three elements.

To obtain a comprehensive characterization of the interactions between an object and its user, we need to explore the related concept of constraint, which refers to a boundary, guide, or structure for action (Kennewell, Tanner, Jones, & Beauchamp, 2008). A constraint is not a physical characteristic, but a perception of a potential for action that is dependent on a user’s knowledge, skills and disposition. Constraint may sometimes be perceived as an obstacle to action. It has been defined as the incapacity, or diminished capacity, to utilize a tool at will (Murphy & Coffin, 2003). A delicate balance between affordances and constraints exists in any form of communication that is mediated by computer (Sherry, 2000). It has been suggested that an improved understanding of the affordances and constraints resulting from a user’s interactions with learning environments is beneficial to teaching and learning (Swan, 2003).

Besides understanding the affordances and constraints of the wiki, it is also important to investigate primary students’ attitudes of using the wiki for educational purposes. As applied to wikis, pedagogical value has been defined as the capacity of students to take part in learning through active participation in group interactions based on constructivist learning principles (Hazari & North, 2009). This evaluation approach generates learners’ feedback that is specifically relevant to a technology efficacy in facilitating collaborative learning.

Conceptual framework

Theoretically, the use of wikis in CSCL is mostly grounded in constructivism (Larussou & Alterman, 2009; Parker & Chao, 2007). Constructivism is a theory of learning which asserts that learners can actively learn and construct rather than passively receive and store knowledge through their own inferences and discoveries based on their prior knowledge (Piaget, 1976; Vygotsky, 1978). Vygotsky states that learning is fundamentally social in nature, emphasizing the important role of social interaction and activity sharing in individuals’ construction of knowledge and understanding (Cole & Wertsch, 1996). Based on social constructivist principles, collaborative interactions among students have been shown to enhance learning through exposure to alternative perspectives (Brett & Nagra, 2005). Collaborative learning also emphasizes social and intellectual engagement, and mutual responsibility (Smith

& MacGregor, 1992). As such, peer interactions that ensue from a collaborative approach represent an important component of the learning experience (Pascarella & Terenzini, 2005).

Since collaborative learning lays great stress on the extent of the exchanges that occur among students in a given environment (Dillenbourg & Schneider, 1995; Golub, 1998), the discussion that occurs during task engagement is an important consideration in a CSCL environment. It has been theoretically suggested, on the basis of their functionalities, that wikis can be used to promote collaborative learning (Augar, Raitman, & Zhou, 2004; Felder & Brent, 2003; Hsu, 2007).

Methodology

This study employed a mixed methods research design, using quantitative and qualitative data sources, to examine the usefulness of a wiki for P5 students' GS group projects.

Participants

The participants were 388 P5 students with an average age of ten years from four local primary schools.

Procedures

In a naturalistic setting, the P5 students were tasked to conduct group research projects during the 11-week period of the course (Seen in table 1). Students in groups of 5-6 worked on a GS project and each group chose a project topic under four themes proposed by the Curriculum Development Council (2011): (1) Life: Change, Change, Change, (2) Life in the city, (3) To know about my country, and (4) Beyond our earth. Google Sites was chosen as the wiki platform in this study because it does not require much setup, maintenance or technical knowledge, which makes it suitable for novice users (Herrick & Collins, 2009). In addition, Google Sites supports Chinese (Traditional) which is the mother language for the students.

Table 1. Timetable of the instructional design

Week	GS lesson	IT lesson	Library lesson
1		Students learned information and communication (ICT) skills, with a focus on the use of Google Sites.	
2			Students learned information literacy (IL) skills
3			
4	Students teamed up and made a plan for their group work.		
6-7	Information search and analysis		
8-11	Report construction on Google Sites		

This study adopted a collaborative teaching model that involved two kinds of subject teachers and the school librarian working together to implement the teaching objective. Such a teaching approach has been found to be beneficial in scaffolding students more effectively during the process of project completion (Chu, 2009). The roles of the different kinds of teachers are described as follows.

- The GS teachers focused on the subject aspect and research process of the projects - whether students were asking appropriate questions for the projects, classifying information found sensibly, and selecting suitable materials to be included in their project presentation. The GS teachers monitored students' work and commented on the wiki pages.
- The IT teachers were responsible for training students in the IT skills, focusing on the use of Google Sites. A project sample was provided on the first wiki page by the IT teachers (see Figure 1), and the groups were then free to start their pages to conduct their group work.
- The teacher librarian conducted activities to help equip students well with the information literacy skills that they would need to search, locate, and use relevant information sources for their projects.

Figure 1. Project sample-The History of Hong Kong

Data collection and analysis

Qualitative and quantitative data were collected alongside the implementation of the students' group projects in the GS course. Qualitative data sources included (1) focus group interviews (8 groups, 42 students: 9 students from KF, 5 students from CPS, 11 students from SH and 17 students from WSK); (2) students' reflections written on the wiki pages (12 groups: 3 groups from KF, 1 group from CPS, 4 groups from SH and 4 groups from WSK); and (3) students' activities on the wiki platform (12 groups as above). Focus group interviews were conducted at the end of the projects, in which open-ended questions probed students on their experiences in using Google Sites for project con-construction. Students were asked to write reflections about their experiences with the wiki pages, either individually or in groups. The wiki can record every revision, so we tracked students' contributions to the wiki pages (e.g., co-construction of reports and online communications).

The quantitative data source was a questionnaire-format instrument investigating students' perceptions of the pedagogical value of the wiki. For the qualitative data sources, one unit of analysis was defined as a transcription that corresponded to an action taken or a comment made by a student on a wiki page or recorded wiki revisions. Responses to open-ended questions in the group interviews were also transcribed and analyzed to reveal themes that appeared to illustrate affordance and constraints. The qualitative data sources were uploaded as text files into NVivo 8.0 software and coded based on the framework of affordances of CSCL environments. To determine the affordances, all qualitative data sources were coded using the framework of affordances of online learning environments as summarized in Table 2.

The first level categories of affordances included educational, technological and social affordances (Kirschner et al., 2004). Technological affordances are further defined in a second level of affordance categories: media, spatial, temporal, navigation, synthesis, and access-control (Bower, 2008). However, with regard to educational and social affordances, second level categories have not been identified in previous studies. As such, these emerged from the current data naturally through an interactive process of coding based on the definitions of affordances, identifying themes at the second level, and clarifying the definitions. Such an approach is a commonly employed strategy in cognitive studies (Chu, Chan, & Tiwari, 2001; Lee, Chan, & van Aalst, 2006). Preliminary coding was done by the authors in order to refine the second level of categories. Various iterations were discussed to clarify the definitions of categories. For inter-rater reliability, the first and third author independently coded 30% of data covering three sources in the first round, which resulted in 75% inter-rater agreement. After further discussion, all data were independently coded in the second round, which yielded 95% inter-rater agreement. In this study, five categories of educational affordances, and two categories of social affordances were found (See Table 2).

Table 2. Wiki affordance categories generated by the qualitative analysis

First Level Category	Second Level Category & Its Definition	Sample Contents & Its Source Number
Educational affordances	1. Group project management (Students are able to designate and schedule the assignment.) 2. Group report co-construction (Students are able to participate in the document revision at will.) 3. Information sharing (Students are able to publish links to sources of.) 4. Knowledge sharing (Students are able to post their insights and interpretations on a concept or topic.) 5. Feedback sharing (Students are able to request and provide feedback between each other.)	<i>X and I work together every Thursday. (A-SH-5B-3-C)*</i> <i>Google Sites is a collaborative environment, which allows us to do our work more conveniently. It is a platform for us to do our work and amend it together. (I-SH-5B-K)</i> <i>Source: http://politics.people.com.cn/BIG5/8198/58705/index.html (A-KF-5A-2-T)</i> <i>We can exchange opinions with each other in order to acquire more knowledge. (I-KF-5B-A)</i> <i>It would be better if you add more information about the consequence. (A-SH-5B-4-Z)</i>
Social affordances	1. Communication (Students can communicate online within a platform.) 2. Motivation (Students can enhance motivation among group members.)	<i>Google Sites is better as there is a chat box so we can chat with others while doing the project. (I-SH-5A-B)</i> <i>We see other groups' work that encourages us to work hard. (R-SH-5B-4-W)</i>
Technological affordances	1. Media (The ability to input and output various media forms, such as text, images audio and video) 2. Spatial (The ability to resize, move or place contents within an interface) 3. Temporal (The ability to access anytime anywhere as well as to record and play back information) 4. Navigation (The ability to browse and search other sections of the interface, as well as to link and sort sections) 5. Synthesis (The ability to combine and integrate multiple components and create a mixed-media platform) 6. Access-control (The ability to allow or deny access and contributions)	<i>We can insert video and pictures into Google Site. We can use multi-media to present our work and then other students can understand our work more easily. (I-CPS-5B-E)</i> <i>The contents are arranged in perfect order. (A-SH-5B-4-T)</i> <i>Google Sites allows us to do our work at home. We need not gather in front of one computer, or do it separately on our own computers using 'read-only'. (I-SH-5B-J)</i> <i>The side-bars are very user-friendly. I can just click into any page that I want to see. (I-WSK-5C-D)</i> <i>I can synthesize other Google functions to create a better collaborative environment. (I-GPS-5B-K)</i> <i>Google Sites allows multi-users to amend the documents. (I-SH-5B-J)</i>

Note. *The source number constitutes source type, school code, class number, group number and student code.
 (Source type: I for group interviews, R for students' reflections; and A for students' activities)

While the literature suggests that a balance between affordances and constraints is ideal in the use of technology, no structural framework has been found to examine constraints. Thus, to explore this, the iterative approach was again used to code the qualitative data units that referred to a boundary, guide, or structure for action (Kennewell et al., 2008) that may have resulted in decreased capacity to utilize a tool at will (Murphy & Coffin, 2003). The categories emerged from the data naturally and were summarized in Table 3.

Table 3. Wiki constraint categories generated by the qualitative analysis

Category	Definition	Sample Contents & Its Source Number
Lower familiarity	Distinction from traditional technology format, such as MS office, email, and telephone	<i>Compared to wiki, I can work faster with word processing software because I use it frequently before.</i> (I-CPS-5B-F)
Wiki formatting system	The distinct formatting rules that students find problematic in the co-construction of materials.	<i>Sometimes the format view under “edit” and “view” pages appear differently.</i> (I-WSK-5B-B)
Internet dependence	The inability to contribute work without internet access	<i>I have to re-do my work due to internet connection problem.</i> (I-SH-5A-K)

Note. *The source number constitutes source type, school code, class number, group number and student code.

(Source type: I for group interviews, R for students' reflections; and A for students' activities)

An instrument to assess students' perceptions of the pedagogical value of wiki technology (Hazari & North, 2009) was used. The standard for instrument reliability for Cronbach's alpha by Robinson, Shaver, and Wrightsman (1991) was used to evaluate the quality of the scales of the attitude measures. The standards were: 0.80 or better – exemplary reliability; 0.70-0.79 – extensive reliability; 0.60-0.69 – moderate reliability; and <0.60 – minimal reliability. This instrument measured the following constructs: overall learning, motivation, group interaction, and technology (Hazari & North, 2009). Responses from all four schools were analyzed quantitatively as a whole and focus group interviews were also analyzed to document the findings further. There were five items per construct, and a Chinese version of the instrument was given to avoid language misunderstanding. A 5-point Likert type scale was used: 0 representing "I don't know", 1 representing "Strongly disagree", 2 representing "Disagree", 3 representing "Neutral", 4 representing "Agree" to 5 representing "Strongly agree". Statistical tests were done using SPSS 16.0.

Findings and discussion

Affordances

A total of 549 references to affordances were found: 79 from students' responses to open-ended questions in interviews, 63 from students' reflections on the wiki pages, and 407 from the wiki recorded students' activities on the wiki platform. The number of coded references and their percentage distribution in all three major categories are summarized in Table 4.

A synthesis of the findings from the different data sources showed that technological affordances were most apparent, followed by educational affordances and social affordances. First of all, for students' responses in group interviews, the most prominently reported affordances were related to technological aspects. Specifically, temporal affordance was mostly reported. With respect to educational affordances, the analysis revealed that the wiki allowed group report co-construction with simultaneous contributions for collaborative work and provided a platform to share information, knowledge and comments. The wiki was also found to provide a social affordance by serving as a platform for communication and motivation. Secondly, in terms of students' reflections posted on the wiki pages, educational affordances were found to be the most prominent (73%). The top education affordance was that the wiki provided students with a platform to co-construct their group reports (36.5%). There were a small percentage of technological affordances. References coded to social affordances were distributed between communication and motivation. Lastly, most of the references from students' activities were centered on the technological aspects, and more than half of the coded references were media affordances.

The usefulness of a CSCL environment consists of its usability and utility, is determined by the various types of affordances (Kirschner et al., 2004). Usability, which is the extent to which the CSCL environment is used by students in supporting their collaborative group work, is determined by technological affordances (Vatrapu, Suthers, & Medina, 2008). Our findings provided evidence that supported the usability of wikis as a CSCL environment. The observation of students' online activities highlighted the technological affordances. Consistently, throughout all sources of data, media affordance was found to be the most prevalent. This is not surprising since the primary function offered by wikis is the ability to combine reading and writing within a web browser, and the wiki allows several users to create and link web pages simultaneously (Lamb, 2004). Temporal affordance was reported most during the interviews. For example, one student (I-SH-5B-F) reported, "We can share with each other at anytime and

anywhere. We need not to write it down, or go to others' homes”. This showed that students enjoyed this learning experience mostly because they were able to carry out the project at their convenience. The synthesis affordance is an important aspect of the wiki as a technological support for collaborative learning, but it was less prominent in this study. This may be because primary-school students have low “combine-ability” and “integrate-ability”.

Table 4. Wiki affordances found in different data resource

Affordance	Number of coded references (%)			Sub-total
	Interview	Reflection	Activities	
<i>Educational</i>				
1. Group project management	1 (1.3%)*	8 (12.7%)	11 (2.7%)	20 (3.7%)
2. Group report co-construction	6 (7.6%)	23 (36.5%)	26 (6.4%)	55 (10%)
3. Information sharing	2 (2.5%)	0 (%)	32 (7.9%)	34 (6.2%)
4. Knowledge sharing	1 (1.3%)	8 (12.7%)	17 (4.2%)	26 (4.7%)
5. Feedback sharing	6 (7.6%)	7 (11.1%)	27 (6.6%)	40 (7.3%)
Sub-total	16 (20.3%)	46 (73%)	113 (27.8%)	175 (31.9%)
<i>Social</i>				
1. Communciation	19 (24%)	2 (3.2%)	15 (3.7%)	36 (6.6%)
2. Motivation	1(1.3%)	5 (7.9%)	7 (1.7%)	13 (2.3%)
Sub-total	20 (25.3%)	7(11.1%)	22 (5.4%)	49 (8.9%)
<i>Technological</i>				
1. Media	8 (10.1%)	5 (7.9%)	251 (61.7%)	264 (48.1%)
2. Spatial	2 (2.5%)	2 (3.2%)	14 (3.4%)	18 (3.3%)
3. Temporal	23 (29.1%)	0 (0%)	0 (0%)	23 (4.2%)
4. Navigation	4 (5.1%)	2 (3.2%)	3 (0.7%)	9 (1.6%)
5. Synthesis	1 (1.3%)	0 (1.6%)	2 (0.5%)	3 (0.5%)
6. Access control	5(6.3%)	1 (0%)	2 (0.5%)	8 (1.5%)
Sub-total	43 (54.4%)	10(15.9)	272 (66.8%)	325 (59.2%)
Total	79 (100%)	63(100%)	407 (100%)	549 (100%)

Note. * percentage is calculated within each data source

Utility is determined by the combination of educational and social affordances (Kirschner et al., 2004), and these two dimensions have been proposed as the core educational affordances in designing CSCL environments (Bower, 2008). This current study corroborates earlier findings showing that wikis have been useful for similar purposes of group project management and report construction through questionnaire-based feedback (Chu & Kennedy, 2011). The wiki is able to provide these educational affordances because it provided group members with a platform to engage in several iterations of project plans and report construction. This appears to be related to the technological affordance, but we propose that educational affordances are achieved when the technological aspect is supported by pedagogical factors. It has been suggested that educational affordances are related to the characteristics of a learning program (Kirschner et al., 2004). In the contest of the learning activity in this study, the students were given course instructions that prepared them to use the wiki for planning and managing their group projects. They were also required to build their own group report on the wiki, instead of using other traditional forms of word processing technology. With such course-specific learning conditions, the affordances were not limited to the technological dimension.

Social affordances were relatively less pervasive in the findings of this study. This dimension was found to be generally centered on the provision of a communication platform. Kreijins, Kirschner and Jochems (2002) have emphasized that social affordance technologies must be able to support or anticipate users' social intentions. A social affordance technology will facilitate a group member's initiation of a communication episode with other members who have been perceived to be present. These characteristics were found to be present in the wiki that was used in this study, as evident in the exchange of comments on the wiki pages. During observed activities, students were also found to respond to comments. When seeing “*you could think more about why Miao males have such habits of dressing*”, students immediately responded “*thanks for your questions, we are looking for answers*”. Furthermore, one students (I-SH-5B-J) reported “*Google Sites is better as there is a chatbox so we can chat with others at our own homes instead of having to meet out*”, confirming that the students utilized the wiki platform as a means of engaging in communication.

Constraints

Table 5 summarized the constraints that were identified from the coded references from different data sources. Constraints were mostly revealed by the students' responses in the group interviews, with 40 coded references. The most often reported constraint was related to the wiki formatting system (45%), followed by the distinction between the wiki and more familiar forms of technology (25%). For students' activities with Google Sites, 16 references were coded. Only two constraints were found, lower familiarity (37.5%) and the wiki formatting and technical system (63.5%). Few references were coded from students' reflections on the wiki pages.

The wiki's formatting system was found to be an obstacle to building wiki pages efficiently. The users encountered difficulties in achieving the desired organization and appearance of their wiki pages, and they generally attributed this to the formatting system of the wiki. As such, it might be considered that the degree of constraint associated with wiki's formatting system might differ according to the distinct wiki variants that are freely available (e.g. Media Wiki, PB Works, TWiki).

Table 5. Wiki constraints found in different data resource

Constraints	Number of coded references (%)		
	Interview	Activities	Reflection
1. Lower familiarity	12 (30%)	6 (37.5%)	2 (40%)
2. wiki formatting system	18 (45%)	10 (63.5%)	3 (60%)
3. Internet dependence	8 (20%)	0 (0%)	0 (%)
Total	40 (100%)	16 (100%)	5 (100%)

Note. *percentage distribution is within each data source

In this case, our findings showed that the distinction between the wiki and traditional forms of technology was a constraint because of the users' relatively greater familiarity with the latter. Fortunately, students were found to adopt not a passive but an active attitude towards constraints. Student (1-SH-5A-D), for example, said, "*I would choose Google Sites as it allows us to use a more difficult tool to do projects that can train our brain*". When students were asked how they addressed the problem, two students reported that they read the instructional manual, while others sought help from teachers and peers. This highlights the fact that constraints are not necessarily negative attributes, but can be perceived as obstacles to the effective use of functions (Murphy & Coffin, 2003) that may enhance students' learning. On the other hand, it implies that extra training sessions could be scheduled, after students have been conducting their projects for 2-3 weeks, in which instructors can ask the students to demonstrate different tasks on the wiki to increase students' familiarity with the tool. Subject teachers are expected to have sufficient knowledge about wikis in order to assist students in the whole process.

Additionally, the dependence of the wiki system on internet access was also a constraint. While dependence on an internet connection might be related to the temporal technological affordance that allows simultaneous contributions, students reported problems of lost page revisions which were thought to have been saved. Google Sites manages conflict handing by page locking, which results in having only one user allowed to edit the pages at a particular time. Other systems like MediaWiki, which is the system used by Wikipedia, manages conflict handing by SVN merging (MediaWiki, 2012).

Students' attitudes

All 388 participating students were invited to fill in the self-administered survey. But the sample sizes for the different items varied, because some students did not respond to some of the statements. The mid-point of the rating scale is 3 (Moderate). Hence, any rating that was larger than 3.00 would be considered as edging towards positive perception and vice versa. Table 6 showed the quantitative analysis of the students' ratings.

Table 6. Descriptive Statistics of Wiki perceptual survey

Construct	Question Items	M (SD)	Median	Cronbach's alpha
Overall learning	Q5. Use of the wiki aided me in achieving the course objectives.	3.71 (1.294)	4.00	.870***

	Q7. I would like to see wikis being used in other courses.	3.71 (1.224)	4.00	
	Q9. I participated in the assignment more because of using the wiki.	3.54 (1.245)	4.00	
	Q14. I will retain more material as a result of using the wiki.	3.59 (1.341)	4.00	
	Q19. The use of wiki enhanced my interest in the course.	3.58 (1.360)	4.00	
Motivation	Q3. I would prefer projects that use a wiki over other projects that do not use a wiki.	3.58 (1.357)	4.00	
	Q6. I stayed on the task more because of using the wiki	3.58 (1.289)	4.00	
	Q8. The benefits of using a wiki are worth the extra effort and time required to learn it.	3.49 (1.247)	4.00	.863***
	Q15. I would recommend classes that use wikis to other students.	3.55 (1.361)	4.00	
	Q20. I will continue to explore use of a wiki for project work.	3.65(1.414)	4.00	
Group Interaction	Q2. I like seeing other students' interaction with material I posted in the wiki.	3.40 (1.311)	3.00	
	Q11. Use of the wiki for the assignment helped me interact more with other students.	3.52 (1.266)	4.00	
	Q13. Because of using the wiki, my group was able to come to a consensus faster.	3.46 (1.285)	4.00	.864***
	Q17. Use of the wiki promoted collaborative learning	3.57 (1.300)	4.00	
	Q18. I learned more because of information posted by other students' in the wiki.	3.50 (1.285)	4.00	
Technology	Q1. The wiki interface and features were overall easy to understand.	3.78 (1.228)	3.00	
	Q4. Browsing/editing information in the wiki was easy.	3.69 (1.302)	4.00	
	Q10. Benefits of using the wiki outweighed any technical challenges of its use.	3.36 (1.361)	4.00	.848***
	Q12. Technical features in the wiki helped enhance my learning.	3.59 (1.341)	4.00	
	Q16. Compared to other online discussion boards, the wiki was easier to use.	3.47 (1.352)	4.00	

Note. ***0.80 or better – exemplary reliability

This scale exhibited extensive reliability, and we were able to analyze four subscales. The averages of the students' ratings on all of the 20 statements were above 3.0, indicating that students were positive about the influence of the wiki on their experiences. This result is consistent with the findings of earlier studies that primary-school students are positive about using a wiki for collaborative tasks (Li et al., 2012; Woo et al., 2011).

- *Overall learning.* The ratings of the five components contributing to this factor indicated that students generally perceived the wiki as an effective tool to foster learning. Students' learning interests were shown to be enhanced with the use of the wiki. One student (I-SH-5B-J) reported that he had "*little interest [in the beginning] but after doing this project, [he] feel[s] like more funny and interesting and want[s] to learn more.*" The new learning approach also reinforced students' knowledge acquisition by providing them with opportunities to learn from experiences which are meaningful and significant to them (Dewey, 1916). Another student (R-WSK-5A-L) wrote, "*After this project, I learnt that the harm of solar storm is closely related to us*".
- *Motivation.* One of the anticipated challenges of implementing a wiki system with P5 students was the steep learning curve caused by the technical constraints, which could have suppressed students' enthusiasm in making use of the new technology for their projects. However, students held positive opinion on the wiki as they

generally agreed that the benefits associated with the wiki outpaced the extra time and effort needed to learn about it. According to the students' reflections, it found that they "*cherished this opportunity and expected more group work with a wiki*".

- *Group Interaction.* Communication among group members was enhanced and consensus was reached more efficiently owing to the use of the wiki. Students generally showed enthusiasm in group collaboration on the wiki. The students' ratings and discussion responses demonstrated generally positive attitudes of students towards peers' contribution to their project via wiki technology. One of the students (I-KF-C) reported "*Google Sites allows other people to comment on our work and we can learn more from that*".
- *Technology.* Notwithstanding the potential technical difficulties that they might encounter, the students perceived the impact of the technology on their learning to be positive. Students reported that the functions of wiki technology were user-friendly and helpful. For example, when compared to the more traditional ways of completing a group project, one student (I-KF-A) commented that "*[Google Sites] all group members can do the group project at the same time, unlike Microsoft Word, [which] is simpler and easier to manage*". Another student (I-SH-F) reported that "*[We] can share with each other at anytime and anywhere. We need not to write it down, or go to others' home*".

Conclusion and implications

This study evaluated the use of a wiki as a CSCL environment in terms of affordances and constraints, as well as students' perceptions. Using a combination of qualitative and quantitative data sources, we demonstrated that a wiki was a useful platform that supports collaborative learning. Usability was supported by technological affordances that centered on the ability to build and perceive mixed-media wiki pages. Utility was substantiated by educational affordances that were related to group project management and group report co-construction, as well as by social affordances that focused on the ability of group members to communicate with one another.

The study also identified constraints that were related either to the characteristics of the wiki technology itself or to users' disposition. These findings offer relevant insights for educators' decision-making when using wikis in their classrooms. They suggest that when choosing a wiki variant as a learning environment, educators may need to take into account a formatting system that is suited to the intuitive tendencies of users. Furthermore, pedagogical instruction must account for users' personal dispositions to facilitate the affordances and manage the constraints.

Finally, this study suggests that primary-school students tend to have positive attitudes of the wiki for collaborative project learning. Future studies can examine and compare the perceived effectiveness and user experience of different wiki variants in facilitating primary-school students' group project work that may offer more sufficient advice for educators to select a suitable wiki variant. Furthermore, students' interactions with a wiki platform during different phases of their learning process could be further explored in order to expand our understanding of wiki-supported collaborative learning instruction.

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Gender Differences in the Reading of E-books: Investigating Children's Attitudes, Reading Behaviors and Outcomes

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ABSTRACT

As indicated by some studies, the problem of “falling behind” often exists when using computer-assisted learning with children, and gender may be a factor in this. While digital contents presented on various e-readers are promising replacements for paper-and-ink books, the question arises as to whether this emerging technology will have the same effect with boys and girls? Conventionally, boys are believed to have more aptitude for using computer and information technologies, and it is of interest to see if this is true when using e-books in an educational context. In this study, two investigations were conducted to explore children's attitudes, reading behaviors and outcomes in order to find out if there were any gender differences in the reading of e-books. The first investigation was conducted with 166 elementary school students to evaluate their attitudes towards reading with an Interactive E-book Learning System (IELS), a tailor-made e-book learning environment for children. The results showed that the gendered attitudes in terms of the Satisfaction dimension and the expectation for the usable functions were different. Twenty-three sixth-grade children then participated in the second investigation, in which they silently read two e-books in the IELS with a reading behavior tracking technique, and a retrieval test was conducted to assess the reading outcome for each e-book. The results show that while the girls mostly had the behavior of Skimming during the reading process, they outscored the boys in the retrieval tests. Although the application of personalized reading technologies in education, such as reading e-books with IELS, tends to diminish the gap in technology adaptation between the genders, however, the gender differences, as revealed in this work, are still substantial and considerable to factor in children's reading of e-books. In practice, the results of this study suggest that these differences may create reading barriers for some children, and thus should be taken into account when e-books are used for formal learning.

Keywords

Gender differences, E-book reading, Reading attitude, Reading behavior, Reading outcome, Elementary school

Introduction

Gender differences in learning

Various studies of gender issues in academic learning show that gender differences are substantial characteristics among students. For example, Meelissen and Drent (2008) pointed out that the participation of females in ICT (Information and Communications Technology) professional careers is not only low, but is also still falling in most western countries. They thus investigated various factors related to elementary schools or teachers that may influence girls' attitudes toward computers. The results showed that girls' attitudes toward computers are less positive than those of boys. Although digital natives tend to have a high level of technology acceptance (Liu, 2005), gender differences still exist among children in their computer attitudes, affecting learning performances and leading to a problem that is known as “falling behind” (Meelissen & Drent, 2008).

Table 1. Findings of gender differences in earlier studies

Research	Issues	Findings	Is the gender gap existed? (Yes/No)
Gömlekşiz (2012)	Students' perceptions of science and technology classes by gender in a Turkish elementary school context	Males considered learning science and technology more necessary and important than females did.	Yes
Goh (2011)	Gender differences in a short message service (SMS) library	SMS efficiency has a significant influence on self-efficacy for	Yes

	catalog search service adoption	males, but not for females.	
Tong, Lara-Alecio, Irby, and Mathes (2011)	The effects of an instructional intervention on dual language development	Females demonstrated a faster rate in dual language comprehension than males.	Yes.
Kay and Lauricella (2011)	Gender differences in the using behaviors (on-task and off-task behaviors) of laptops in higher education classrooms	Females reported significantly more note-taking and participation in academic laptop-based activities.	Yes.
Ding, Bosker, and Harskamp (2011)	The effects of gender and gender pairing on students' learning performances and knowledge elaboration processes in CSCL	Females in single-gender dyads significantly outperformed females in mixed-gender dyads.	Yes.
Chiu and Chow (2010)	The associations in culture, motivation, and reading achievement of high school students in 41 countries	Females outscored males in most countries.	Yes.
Prinsen, Volman, Terwel, and van den Eeden (2009)	The effects on participation of an experimental CSCL-program to support elaboration	Males benefited less than females from the program in terms of the quality of their participation.	Yes.
Meelissen and Drent (2008)	Gender differences in computer attitudes	Females' attitudes toward computers were less positive than those of males.	Yes.
Smith, Hardman, and Higgins (2007)	Gender differences in whole class classroom interaction with an interactive whiteboard (IWB)	Males dominate classroom interaction in terms of the frequency of certain discourse moves.	Yes.
d'Ailly (2004)	A distinctive cultural and gender difference in efficacy, interest, and effort	The Canadian boys had a lower efficacy belief and consistently showed less interest and effort than the girls; this gender gap, however, was not evident in a Taiwanese sample.	Canadian: Yes. Taiwanese: No.

Issues related to gender differences have been widely investigated in many fields, such as motivation and interest (d'Ailly, 2004), behavior and emotion (Shih, 2008), language learning (Tong et al., 2011), computer attitudes (Meelissen & Drent, 2008), Computer-Supported Collaborative Learning (CSCL) (Ding et al., 2011; Prinsen et al., 2009), and classroom interactions (Smith et al., 2007). No matter what the learning situation, as shown in Table 1, many previous studies have demonstrated that gender differences are key factors in academic contexts (Chiu & Chow, 2010; d'Ailly, 2004; Gömlekşiz, 2012). Smith et al. (2007) noted that as the provision and use of ICT within schools is now increasing, it is important to continue observing the potential impacts of this on both genders when using ICT, and that more studies are needed to examine this issue from various perspectives.

Gender differences in the reading of e-books

A gender gap has also been reported in reading (Chiu & Chow, 2010; Liu & Huang, 2008). For example, Chiu and Chow (2010) reported that the reading test scores (PISA, the Programme for International Student Assessment) of adolescent students showed that girls outscored boys in most of the 41 countries examined. Gender issues can also lead to different reading behaviors. For example, Liu and Huang (2008) explored how Chinese college students' gender differences were related to their online reading behaviors, and the results showed that male and female students' preferences for reading with digital and printed media were significantly different.

Reading e-books involves a different set of reading processes and behaviors to those of reading printed ones. Both digital and printed media have advantages and limitations, and the presentation of each medium tends to meet the needs of readers based on their purposes and preferences, and these diverse reading needs are often due to differences in gender (Salmerón & García, 2011).

Liu and Huang (2008) found that adult readers print out electronic documents to read more frequently than younger ones, a group that is also known as digital natives, who tend to have different expectations and behaviors toward the use of digital media due to the fact that they have grown up using such technology. Liu (2005) also noted that people's reading behaviors have changed over the previous decade, and that screen-based reading is becoming more popular. Several studies (de Jong & Bus, 2004; Grimshaw, Dungworth, McKnight, & Morris, 2007; Korat & Shamir, 2007, 2008) support these views, and further demonstrate that e-books are able to provide individualized and on-demand multimedia features that can promote the learning effectiveness. Therefore, further studies on the use of e-books for reading are needed, especially in the context of a digital learning environment, in which younger students seem to prefer reading e-books (Wood, Pilling, & Jackson, 2010) to a greater extent than older ones (Woody, Daniel, & Baker, 2010).

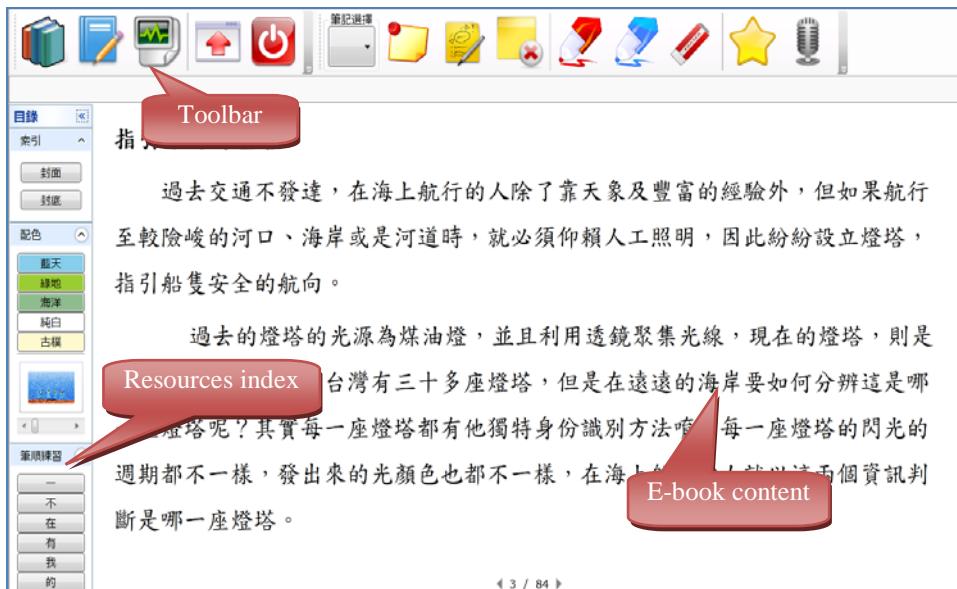
The research question and investigations

Many researchers (Berg, Hoffmann, & Dawson, 2010; Bierman, Ortega, & Rupp-Serrano, 2010; Lam, Lam, Lam, & McNaught, 2009; Pattuelli & Rabina, 2010; Woody et al., 2010) have examined and supported the use of e-books in academic contexts. However, few works have examined whether gender differences are the factors in reading e-books among children. This problem should be properly coped with before e-books become more widely used in formal educational practice. Based on the results of this investigation, both instructional and learning strategies could be adjusted to provide more an adaptive learning experience for children.

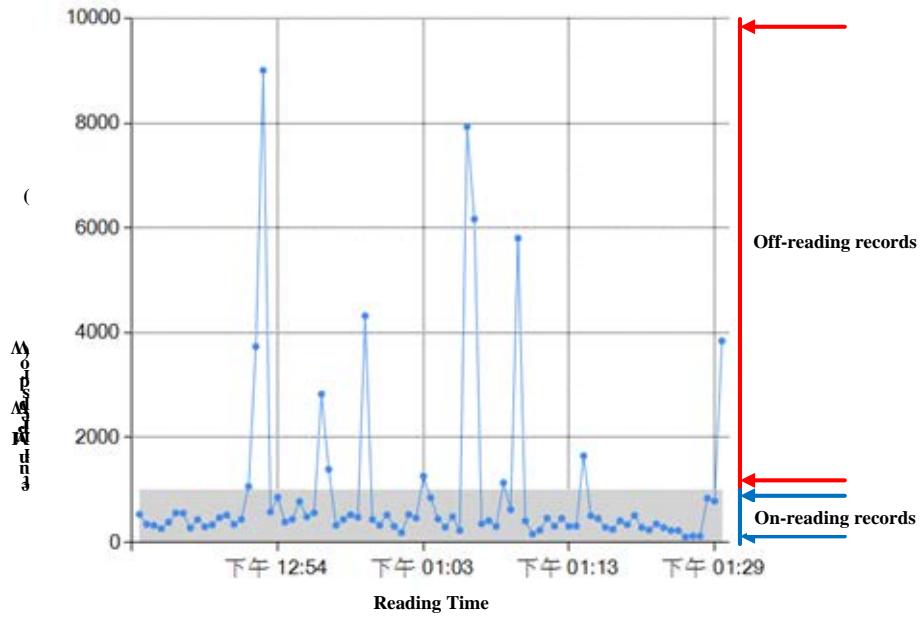
To achieve this goal, this study examined whether there are any gender-related differences with regard to children's attitudes (Lam et al., 2009; Pattuelli & Rabina, 2010), reading behaviors and outcomes (Berg et al., 2010) when reading e-books, carrying out two investigations. The first surveyed the boys' and girls' attitudes towards reading e-books, and the second examined gender differences in reading behaviors and outcomes when reading e-books.

The e-book reading environment and reading behavior tracking technique

As shown in Figure 1a, this study adopted an Interactive E-book Learning System (IELS; Huang, Liang, Su, & Chen, 2012), a tailor-made e-book learning environment for elementary school students.



(a) A screenshot of the Interactive E-book Learning System (IELS)



(b) A line chart of reading rates from the individual real-time report for reading behavior tracking
Figure 1. The Interactive E-book Learning System and the reading behavior tracking technique

In order to uncover the gender differences in e-book reading behavior, a behavior tracking technique, including the tracking, recording and analyzing functions embedded in the IELS was used. The behavior tracking approach used the reading rate (the words read per minute, wpm) as an indicator to identify various reading behaviors, and all of the students' reading process profiles were collected through the network by the central server. These datasets were then used to examine the variations in reading rates. Finally, the individual reading process report (as shown in Figure 1b) is provided for representing the children's actual reading behavior by analyzing individual reading rate records in real time.

The reading rate, which is positively correlated with reading comprehension (Joshi & Aaron, 2000), can be used to assess students' reading performance (Rasinski, 1999, 2000). As shown in Table 2, this study examined the links between intended and actual behaviors by means of the list of reading rates and statuses associated with reading behaviors in the literature.

Table 2. The reading rates and statuses associated with reading behaviors in the literature

Reading status	Reading rate (wpm)	Reading behavior	Study
On-reading	0-1,000		
<i>Slowing</i>	<50	Excessively slow Inefficient reading Disfluent Labored Inexpressive Unenthusiastic rendering	(Harris & Sipay, 1990; Rasinski, 2000; Walczyk, Marsiglia, Bryan, & Naquin, 2001)
<i>Memorizing</i>	50-100	Sustained attention	(Carver, 1977, 1990; Duggan & Payne, 2009; Fraser, 2007; Gillett & Temple, 1986; Harris & Sipay, 1990; Liu, 2005; Liu & Huang, 2008; Rasinski, 1999;
<i>Learning</i>	100-200	In-depth reading Oral reading Concentrated reading Annotation (highlight)	Reader & Payne, 2007; Reading, 2012;
<i>Rauding</i>	200-400	Silent reading*	Stroud & Henderson, 1943)
<i>Skimming</i>	400-700	Keyword spotting	

<i>Scanning</i>	700-1,000	One-time reading Reading selectively Browsing and scanning Non-linear reading	
Off-reading	$\geq 1,000$		
<i>Flipping</i>	$\geq 1,000$	Flip page Glance and glimpse	(Carver, 1977, 1984; Harris & Sipay, 1990)

Note. “※” represents the subject of reading behaviors examined in this study.

Investigation one: A survey of gendered attitudes toward e-book reading

The participants and research procedure

The first investigation was carried out to collect the gendered attitudes from six selected classes (one class per grade in a technology-rich elementary school). A total of 166 children (85 boys and 81 girls) participated in the 80-minute activity of evaluating e-book reading with the IELS.

Holzinger's usability test methods (2005) were used, including thinking aloud, field observation, and questionnaire survey. The process began with the introduction of the IELS (20 minutes), in which the thinking aloud method was carried out by the experimenter. Subsequently, the procedure of IELS operation with a field observation (paired group evaluation, 40 minutes, as shown in Figure 2a) was conducted to evaluate the reading of e-books, with interactive discussions encouraged. To this end, this study typeset six e-books (one book per grade) with content related to classical Chinese poetry taken from the printed books currently used in the school. Finally, a questionnaire survey (20 minutes, as shown in Figure 2b) was used to gather each child's perceptions of e-book reading. In this phase, the experimenter reminded the children that they should compare their perceptions of reading of e-books with printed books, and the results of the questionnaire were then analyzed.



(a) Investigation 1: Paired group students were testing the IELS.



(b) Investigation 1: The questionnaire survey.

Figure 2. Investigation one conducted in this study

The questionnaire design

The questionnaire consisted of 48 questions designed to assess the children's perceptions of e-book reading with IELS. The first part of the questionnaire contained 30 questions on system usability, which were adopted from Lund's USE Questionnaire (2001) and translated into Chinese. The second part of the questionnaire consisted of 15 questions on perceptions of the functionality of IELS. All the questions in the first and second parts used a five-point Likert scale. The third part of the questionnaire consisted of three open-ended questions, which asked the children to briefly describe the advantages and disadvantages of the IELS, and any suggestions that they had about using the system.

The internal consistency and reliability were tested by means of the Cronbach's alpha coefficient, and the result for the sample as a whole was .96. For the various dimensions, the coefficient ranged from .86 to .91 (*Usefulness* = .88, *Ease of use* = .86, *Ease of learning* = .88, *Satisfaction* = .87, *Functionality* = .91), indicating the questionnaire was acceptable with good internal consistency and reliability. The independent sample *t*-test method was then used to analyze if there was any significant differences in the five dimensions in terms of male and female students.

The findings of gendered attitudes to e-book reading

In general, all of the children made very positive comments about the reading of e-books, as shown in Table 3, somewhat different to the findings in Lam et al. (2009), which examined the opinions of older readers. This is not surprising, as the boys and girls in this study are all digital natives, and thus have higher levels of technology acceptance than older individuals (Holzinger, Searle, & Wernbacher, 2011).

Although Meelissen and Drent (2008) suggested that the gender differences in attitudes toward using computer at school are small or even negligible, there was a significant difference in the *Satisfaction* dimension for all children. The results indicated that the girls ($m = 4.48$) were more satisfied with reading an e-book than the boys ($m = 4.20$). Moreover, in the other dimensions the girls also had slightly positive attitudes than the boys, although overall these gender differences were not significant.

The application of personalized reading technologies, such as e-books with IELS, as used in this work, can better support individualized reading, and thus is likely to reduce the gender inequalities related to the use of the technology in the classroom (Smith et al., 2007). In support of this, both genders represented positive attitudes towards the reading of e-books, rarely negative, as seen in gender related studies (e.g. Lam et al., 2009; Meelissen & Drent, 2008).

Table 3. The descriptive statistics and t-test results of the children's attitudes

Grade	Gender	Dimensions					Average	
		Usefulness	Ease of use	Ease of learning	Satisfaction	Functionality		
Grade 1	male n=11	m (s.d.)	4.77 (0.19)	4.46 (0.51)	4.52 (0.72)	4.81 (0.25)	4.58 (0.48)	4.63 (0.38)
	female n=14	m (s.d.)	4.46 (0.57)	4.08 (0.73)	4.14 (0.95)	4.59 (0.69)	4.44 (0.77)	4.34 (0.59)
		<i>t</i>	1.76	1.47	1.10	0.97	0.52	1.39
Grade 2	male n=15	m (s.d.)	4.53 (0.54)	4.26 (0.59)	4.23 (0.62)	4.43 (0.57)	4.50 (0.55)	4.39 (0.51)
	female n=12	m (s.d.)	4.60 (0.37)	4.70 (0.26)	4.69 (0.39)	4.69 (0.36)	4.73 (0.40)	4.68 (0.28)
		<i>t</i>	-0.43	-2.56*	-2.20*	-1.38	-1.20	-1.77
Grade 3	male n=13	m (s.d.)	3.90 (0.75)	3.63 (0.87)	3.81 (1.15)	3.93 (0.76)	3.97 (0.78)	3.85 (0.65)
	female n=12	m (s.d.)	4.10 (0.88)	4.12 (0.83)	3.75 (1.58)	4.54 (0.69)	4.28 (0.90)	4.16 (0.89)
		<i>t</i>	-0.62	-1.44	0.10	-2.06	-0.93	-1.00
Grade 4	male n=16	m (s.d.)	3.94 (0.64)	3.50 (0.67)	3.88 (0.97)	4.12 (0.58)	4.05 (0.70)	3.90 (0.55)
	female n=14	m (s.d.)	4.17 (0.55)	4.07 (0.55)	4.16 (0.96)	4.52 (0.42)	4.40 (0.63)	4.27 (0.49)
		<i>t</i>	-1.07	-2.54*	-0.81	-2.16*	-1.43	-1.92
Grade 5	male n=16	m (s.d.)	3.93 (0.84)	4.08 (0.69)	4.41 (0.75)	3.97 (0.77)	4.03 (0.34)	4.08 (0.49)
	female	m	3.98	4.02	4.33	4.25	4.25	4.17

	n=15	(<i>s.d.</i>)	(0.91)	(0.78)	(0.84)	(0.84)	(0.70)	(0.73)
		<i>t</i>	-0.14	0.21	0.25	-0.95	-1.12	-0.37
Grade 6	male	m	4.15	4.08	4.32	4.08	4.12	4.15
	n=14	(<i>s.d.</i>)	(1.13)	(0.90)	(0.83)	(1.05)	(1.09)	(0.94)
	female	m	4.10	4.09	4.18	4.36	4.38	4.22
All	n=14	(<i>s.d.</i>)	(0.93)	(0.81)	(1.12)	(0.79)	(0.64)	(0.81)
		<i>t</i>	0.14	-0.04	0.38	-0.79	-0.76	-0.21
	male	m	4.18	3.98	4.19	4.20	4.20	4.15
All	n=85	(<i>s.d.</i>)	(0.79)	(0.77)	(0.87)	(0.75)	(0.72)	(0.65)
	female	m	4.23	4.17	4.21	4.48	4.41	4.30
	n=81	(<i>s.d.</i>)	(0.75)	(0.71)	(1.03)	(0.66)	(0.68)	(0.67)
		<i>t</i>	-0.40	-1.61	-0.17	-2.57*	-1.96	-1.47

Note. * $p < .05$. "m" represents the mean value of the children's scores in the related dimension, and "*s.d.*" means the standard deviation of the children's scores in the related dimension. "*t*" means the independent sample *t-test* value, and the **bold** values mean that the scores between the male and female children were significantly different.

In the open-ended questions, the children's feedback was still positive and similar to the findings shown in Table 4. However, by examining their answers to the question as to whether any improvements are needed to IELS, 27.72% of the children hoped it could have more functions, such as games, drawing and annotation tools. As shown in Table 4, the boys were more likely to feel that the functions of the IELS fell short of their expectations, especially with regard to games.

Table 4. The descriptive statistics for the children's suggestions for improving the IELS

Suggestion	Males		Females	
	N	(%)	N	(%)
Games	9	10.59	1	1.23
Drawing tools	6	7.06	2	2.47
Annotation tools	13	15.29	15	18.52
Total	28	32.94	18	22.22

Note. "N" represents the number of children suggesting the related item, and "%" means the children's percentage of all gendered participants (males = 85 and females = 81).

These results echo the observation of Kay and Lauricella (2011) that male students played significantly more games during laptop-based learning, whereas the female students carried out significantly more note-taking, while Sim, MacFarlane, and Read (2006) also found that males engaged in more behaviors unrelated to learning in a similar context. Therefore, there were significant gender differences in the functions requested for the e-book platform.

Such usability-oriented requests raised among the children are substantially existed towards the e-book reading. The results thus show that usability does matter to children, although the genders have different ideas about how to improve it, and this issue deserves further investigation.

Investigation two: Identifying gender differences in reading behaviors and outcomes

The research procedure

As shown in Figure 3, the research procedure was designed to investigate whether there were any differences in the reading behaviors and outcomes between genders.

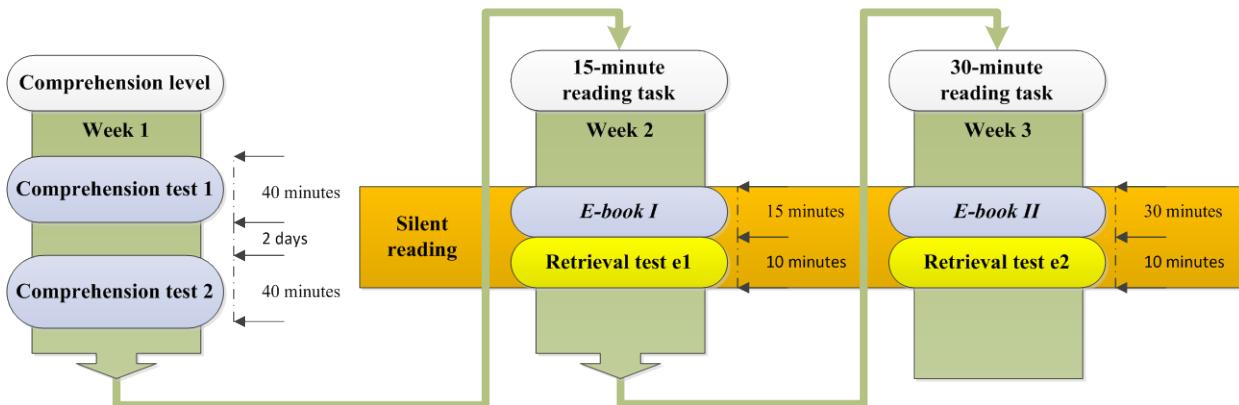


Figure 3. The research procedure of the investigation two for identifying the gender differences in reading behaviors and outcomes

Since silent reading is widely adopted in general classroom practice, it was thus considered the ordinary reading condition in this study. In the silent reading activity, the children were able to read at their own optimal rates, and this is in line with what Fraser (2007) noted about the *Rauding* status, which is an individual's preferred reading rate, at which they can effectively assimilate the ideas across sentences at a pace that follows their own cognitive speed. Moreover, this study adopted two different reading durations (15 and 30 minutes) that conventionally occur in the classes held at Taiwanese elementary schools (40 minutes).

The participants and reading materials

This study recruited 23 sixth-grade children (12 males and 11 females) with the consent of their parents to participate the reading experiment. Before the reading experiment, the children were asked to finish two comprehension tests to ensure that the genders were at similar reading comprehension levels that would not cause significant differences in their reading rates (Joshi & Aaron, 2000). As shown in Figure 4a, every participant was asked to silently read two e-books (one e-book per week) with an e-reader (FIC Tycoon TVB00). Meanwhile, an observer was arranged to unobtrusively sit in as a teacher and assist students if needed.



(a) Investigation 2: the e-book reading task



(b) Investigation 2: the retrieval test.

Figure 4. Investigation two conducted in this study

Two different reading durations (15 and 30 minutes) were used to examine the gendered reading behaviors and outcomes. Two e-books adopted in this study were general science information texts written in Chinese. E-book I (reading time = 15 minutes) consisted of 20 topics, a total of 3,640 words, the average words per sentence was 15 words, and the word frequency was 99.09% within the 5,021 common Chinese words that were selected from the elementary school survey of common words report (Ministry of Education, 2000). E-book II (reading time = 30 minutes) consisted of 24 topics, a total of 5,475 words, the average words per sentence were 14 words, and the word frequency was 99.20% within the above-mentioned set. The use of above level texts was to ensure that the two books

were appropriate with regard to meet the participants' word recognition abilities, so as to avoid a ceiling effect in the experiment.

The reading behavior tracking and reading outcome measuring

In the e-book reading tasks, the reading behavior tracking technique developed in the IELS was used to simultaneously record the reading behavior on the reading process profile of every child (each record comprises reading duration, texts, and page number). These profiles were collected by a central server, and then analyzed to identify any differences in the reading behavior between the genders throughout the reading processes.

Upon completing each reading task, the children were asked to take a 10-minute retrieval test, as shown in Figure 4b. Specifically, they were asked to freely recall some of the knowledge they had just learned by reading (Carver, 1990; Fraser, 2007), and the results were regarded as their individual reading outcomes. If a child did not completely read and understand the text, then the new knowledge may be poorly stored in the long-term memory, or even lost from the working memory, based on the theory of cognitive memory (e.g. Ecker, Lewandowsky, Oberauer, & Chee, 2010; Nation & Cocksey, 2009; Swanson & Howell, 2001).

In every retrieval test the children were asked to write 10 sentences about the scientific information contained in the e-book they had just read. The reading outcomes were then measured according to the correctness of each sentence based on five separate levels (the rating criteria were as follows: four points for completely correct, three points for almost correct, two points for half correct, one point for less correct, and zero points for no answer or completely wrong). Two raters assessed the sentences based on these criteria. The Cronbach's alpha coefficient of their preliminary rating results was .68, showing a good fit for the reliability measure. The raters were then asked to review the results together and reach a consensus through discussion if any discrepancies were found.

The findings for the reading behaviors and outcomes

Gender differences in reading behaviors

To confirm that the students of both genders had similar reading comprehension levels (Joshi & Aaron, 2000), the children took two comprehension tests before the reading experiment. As shown in Table 5, no significant differences were found between genders, and thus the male and female groups had approximately the same comprehension level, and so this did not interfere with the measurement of the reading rate, which was adopted as an indicator of reading behavior in this work.

Table 5. The comprehension test and the t-test results

Comprehension test	Male		Female		<i>t</i>
	m	(s.d.)	m	(s.d.)	
Test1	13.25	(2.09)	13.73	(2.87)	-0.46
Test2	13.92	(3.20)	16.18	(2.44)	-1.89
Total	27.17	(4.32)	29.91	(4.89)	-1.43

Note. "m" represents the mean value of the students' comprehension test scores, and "s.d." means the standard deviation of the students' comprehension test scores. "*t*" means the independent sample *t-test* value of the comprehension test scores between genders.

A total of 1,566 on-reading records were collected from the participants, and then analyzed to identify the gender differences in their reading behaviors. To understand the fluctuation in reading rate throughout the reading process, this study further examined the reading rate in 5-minute periods, and then converted every reading rate into the corresponding reading status according to the categories listed in Table 2. The independent sample *t-test* method was adopted to identify the significant differences in the reading rates between the genders.

As shown in Table 6, overall, the boys' reading rates were lower than those of the girls. A significant difference was found between the genders in the reading rates for the 30-minute reading task. This supports the finding of Burman,

Bitan and Booth (2008) that the girls tend to acquire vocabulary faster than boys, perhaps reflecting different ways of linguistic processing between genders.

According to Carver's (1977) definition, *Skimming* is used to superficially process a large quantity of text. Duggan and Payne (2009) claimed that while *Skimming* can improve memorization of the important ideas in a text, but may pass over the details within it. Our results show that the girls preferred *Skimming*, which is an important reading strategy essential for acquiring a good comprehension level of the gist of the text, as the reading behavior of spotting keywords shown in Table 2.

Reader and Payne (2007) pointed out that an adaptive reading strategy allows a reader to save more time to allocate to better reading, such as improving memorization of the important ideas by *Skimming*, but which reading strategy is the best relies on a complex set of issues (Lawless, Mills, & Brown, 2002; Salmerón & García, 2011), such as the texts, reading tasks, and reading skills. Salmerón and García (2011) claimed that children, starting at around 11 years old, possess the necessary reading skills to implement reading strategies. Nevertheless, how these strategies affect e-book reading comprehension is still an open question.

Table 6. The reading rate, status, and the t-test results

Time (minutes)	15-minute reading task (nr=584)						30-minute reading task (nr=982)							
	Male		Female		Male	Female	m	(s.d.)	st	m	(s.d.)	st	t	
	m	(s.d.)	st	m	(s.d.)	st	t							
5	307.38	(81.42)	Ra	456.61	(164.34)	Sk	-2.72*			336.49	(118.25)	Ra	422.25	(108.48)
10	351.10	(116.05)	Ra	389.21	(119.64)	Ra	-0.78			361.20	(118.12)	Ra	428.11	(87.24)
15	387.32	(135.14)	Ra	481.84	(142.69)	Sk	-1.63			335.12	(101.89)	Ra	406.74	(121.08)
20										348.78	(80.71)	Ra	431.42	(155.63)
25										366.41	(85.56)	Ra	460.67	(136.54)
30										346.01	(188.39)	Ra	448.68	(202.12)
Average	348.60	(106.09)	Ra	442.55	(122.20)	Sk	-1.97			349.00	(53.56)	Ra	432.98	(97.74)
													Sk -2.59*	

Note. * $p < .05$, ** $p < .01$. "nr" represents the number of on-reading records. "m" represents the mean value of the students' reading rates in the related period, and "s.d." means the standard deviation of the students' reading rates in the related period. "st" means the corresponding reading status of the related reading rate, "Ra" means the *Rauding* status, and "Sk" means the *Skimming* status. "t" means the independent sample *t-test* value of the reading rate, and the **bold** values mean that the reading rates between the male and female students were significantly different.

The boys' reading rates, all in the *Rauding* status, were very stable throughout the reading process, as expected with the silent reading behavior. However, the girls' reading rates were mainly in the *Skimming* status, which was found for none of the boys.

By contrast, the boys read in the *Rauding* status, at the pace of their cognitive speed (Carver, 1984; Fraser, 2007) throughout the reading process. The reading strategies that were not used by the boys may have been neglected due to their undeveloped reading skills or strategies, if the performance of the girls is regarded as 'the norm'. This is a gender difference in reading behavior when the children were reading e-books. Therefore, instruction in various reading skills and strategies seem to be needed for children, as noted by earlier researchers (e.g., Mayer, 1996; Park & Kim, 2011; Reutzel, Smith, & Fawson, 2005). In practice, teachers can provide a proper instruction of reading skill and strategy towards the gender differences in reading of e-books for promoting them a better reading experience (Park & Kim, 2011; Reutzel et al., 2005; Sung, Chang, & Huang, 2008), and prevent such differences lead to the barrier for children when e-books are used for learning.

Gender differences in reading outcomes

Following the gender difference in reading behaviors identified above, it is unsurprising that significant differences in the reading outcomes of 30-minute reading task were also found between the genders, as shown in Table 7.

Salmerón and García (2011) claimed that the reading strategy used has an effect on comprehension. Therefore, the girls may have used *Skimming* to improve their memorization of important ideas in the e-books, thus gaining better

comprehension of the gist of the text, resulting in the different reading behaviors between the genders. This then had a significant effect on their reading outcomes, leading them to outperform the boys, which is in line with the finding of Chiu and Chow (2010) that most female students did better than the male ones with regard to their reading achievement in high school, and this another example of a “falling behind” problem in reading achievement.

Table 7. The reading outcomes and the t-test results of the reading tasks

Retrieval test	Male		Female		<i>t</i>
	m	(s.d.)	m	(s.d.)	
e1 (15-minute)	14.00	(4.49)	16.09	(4.28)	-1.14
e2 (30-minute)	15.17	(4.80)	21.18	(4.47)	-3.10 **
Total	29.17	(6.73)	37.27	(7.09)	-2.81 *

Note. **p* < .05, ***p* < .01. “m” represents the mean value of the students’ retrieval test scores, and “s.d.” means the standard deviation of the students’ retrieval test scores. “*t*” means the independent sample *t-test* value of the retrieval test scores between genders, and the **bold** values mean that the scores between the male and female students were significantly different.

However, this problem is different from the one found for children with regard to their attitudes towards computers, as reported by Meelissen and Drent (2008). In fact, the differences in reading behaviors and outcomes found in the current study may disappear when the development of sensory processing in boys catches up to that of girls, as the adult language processing of both genders relies similarly on the efficiency of the linguistic network, as noted by Burman et al. (2008).

General discussion and conclusion

The gender differences in reading e-books

Although screen-based reading is becoming more popular and has changed the reading behaviors of digital natives (Liu, 2005), gender differences in reading may still exist (Chiu & Chow, 2010; Liu & Huang, 2008). However, our results reveal that these differences when reading e-books may not be directly related to those found in students’ computer-assisted learning.

In fact, Meelissen and Drent (2008) emphasized that gender difference in attitudes towards using computers leads to a “falling behind” problem between genders. Based on our experimental results, the effect of gender was against expectation with regard to reading e-books. In addition, the reading process is individualized and varied, as reflected in the gender differences in reading behaviors revealed by this work. Moreover, the students’ use of reading skills and strategies also seemed to be gendered, leading to the gap in reading outcomes between the girls and boys. Therefore, restructuring the understanding of gender differences in reading of e-books is a critical issue before this technology is more widely used for formal learning.

In general, our results for the attitudes, reading behaviors and outcomes of reading e-books show the significant differences between genders. The girls expressed more satisfaction attitude to demonstrate a tactical reading so as to represent better reading outcomes. By contrast, the boys also had the positive attitude but emphasized a higher expectation of versatile functions, and did not read in an active manner, like the girls, leading to their worse reading outcomes. Nevertheless, the generalizability of our findings may be somewhat limited, mainly because the experiment was conducted with a relatively small sample size. More empirical studies are thus needed to disclose a more complete picture of the gender differences that arise when reading e-books.

Conclusion

Since the “falling behind” problem between genders has been shown to affect children’s computer-assisted learning, it is worth examining whether this problem also applies to e-book reading. This work thus examined gender differences among children reading e-books, serving as a preliminary study of this issue.

In this study, we presented the evidence obtained from two investigations to identify the related gender differences, including attitudes, reading behaviors and outcomes towards the e-book reading. Based on the results of both investigations, the gender differences are considerable factors in children's reading of e-books. Our findings revealed that the boys did not have the better performance, against expectations. One possible reason for this is the boys may have been distracted by the e-book itself due to their greater technology acceptance, and this meant they were less good at reading task. Nevertheless, a large experiment is required to confirm this assertion.

With the aim of further dealing with the gender differences in e-book reading, our future work will focus on the use of the adaptive scaffolding when the "falling behind" problem occurs due to gender differences, as this will help children to better use e-books in an academic context.

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Level Up, My-Pet: The Effects of Level-up Mechanism of Educational Agents on Student Learning

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ABSTRACT

A number of studies have been devoted to investigating the influence of educational agents on different aspects of student learning. However, little attention has been paid to the effects of the level-up mechanism of educational agents on students although this is a significant issue. Thus, this study develops an educational agent with the level-up mechanism so that the effects of the level-up mechanism can be addressed. The results of a within-subject experiment conducted in an elementary school showed that the level-up mechanism of the educational agents can help students develop a positive relationship with the educational agent, and further enhance their motivation in terms of attention, relevance, and satisfaction.

KEYWORDS

Educational agent, Level-up, Game-based learning

Introduction

In recent decades, one direction of technology enhanced learning that has been attracting increased attention is the study of educational agents, which are human-like virtual characters that play specific educational roles in their interaction with students. There are two reasons for the development of educational agents. First, people are attracted to human-like features, given face and eye contact, humanizing the human-computer interaction (Weinschenk, 2011) and therefore allowing them to treat computers as social actors (Reeves & Nass, 1996). Thus, the educational agents are regarded as friendly interfaces that can facilitate interaction with students, leading to enhanced motivation and the perception of improved ease and comfort (Gulz, 2004). Such features can also be applied to benefit student learning so that they can become engaged in the learning environment (Gulz, 2005).

Second, a number of advantages have been reported to learning with the support of different types of educational agents on specific aspects, such as exploration (Höök et al., 2000), reflection and articulation (Tholander et al., 1999), communication (Johnson et al., 2000), and negotiation (Bull, 2004). This might be because educational agents can serve as learning companions offering virtual participation in an individual environment. By doing so, students are encouraged to interact with the educational agent in a social context and experience an enjoyable learning process, which, in turn, results in the aforementioned learning advantages.

Further looking into the design of educational agents, several pedagogical strategies have been incorporated to promote student learning based on human teaching and learning theory (Woolf, 2009). For example, the AutoTutor system employs dialog in natural language to help students construct answers to difficult questions (Graesser et al., 2008). The Herman system, an insect-styled agent, offers students problem solving advice in the domain of plant structures (Lester, Towns, & Fitzgerald, 1998). In addition, to maximize the influences of educational agents, the affective design of educational agents are also concerned (de Vicente & Pain, 2002), such as empathic responses (McQuiggan & Lester, 2007) and emotional expression (Beale & Creed, 2009; Brave et al., 2005).

Although past studies contribute to our understanding of the development of educational agents, most of them have focused upon fixed-style educational agents rather than incremental ones. For example, the appearance and skills of educational agents can level up gradually while interacting with students. This level-up mechanism is significant because it, on the one hand, is commonly used to promote students' goal-pursuing in digital games, where students' progress and feedbacks on how to improve are clearly offered. Thus, students might benefit from this mechanism while it is incorporated into the design of educational agents. On the other hand, the incremental agent is closely related to the concept that virtual characters as active mirrors to reflect students' learning status (Chen et al., 2007), which gives great educational potential to facilitate the students' self-awareness and self-reflection. Nevertheless, few studies have explored this issue although there have been some emphasizing the influence of educational agents with different characteristics, such as a human-like persona and expressive manners (Beale & Creed, 2009; Groom et al., 2009; Wang et al., 2008). Thus, there is a need for further research on this problem.

To address this issue, this study first develops a level-up mechanism for the educational agent, and then goes on to investigate its influence on student learning. The research question addressed in this study is: “*What are the effects of the level-up mechanism of educational agents on student learning?*” This research question can be further divided into two sub-questions: (1) *What is the influence of the level-up mechanism of educational agents on students' motivation?* (2) *What is the influence of the level-up mechanism of the educational agent on students' perceived relationship?*

Literature review

Educational agents are human-like computer simulated characters that are designed to improve student learning in an individual environment through virtual participants (Chou, Chan, & Lin, 2003). In addition to the *cognitive aspects* of the design of educational agents, the *affective aspects* have recently attracted more and more attention. This is because the influence of the educational agent on student learning can be expanded by taking the affective qualities of the virtual character into account in the design (de Vicente & Pain, 2002). Furthermore, these affective concerns can be categorized into three classes: *visual style*, *human-like persona*, and *expressive means*, as illustrated in Table 1.

Table 1. Affective design of educational agents on student learning

<i>Features</i>	<i>Authors</i>	<i>Descriptions</i>
Visual styles	Gulz & Haake (2005)	Different visual styles (e.g., realistic or iconic) of virtual characters influence students' choice preferences.
	Baylor et al. (2003); Baylor (2005)	Different visual appearances (e.g., ethnicity and gender) of virtual characters influence students' choice preferences.
	Groom et al. (2009)	Behavioral realism (e.g., consistent high/low realism and mixed realism) of virtual characters influences students' responses.
Human-like persona	McQuiggan & Lester (2007)	Empathy characteristics of virtual characters influence students' perception.
	Wang et al. (2008)	Politeness characteristics of virtual characters influence students' perception.
Expressive manners	Baylor & Kim (2003)	Different expressive styles (e.g., limited intonations, enthusiastic or calm) of virtual characters influence students' perception and choice preferences.
	Beale & Creed (2009); Bartneck & Reichenbach (2005); Brave et al. (2005)	Different emotional expressions (e.g., present/absent self-oriented emotion and present/absent empathic emotion) of virtual characters influence students' attitudes, perceptions, and behavior.

Regarding visual style, the focus is on the representation of the educational agents, and investigating the effects of its visual appearance on the students (Gulz & Haake, 2005). A human-like persona with human-like characteristics, such as empathy and politeness allow the educational agent to have an impact (Wang et al., 2008; McQuiggan & Lester, 2007), although the effects of the expressiveness of different expressive styles, such as expressions of enthusiasm or calmness should also be emphasized (Baylor & Kim, 2003).

However, although past studies contribute to our understanding of the development of educational agents, most emphasize the influence of fixed-style educational agents rather than incremental ones, whose visual appearance changes according to the student's achieved learning levels. Few studies have investigated the influence of the level-up mechanism of the educational agent based on the student's learning, leaving a gap in the literature that needs to be filled. To address this research question, this paper first develops a level-up mechanism, which is embedded in an educational agent system, named trainable My-Pet. The trainable My-Pet system is introduced in the next section. We then conduct and discuss an empirical study of the impact of the level-up mechanism on student learning. Subsequently, the findings of the empirical study are further used to answer the research question.

Trainable My-Pet

Conceptual diagram

Trainable My-Pet is an educational agent system employing a reciprocal caring strategy with pet-styled educational agents. We employ the reciprocal caring strategy to determine how to encourage students to care for the educational agent so that the educational agent has sufficient opportunities to care for students (Chen et al., 2011). In other words, reciprocal caring involves integration of the affective and cognitive aspects of the educational agent to benefit student learning.

More specifically, each student nurtures an educational agent, the My-Pet, and are required to take good care of it (Chen et al., 2007), including *feeding* it and *training* it to learn skills. The purpose of feeding is to develop a close relationship with the My-Pet. This is supported by the finding that enhanced human-computer interaction is helpful to developing a relationship between the educational agent and the student, which further contributes to sustaining the students' participatory motivation. In addition, the purpose of training is to align game-playing with learning through the pedagogy of *learning-by-demonstration*. More specifically, within the pet-training game context, students are able to demonstrate knowledge of the subject domain to their My-Pet, to assist the My-Pets to learn and to raise their level up to a higher one. A conceptual diagram of the process is illustrated in Figure 1.

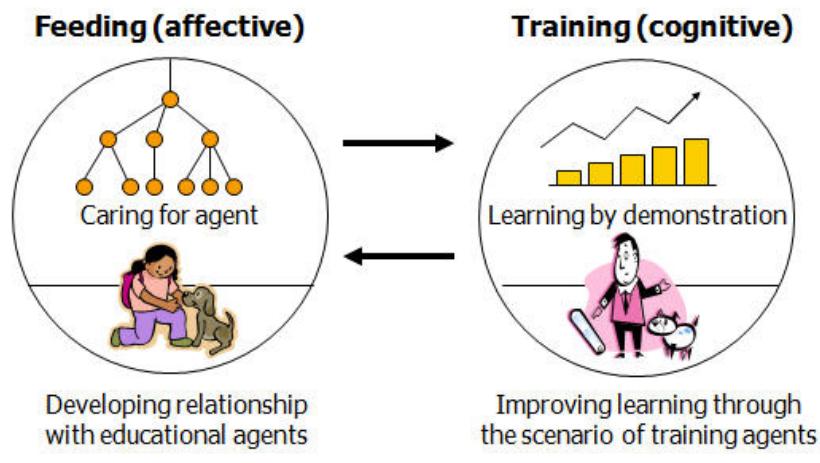


Figure 1. Conceptual diagram of the trainable My-Pet system

System interface

Feeding and training

In the feeding function, students interact with the My-Pet within an interactive environment. The My-Pet's status is represented by a numerical value noted so that the student can take appropriate caring actions. For example, Figure 2(a) illustrates the My-Pet's status, including their age, energy, money, health, mood, and experience. To look after their My-Pets better, students are required to buy food and goods for them with EduCoins, which can be earned from successfully completing learning activities. In this way, the My-Pets play the role of "motivator" so that their habits of pet-nurturing can be aligned with that of subject learning, which might further contribute to the maintenance of the student's participatory motivation for a long period of time.

In the training function, the subject domain of the trainable My-Pet system is to complete fraction operations in elementary math, which includes five categories of learning tasks: "basic operations," "adding fractions," "subtracting fractions," "multiplying fractions," and "dividing fractions." These tasks are chosen because fraction operations are a significant but a difficult subject to master in elementary math. The trainable My-Pet system can be used to support students' math learning. The fill-in-the-blank question is used in the learning tasks in these categories. For example, Figure 2(b) illustrates the learning task for "adding fractions with unlike denominators". Students are requested to fill in

appropriate numbers in the blank prompt box step-by-step. The process enhances the students' procedure knowledge of the fraction operation.



Figure 2. Interface of the trainable My-Pet system

Level-up mechanism

To facilitate learning, a level-up mechanism is incorporated, which is designed to enhance the students' awareness of what they have learned and to motivate them to improve their mastery. This objective is realized in two ways. The first is related to the My-Pet's *representation*, where symbolic marks (e.g., badges) and outside appearance and accessories (e.g., styles) indicate the student's current level of achievement. The second is related to the My-Pet's *skills*, or sets of abilities that the My-Pet can show. Table 2 illustrates these different skills for different levels. In short, the level-up mechanism of the My-Pet provides a continuous ladder leading to the learning objectives, where detailed information is presented to inform the student what their learning progress is along these ladders. By doing so, students are encouraged to complete learning tasks so that the My-Pet can be promoted to the next level. The My-Pet plays the role of "facilitator," which establishes an immediate goal for students to pursue and sustains their willingness and motivation during this process, which in turn fosters student learning.

Table 2. Level-up mechanism

	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Badge	Non	★	★★	★★★	★★★★	★★★★★
Style						
Skill	Non	(Hoop jumping)	(Ball rolling)	(Wire walking)	(Somersault turning)	(Waltz dancing)
Task	Non	Basic operations	Adding fractions	Subtracting fractions	Multiplying fractions	Dividing fractions

Methodology

To address the research question, a within-subject quasi-experiment was conducted in a one-to-one digital classroom environment, in which every student had access to a computing device with wireless capability to enhance their learning (Chan et al., 2006).

System instrument

Two variant versions of the My-Pet system were used in the experiment but the subject domain of the two versions is the same (i.e., fraction operations). In other words, the major difference between the two versions lies in whether the My-Pet can be trained to change levels according to the students' learning progress. Table 3 summarizes the major differences between the two system instruments.

Table 3. Different system instruments

<i>Version</i>	<i>Description</i>
Trainable version	Students learn fraction operations via training their My-Pets which can level up according to students' learning progress.
Non-trainable version	Students learn fraction operations via training their My-Pets whose levels cannot be promoted according to students' learning progress.

Participants and procedure

The participants were 31 fifth-grade (average age 11 years-old) elementary school students, including 16 boys and 15 girls. Since there was a similar number of boys and girls, it was assumed that the bias effect resulting from gender difference could be prevented. Figure 3 illustrates the experimental procedure. The experiment was divided into two phases. In the first phase students used the non-trainable version of the My-Pet system; in the second phase they used the trainable version. Each phase was completed in 10 fifteen-minute sessions over a period of six weeks.

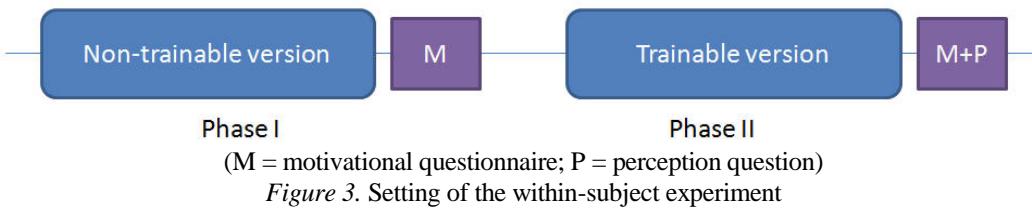


Figure 3. Setting of the within-subject experiment

Measurement

Motivational questionnaire

A motivational questionnaire based upon the 5-point Likert scale developed by Dempsey and colleagues (Dempsey, Rasmussen, Haynes, & Casey, 1997), was utilized to collect comprehensive information in terms of attention, relevance, confidence, and satisfaction dimensions. However, since the questionnaire was originally designed mainly for college students, not all of the items were suitable for the sample in this study, which were elementary school students. In addition, the questionnaire had too many items ($N = 36$) for elementary school students. Thus, we systematically eliminated 12 items so that the simplified version contained 24 items (each dimension contained 6 items). The items used are listed in the Appendix, and the four dimensions of the questionnaire had a relatively high reliability (Cronbach's $\alpha = 0.84, 0.72, 0.78$, and 0.61 , respectively).

Perception questions

At the end of second phase, all students were asked a semi-structured question about their perception: "Did you feel a close relationship with your My-Pets in the trainable version?" If the answer was "yes," students were further asked to mark the functions provided for deepening this relationship. Students could mark multiple items from the six functions, including naming, feeding, training, playing, exercising, and bathing.

Data analysis

The independent variable for the experiment was the difference in settings for the two system versions, whereas the dependent variables were the motivational questionnaire and perception questions. Regarding the motivational questionnaire, four repeated measurement t-tests were conducted to examine the significance between the two phases in terms of the four aspects. Regarding the perception question, the frequency of students' chosen functions was calculated.

Results

Trainable levels

Table 4 shows the achievement levels obtained by the students in the experiment, which can be regarded as reference information from which to interpret the results from the motivational questionnaire and perception questions. The results show that approximately half of the pupils (52%) trained their My-Pets to the highest level, implying that they experienced all of the learning levels. Inversely, it should be recognized that some students (16%) did not train their My-Pets to any higher levels but simply maintained the initial level.

Table 4. Trainable levels in this experiment

<i>Levels</i>	<i>Numbers (Percentage)</i>
Level 6	16 (52%)
Level 5	3 (10%)
Level 4	4 (13%)
Level 3	1 (3%)
Level 2	2 (6%)
Level 1	5 (16%)

Motivational questionnaire

Table 5 shows the means and SD of the motivational questionnaire in terms of four aspects. A further t-test showed that the aspects of attention, relevance, and satisfaction were statistically significant ($t = 4.19, p < .01$; $t = 2.92, p < .01$; $t = 2.31, p < .05$, respectively), whereas the aspect of confidence was not significant, although it also improved. This implies that the level-up mechanism of My-Pet was worthy of attention, helpful to enhancing the link between learning goals and what the My-Pets do, and reinforcing of student satisfaction.

Table 5. Results of the motivational questionnaire

	Pre-test		Post-test		<i>t</i>
	Mean	SD	Mean	SD	
Attention	20.97	4.62	25.19	2.90	4.19**
Relevance	22.13	3.81	24.84	3.11	2.92**
Confidence	23.81	4.09	24.90	3.30	1.10
Satisfaction	22.23	3.46	24.35	3.47	2.31*

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

One possible interpretation is that the level-up mechanism in the game enhanced the human-computer interaction between the My-Pet and the student, evoking perceptual arousal because of the meaningful context: Training their pets. Thus, students were required to pay more "attention" to their My-Pets, and invested a greater effort in learning tasks. Nevertheless, an alternative explanation is that such effect is related to the integration of a new tool in the educational process (i.e., the novel effect). There is a need to clarify the reason for this effect in the future. Moreover, while students used the trainable version, the learning goal and training goal could be aligned with each other so that the aspect of "relevance" was enhanced. In addition, people tend to develop an emotional attachment to their pets (Melson, 2001; Beck & Katcher, 1996). Thus, students might also become emotionally attached to their virtual pets as facilitated by the design of the human-computer interaction (Kusahara, 2000) such as naming, feeding, touching, and training. This would reinforce students' "satisfaction" during the process of training their My-Pets.

The reason why “confidence” was not significant might lie in the fact that the development of confidence is closely related to the inner nature of the subject domain, and needs a long period of time to develop. In this study, some students did not reach the top level, so their learning process might have been insufficient to have a significant impact on the improvement of confidence.

Perception question

Table 6 lists students’ self-reported responses to questions asking whether they felt a close relationship to their My-Pets. 74% of the students answered “yes,” and 26% answered “no”. This confirms that using a trainable My-Pet to enhance interaction with educational agents might be a suitable approach for some students, but not all. Furthermore, reasons were analyzed for those students who answered “no,” and these included the lack of time (e.g., “not sufficient time to develop a relationship” from S12 & S5), the lack of reality (e.g., “behaviors are not like those of real dogs” from S6 & S32), and the lack of uniqueness (e.g., “all dogs are similar in appearance” from S13 & S28) and some students felt the My-Pets were “just virtual ones on the screen” (from S3 & S10).

Table 6. Functions for developed relationship

<i>Answer</i>	<i>Numbers (Percentage)</i>
Yes	23 (74%)
No	8 (26%)

Those students who answered “yes” were asked to rank the functions that helped them develop a relationship. The results are listed in Table 7, with “training” being perceived as the most significant function. In addition, students also discussed the impact of the training mechanism on their learning, including enhanced goals (e.g., “My goal is to let my pet learn all of the skills” from S21; “In the second version, I have a clear goal to take actions to achieve” from S3), greater enjoyment (e.g., “It is more fun to learn mathematics in this version” from S16; “It is interesting to learn math with the My-Pet in the dog-training place” from S1; “The function of training My-Pet makes this system more attractive” from S30), and more satisfied (“When my pet has learned the skills, I feel satisfied with the achievement” from S3; “I feel a sense of achievement in My-Pet’s going up a level” from S15; “I am satisfied when I complete these learning tasks even though the tasks are difficult” from S21).

Table 7. Functions for developed relationship

<i>Functions</i>	<i>Ranking (Percentage)</i>
Training	19 (%)
Feeding	17 (10%)
Exercise	17 (13%)
Playing	11 (3%)
Bathing	10 (6%)
Naming	9 (16%)

Discussion

Level-up mechanism: From the motivational perspective

Previous studies have indicated that it is important to discuss long-term influences on students’ motivation, especially when we consider both the cognitive and affective aspects in the educational agent design. This is because the affective design of educational agents (e.g., feeding) might be separated from the cognitive design (e.g., learning). From the perspective of motivation theory, the affective design of the training My-Pet might be useful for some students who are not initially interested in the subject domain. However, for those students who have a strong motivation to learn a subject, they might perceive that such an affective design to be unrelated to the subject domain and regard this as a negative condition, decreasing their intrinsic motivation toward learning this subject domain in the long run (Waterman, 2005).

To avoid this disadvantage, it has been suggested that the aspect of motivation (Brophy, 2008) and a positive view of effort be emphasized (Dweck, 2000; Van Overwalle & De Metsenaere, 1990). Specifically, students should learn not

only to retain content, but to value and appreciate what are taught. By doing so, they will be willing to learn and desire to learn more. From the perspective of game-based learning, the level-up mechanism proposed in this study seems to serve as a game-playing model, in which students are able to enjoy the effort spent on learning tasks, which in turn, might contribute to the alignment between learning goals and gaming goals. In other words, when students exert efforts at training their My-Pets they are not only engaged in the pursuing the process of learning math, but are also pursuing the process of improving their level of achievement. They obtain immediate feedback through the visual representation of the educational agents in an enjoyable and pleasurable way. Thus, level-up mechanism could encourage students to value and appreciate what they have learned, providing the learning goals and gaming goals can be aligned with each other.

Moreover, incorporating game strategy with subject learning through educational agents involves a complex interaction of student motivation. It is argued that motivation is multi-faceted: some facets are directly related to the subject domain (i.e., intrinsic motivation) whereas some are indirectly related to the subject domain (i.e., extrinsic motivation). Although intrinsic motivation is significant, extrinsic motivation is also helpful to foster learning, because many of the tasks that students need to perform are not inherently interesting or enjoyable (Deci & Ryan, 1985). In other words, extrinsic motivation is not always harmful to student learning (Zichermann & Cunningham, 2011). When students can be extrinsically motivated to value tasks, they are gradually able to self-regulate their learning process. Accordingly, it might be good for students to be stimulated by multi-faceted motivation. In particular, if students find that learning is intriguing and rewarding in the long run, this extrinsic motivation might transfer into direct motivation related to subject learning.

Level-up mechanism: From the development perspective

The results of this study provide some reflections related the future development of educational agents. The first reflection asks a basic question: Why and how are close relationships developed with educational agents? It is argued that people tend to treat computers as social actors rather than tools (Reeves & Nass, 1996). People like to develop relationships with the subjects they interact with. This offers a meaningful rationale to create computer-simulated educational agents which can help to maximize their impact on learning. The training My-Pet takes advantage of the close relationship of students with their virtual pets (Melson, 2001). Specifically, pet characteristics are incorporated into the educational agents, and the human-computer interaction is further enhanced through the addition of the level-up mechanism. The findings show that three functions (i.e., training, feeding, and exercising) had the greatest impact on the relationship that developed between the students and their educational agents. Analyzing these three functions, it can be found that they involve more complex interactions that might elicit the personal attachment of students with their pets. This is consistent with the finding that interactivity can be helpful to develop the sense of reality in relation to digital pets (Kusahara, 2000). This result seems to suggest that developing a close relationship (even emotional attachment) with their educational agents might contribute to participatory motivation.

The second reflection follows the first but further focuses on the learning perspective: How can one facilitate student learning underpinned by this close relationship? The results of this study reveal that such design could enhance certain students' motivation, but there are still crucial issues that need to be addressed related to the motivational perspective, as discussed above. A number of pedagogies have been suggested as related to the influence of educational agents, including cognitive apprenticeship (Collins et al., 1989), reciprocal teaching (Palincsar & Brown, 1984), learning by disturbing (Aimeur & Frasson, 1996), and the teachable agent paradigm (Chase et al., 2009). Although the training context of the level-up mechanism is based on the model of "learning by demonstration," its effects on students' learning achievement are not examined in this study. There is a need to further investigate the effects of the level-up mechanism on students' learning achievement, seeking for ever more effective pedagogies, which would help maximize the impact of educational agents on student learning, the ultimate goal of the design of educational agents.

Conclusion

In response to the first sub-research question, what are the influences of the level-up mechanism on students' motivation, the research findings from this study reveal that the level-up mechanism could enhance students' motivation in terms of attention, relevance, and satisfaction. In response to the second sub-research question, what are the influences of level-up mechanism on the students' perceived relationship, the results indicate that the level-up mechanism has a significant impact that could help students develop a positive relationship with the educational agents.

Nevertheless, there are some limitations to this study: (1) This study was merely a short-term research project although it did show the positive effects of educational agents on students. There is a need to further investigate the long-term impact on student learning. (2) Due to the limitations of the quasi-experimental setting in the primary school, the within-subject experiment did not contain two conditions with different treatment orders so that the bias resulting from different treatment orders could be alleviated. Its possible influences should be further clarified in future work. (3) Although this study reported the increased attention on students' attention, it contained the overall effect of the agent and subject domain. More experiments are required to further address the issue that such increased attention is related to the agent or subject domain.

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Appendix

Attention

- 01) The material presented in this game was eye-catching.
- 02) The screen design was boring.
- 03) The game had elements that stimulated my curiosity.
- 04) I didn't really care what happened during the game.
- 05) The variety of screens and interactions helped to maintain my attention.
- 06) The amount of repetition in this game caused me to be bored.

Relevance

- 07) I was able to set my own goals during the game.
- 08) From the beginning of the game the goals were unclear.
- 09) The content of the game is relevant to my interests.
- 10) The content of this game will be useless to me.
- 11) I could relate the contents of this game to things I have seen, done or thought.
- 12) This game was very foreign to my background and interests.

Confidence

- 13) After being given verbal directions, I felt confident that I knew how the game was played.
- 14) After being given verbal directions, I was not confident that I knew what the objectives of the game were.
- 15) As I played the game, I felt confident that I could succeed.
- 16) The game was always too difficult.
- 17) When I did well at this game, I felt it was through my efforts.
- 18) I did not always feel in control in this game.

Satisfaction

- 19) It felt good to successfully complete the game.
- 20) There were few ideas or skills I acquired that I might be able to use in my life.
- 21) I did not get a lot out of playing the game.
- 22) Completing the game gave me a satisfying feeling of accomplishment.
- 23) The competition was fair.
- 24) My opponent (or the computer) had too much of an edge.

A Service-Based Program Evaluation Platform for Enhancing Student Engagement in Assignments

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ABSTRACT

Programming assignments are commonly used in computer science education to encourage students to practice target concepts and evaluate their learning status. Ensuring students are engaged in such assignments is critical in attracting and retaining students. To this end, WebHat, a service-based program evaluation platform, is introduced in this work to support programming assignment practice. WebHat provides students with immediate assistance via online evaluation services and helps teaching staff monitor student status and progress. Based on the results of this system, teaching staff can dynamically adjust, if necessary, online evaluation services to provide further help to enhance student engagement in the ongoing assignment. To demonstrate the effectiveness of WebHat, an empirical study is conducted with freshman students as the subjects during the *Introduction to Computer Science* course. The results show that students are encouraged to start working on their assignments earlier and develop programs in the desired direction with the aid of the dynamically adjusted online evaluation services. WebHat thus enables students to submit better final products with regard to both functionality and quality.

Keywords

Student engagement, Programming teaching, Programming evaluation service, Service-based learning platform

Introduction

Student engagement is an important factor that contributes to the level of student achievement (Fredricks et al., 2004; Munns & Woodward, 2006; Cano, 2011). In computer science education, programming assignments are commonly used to get students to focus on target concepts and to evaluate their learning status. Through appropriate assignment design with regard to the content, context and expected product, students should be able to progress in their learning and teachers should be able to identify any problems that are occurring on the course. Ensuring student engagement in such assignments is thus critical in attracting and retaining students (Hansen & Eddy, 2007).

Traditional programming assignments proceed with a *release and then evaluate until deadline style*, where the responsibility of teaching staff lies in releasing the initial assignment requirements and then evaluating final assignment products. Students in this learning style complete the programming assignment in a black box manner, and thus most students are not conscious of any problems until they receive unsatisfied grades in the final evaluation. In this context, poor grades not only represent a failure in learning, but also have an adverse effect on student motivation.

Additionally, the success or failure of assignment practice often depends on the individual backgrounds and behaviors of students (Law et al., 2010; Blikstein, 2011). For example, teaching staff usually assume that students have the ability to maintain an appropriate schedule to deal with their assignments, but in reality many students start work too late and subsequently achieve poorer than anticipated grades. Similarly, some students develop their assignment in a wrong direction because of misunderstanding about the requirements. When a significant number of students have such problems, then the entire assignment may be considered a failure. To avoid this, it is thus necessary to monitor student engagement in the assignment and to provide help when it is needed.

This paper thus introduces WebHat, a service-based programming evaluation platform, to support programming assignment practice. A well-designed assignment attempts to ensure student engagement via releasing related

assistance, such as test cases, when the project is announced. Based on the design of the assignment, teaching staff can set online evaluation services on WebHat. By accessing the results of the evaluation of their assignment products while they are being produced, students can acquire immediate assistance before the end of the project. In addition, data about student interactions with WebHat will be collected, and teaching staff can thus monitor the students' status with regard to the assignment, such as whether or not they have started work, and whether they are making efforts to improve based on the results of the online evaluation. Furthermore, WebHat utilizes a service-oriented architecture (Papazoglou, 2003; Papazoglou et al., 2008) to provide teaching staff with the flexibility needed to adjust online evaluation services dynamically. Based on the observations of student status during assignment development, teaching staff can provide students with prompt, active and direct help. The ability to keep accessing the online evaluation services will guide students toward successful outcomes in their assignments.

Background

In the recent years, e-learning systems have been widely utilized as a platform for programming practice (Verdú et al., 2011). One of major benefits of teaching this way is that students can acquire some pre-defined immediate assistance from e-learning systems. To enhance student involvement in programming practice, different levels of assistance are provided by various e-learning systems. For example, ClockIt (Norris et al., 2008) and Retina (Murphy et al., 2009) focus on assisting students in solving syntax, semantics and runtime errors to make their program executable. In contrast, Submit! (Pisan et al., 2003), RoboProf (Daly & Horgan, 2004), Marmoset (Spacco et al., 2006), Web-CAT (Edwards & Pérez-Quiñones, 2008), and NOBASU (Funabiki et al., 2010; 2012), focus on providing online testing to assist students in developing an assignment product that will meet specific requirements. Besides assisting students in ensuring that their assignment product is executable and correct, some systems focus on assisting students in getting more involved in the assignment in order to encourage them to keep improving the quality of their work. For example, Lawrence (Lawrence, 2004) proposed a Critical Mass project in which students develop game strategies via programming for a final Critical Mass tournament. Figure 1 is an example of two major support for a current e-learning system applied in the programming assignment process. As shown in Figure 1(a), the e-learning system provides a fixed set of online evaluations for a specific kind of assistance that can help the students develop their work.

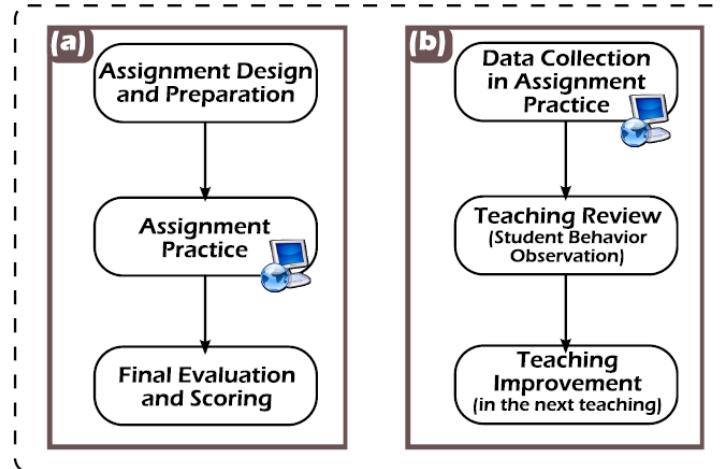


Figure 1. Two major support for a current e-learning system in (a) The programming assignment process, and (b) The teaching review process

The data collected in e-learning systems which reflect the different levels of frustration in learning are valuable. To help teaching staff review their teaching, many existing e-learning systems collect the data about student behavior in programming assignment practice (Spacco et al. 2006; Edwards & Pérez-Quiñones, 2008; Norris et al., 2008; Murphy et al., 2009; Blikstein, 2011). As shown in Figure 1(b), teaching staff can observe student behavior via the data collected by the e-learning system in order to extract certain factors that can be associated with success or failure in programming. For example, according to studies conducted on Web-CAT (Allevato et al., 2008) and ClockIt (Norris et al., 2008; Fenwick et al., 2009), student success in programming (i.e., getting higher grades in the

assignment) is highly related with factors such as an early start in assignment product development, a high frequency of accessing online evaluations, and a low complexity of the finished assignment product. These factors reveal some possible directions for teaching staff consider with regard to improving their teaching.

Many e-learning systems provide student immediate assistance and the related data collected by e-learning systems is effective for teaching review. However, as shown in Figure 1, the support offered by such systems is applied in the distinct processes. These systems only provide fixed assistance. Teaching staff cannot provide further help through the existing e-learning systems even if any student frustration is observed during assignment practice. The data collected during on-going teaching can only be used to improve the next stage of teaching.

Assignment practice with WebHat

To enhance student engagement during assignment practice, this work introduces WebHat with dynamic evaluation services adjustment. Figure 2 illustrates the detailed process during assignment practice with WebHat. To ensure the achievement of a specific assignment, the teaching staff specifies particular evaluation services in WebHat, which will then provide appropriate online assistance to students during assignment practice. As illustrated in the *Student Session* of Figure 2, students keep developing their assignment products during the practice, and when they finish stable versions of their products, they can access the online evaluation in WebHat and check the results. These results provide a basis to guide the subsequent product development, such as fixing bugs and further evolution of the program. Students remain involved in the cycle of assignment product development and evaluation until they have finished work or the deadline is reached, whichever is sooner.

Simultaneously, in the *Teaching Staff Session*, the data about student interactions with WebHat is also collected to help teaching staff monitor their status during the assignment. WebHat provides statistical reports about this status, and teachers can utilize this information to observe student behavior. When student frustration is observed, teachers can offer further help and adjust the evaluation services available in WebHat. The assistance can be immediately provided by the system to enhance student engagement in assignment practice.

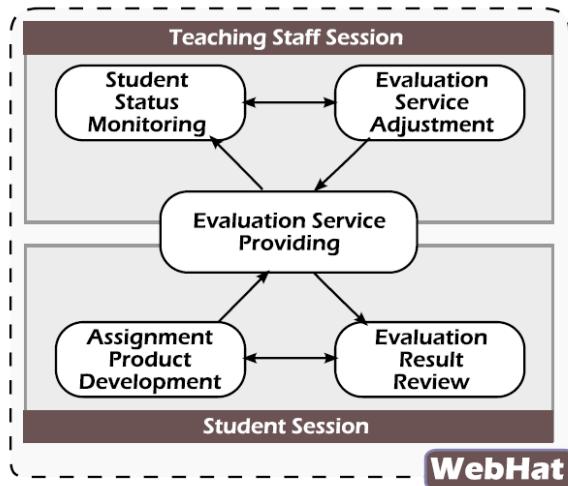


Figure 2. Detailed process during assignment practice with WebHat

Figure 3 presents the architecture of WebHat, which applies a service-based mechanism to support dynamic evaluation service adjustment (Wu & Jiau, 2012). A general flow of assignment evaluation is maintained by an assignment evaluation backbone. As shown in Figure 3(a), students keep submitting stable modifications of their assignment products via *Assignment Product Uploader*, and WebHat checks each iteration to perform the evaluation. All of the evaluation results are record in *Evaluation Result Records*, and both teaching staff and students can access these results via a web browser. The *Evaluation Result Displayer* is responsible for generating a feedback page to display the evaluation results based on who is making the request, a teacher or a student.

Service Manager, as shown in Figure 3(b), maintains a set of service specifications, which is used to describe concrete evaluation services with specifying the necessary functionality at specific points of the assignment evaluation backbone. Teaching staff can specify new service specifications or adjust existing ones through *Service Manager*, even during runtime. Based on the specified service specifications, WebHat can provide the concrete evaluation services with adapting corresponding service components into the evaluation flow (Figure 3(c)). Such adaptation can be performed dynamically to enable evaluation service adjustment during assignment practice.

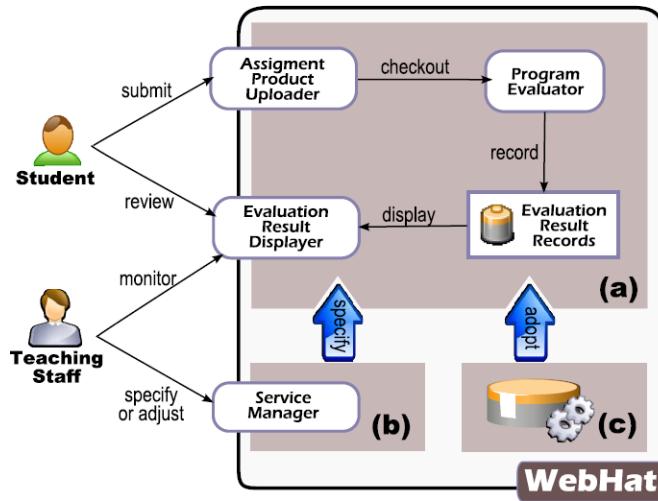


Figure 3. Architecture of WebHat system: (a) Assignment evaluation backbone. (b) Service management subsystem. (c) Service component pool.

Example assignment

WebHat was utilized in an assignment during the *Introduction to Computer Science* course. The goal of the assignment was to help students understand basic programming concepts. Since practicing continuously is the key to better understanding, it is important to motivate students to keep working on their assignment products. To attract the students' interest, the teaching staff selected a simulation game for programming practice, *Resource Craft* (Jiau et al., 2009), as the material for this assignment. In the game, each player controls game entities to find and collect resources. These resources are then transformed to the corresponding player's score. In *Resource Craft*, players aim at developing a strategy that can maximize the final score in a game with a limited duration. To develop the strategy, the player writes Java program code to query and control the game entities using defined interfaces. Through the process of strategy development, the player learns the basic programming concepts in Java. *Resource Craft* supports both single player and two-player competition modes.

Table 1. The evaluation services provided in WebHat

Group	Service Name	Description	Duration (days)
Pre-planned	1P Mode	Evaluate strategy using single player mode.	2-16
	2P Mode	Evaluate strategy using two-player competitive mode.	2-16
	Top Player	List top 5 students with high scores in 1P mode and 2P mode.	11-16
Feedback	Error MSG	Present error messages to help students identify the reason for the failed execution.	3-5

Besides applying a game-based approach, the example assignment also adopted a competitive-based evaluation method (Lawrence, 2004; Guerreiro & Georgouli, 2008) to encourage students to improve their assignment products through positive competition. In this assignment, each student was asked to develop a game strategy in *Resource Craft*, and a *Resource Craft* tournament was held by teaching staff as the final evaluation. In the tournament, every student competed with each other in two-player competition mode, and the student whose strategy attained the higher

score won that particular game. After the tournament, students were ranked according to the number of games that they had won, with better grades being given to the higher ranked students. The duration of this assignment was from November 20 2010 to December 5 2010, a total of 16 days.

For the success of this assignment practice, the teaching staff developed and released an appropriate set of evaluation services to students using WebHat, which helped them assess and further enhance their work. To enable the service implementation, *Resource Craft* runtime software was included as a service component of WebHat. Based on the service component, four online evaluation services were developed to assist students in evaluating their strategies. Once students developed stable modifications and submitted new strategy revisions to the system, they could check the results of the evaluation and then work towards further enhancement of their products.

Table 1 lists the four evaluation services, which are categorized into two groups. In the *Pre-planned* group, the three evaluation services (1P Mode, 2P Mode and Top Player) were planned in advance and prepared by the teaching staff before the assignment practice. In the *Feedback* group, the Error MSG evaluation service was developed during the assignment practice to help students resolve the difficulties faced while developing strategies. These evaluation services were not released simultaneously, but instead were released sequentially during the assignment to appropriately guide students in developing their strategies.

- **1P Mode and 2P Mode.** Providing interactive online assistance enables students to assess the effects of their assignment development (Hulls et al., 2005; Fernández Alemán, 2011). The 1P Mode and 2P Mode services are therefore provided in WebHat throughout the duration of the assignment. In 1P Mode, the service directly used the strategy submitted by the student to execute *Resource Craft*. By evaluating the strategy in a simplified and non-competitive scenario, 1P Mode helped the student check whether it behaved as expected in the early development stage. In 2P Mode, the strategy submitted by the student competed with a strategy that was developed by the teaching staff. The game score from 2P Mode helped the student further assess the competitiveness of his strategy, as the higher their score, the more competitive the strategy. By investigating the evaluation results, students gained direct feedback about the development status of their strategies.
- **Top Player.** Although 1P Mode and 2P Mode evaluation services help students evaluate their developing strategies, they are still unaware of development status of the other students. To maintain a competitive atmosphere during the assignment, the Top Player service ranked the top students with the highest final game scores in 1P Mode and 2P Mode execution. Since the Top Player service aims to encourage students to compete with each other, its effects are highly dependent on the level of the students' engagement. Hence, the Top Player service is not introduced at the beginning of assignment practice, but instead is released only when more than half the students have started the process of strategy development and some of them have developed competitive strategies. In the example assignment, the teaching staff introduced the Top Player service on day 11.

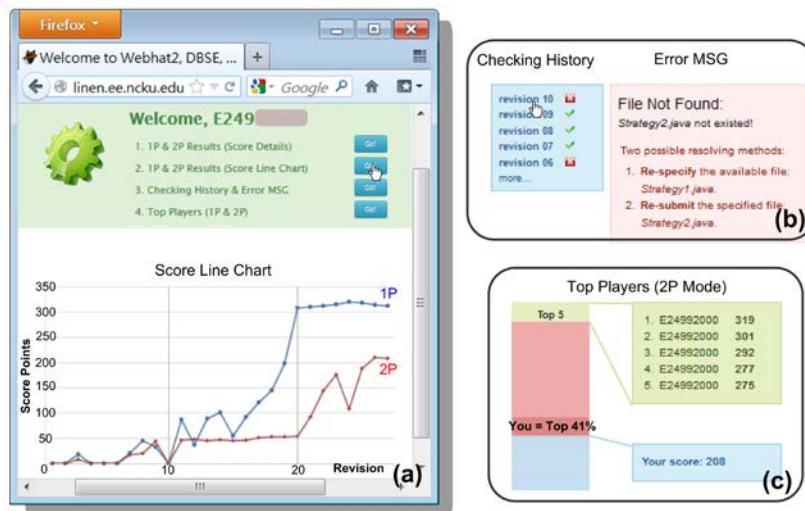


Figure 4. Screenshots of the provided services. (a) Evaluation results of the 1P Mode and 2P Mode services. (b) Error messages generated by the Error MSG service. (c) The Top Player service in the assignment.

- **Error MSG.** The activeness of students' engagement is the key factor in deciding when to introduce the Top Player service. When the 1P Mode and 2P Mode services were first released, the teaching staff, through WebHat, noticed that only few students submitted their strategies for evaluation. Furthermore, most of the strategies that were submitted failed to be executed. Motivating students to develop and submit their strategies more actively, the assistance in compilation error removal is required to lower the barriers in starting assignment development (Kelleher & Pausch, 2005). The teaching staff therefore developed and released the Error MSG evaluation service. The Error MSG service could check compilation errors of submitted strategies via Eclipse Java Development Tool (Eclipse JDT) and interpret the error messages to help students identify possible causes for failed executions. The teaching staff took one day to develop Error MSG and released it in WebHat from day 3 to day 5. By limiting the Error MSG release to the early stage of the assignment, students were expected to be more active in developing and submitting their strategies so that they could find out what was wrong with them.

Based on specifications of the evaluation services, WebHat evaluates students' submitted strategies and presents the results on a web-based interface. Figure 4 shows the screenshots of the result presentation in terms of all provided evaluation services. The upper box of Figure 4(a) lists all available evaluation result presentation choices. A student can select one of them for the result inspection. For example, the line chart of Figure 4(a) presents the results generated by 1P Mode and 2P Mode evaluation for all submitted strategies. As shown in the line chart, some zero scores are appeared in both 1P Mode and 2P Mode evaluation in the early stage of assignment practice. This indicates the difficulties in developing a workable strategy. By checking the results of Error MSG evaluation, the information with regard to compilation errors can be investigated. In Figure 4(b), an error message, "File Not Found", in revision 10 is presented and possible treatments, re-specifying an available file or re-submitting another specific file, are suggested for handling the error. The service helps students remove errors and promotes them to start assignment early.

Besides, students can assess the improvements of their strategies by checking the trends of both the 1P Mode and 2P Mode scores by the line chart of Figure 4(a). For example, the line chart in Figure 4(a) reveals that, between revisions 11 to 20, the student's 1P Mode score increased steadily while the 2P Mode score remained unchanged at approximately 50 points. This alerts the student to the fact that although he is getting familiar with the manipulation of game entities in this stage, the competitiveness of his strategy remains relatively low. The student subsequently began to find out the factors regarding strategy competitiveness and gets the upward trend for the 2P Mode score from revision 21. In the following revisions, the student can keep tracking the 2P Mode score evaluation and adjust his development plan accordingly. For example, the unexpected score decrement in revision 24 warns the student that the newly made changes make the strategy become less competitive. The student needs to perform a special treatment on these changes, such as bug fixing or strategy setting reconfiguration, to retain its competitiveness. Once the treatment is done, the student can confirm the effectiveness of the treatment through the line chart, as the strategy competitiveness continues to be improved after revision 25 in Figure 4(a).

Figure 4(c) shows a screenshot of the Top Player service, in which a bar chart represents a rank of the student in all students by their highest game scores in 2P Mode execution. As shown in Figure 4(c), the student's best score in 2P Mode evaluation came to 208 points and was ranked in top 41%. Besides, the scores of top five students are also highlighted in the ranking bar to motivate students to keep improving their strategies for better competitiveness.

Evaluation

To evaluate the effectiveness of utilizing WebHat, the empirical data from the aforementioned assignment is investigated. A total of 109 students took the *Introduction to Computer Science course*. Among these, 86 successfully submitted their final assignment products and participated in the final tournament. Each version of the strategy submitted by every student, the submission time, and the evaluation results are collected as empirical data. Two questions are examined in this investigation.

1. Do the dynamically adjusted evaluation services in WebHat enhance student engagement in assignment practice?
2. Do students with higher engagement levels in WebHat submit better final assignment products?

The question 1 is first examined by describing the effects of dynamic evaluation service adjustment on motivating students to continuously engage in assignment practice and enhance their assignment products; and then the question 2 is investigated through discussing the correlation between students' engagement level and the performance of their

final assignment products. In the following subsections, the term “strategy” is used to represent the assignment product, because students were asked to submit a *Resource Craft* strategy to complete the assignment.

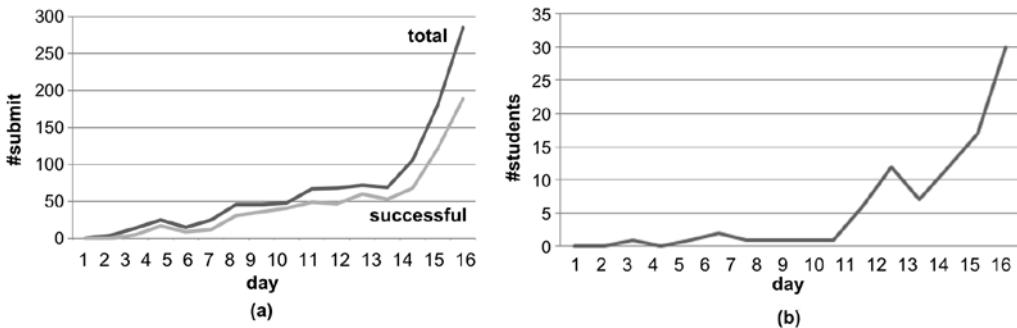
Effects of dynamic evaluation service adjustment

Table 2. Summary of student submissions in the early phase of assignment

day	# submit	# success	#success/#submit
1	0	0	0
2	4	0	0
3	14	5	0.36
4	25	17	0.68
5	15	9	0.60

Error MSG and Top Player were released at different stages of the assignment practice, with both aimed at motivating students to engage in the assignment practice. Error MSG was developed to encourage students to start the assignment practice and submit executable strategies early in the process, while Top Player was aimed at motivating the students to focus on enhancing the competitiveness of their strategies before the final tournament. This section examines whether these two services had the expected effects in enhancing student engagement during assignment practice.

Effects of Error MSG. Table 2 summarizes the daily submission count (**#submit**) in the early stages of assignment practice. The **#success** column shows the number of successful submissions (i.e., those with successfully executed strategies). The daily successful execution ratio is shown in the **#success/#commit** column. On day 2, the 1P Mode and 2P Mode evaluation services were first released and students began to submit their strategies. Four strategies were submitted and all of them failed in execution. With the aim of encouraging the students to start work, the Error MSG service was provided from days 3 to 5. Right after the release of the Error MSG service on day 3, the number of submissions greatly increased (up to 14) and the students started to submit successfully executed strategies (a total of five on this day). On days 4 and 5, the daily successful execution rate was significantly higher, with 25 and 15 submissions, respectively, about 65% of which were executed successfully. This indicates that the Error MSG service did indeed motivate the students to develop strategies earlier, as well as assisted them developing successfully executed strategies.



*Figure 5. The submission statistics over the duration of the assignment. (a) Total and successful submission.
(b) Competitive strategy submission*

Error MSG also caused a chain reaction in motivating students to start their strategy development earlier, as it motivated more active students to start work, which then caused other students to begin the assignment. As a result, the positive effect of Error MSG was sustained throughout the rest of the assignment. Figure 5(a) presents the number of daily submissions, and even after terminating the Error MSG on day 5, the number of total and successful submissions still increased stably over time.

Impacts of Top Player. Figure 5(b) presents the daily number of students who submitted competitive strategies. A strategy is classed as competitive if it achieves a score of more than 200 points in the 2P Mode evaluation service. Before day 10, there were already some students (one or two per day) who submitted competitive strategies. The Top

Player service was released on day 10 to bring a more competitive atmosphere to the assignment. By announcing the best performing students, the Top Player service successfully encouraged others to develop more competitive strategies. As shown in Figure 5(b), after releasing Top Player service on day 11, the number of students who submitted competitive strategies rapidly increased throughout the final stage of the assignment practice.

Correlation between engagement level and final performance

The engagement level of a student represents the degree of activeness with which they are engaged in the strategy development. To quantize the student engagement level, the assignment practice duration is split into several periods. The student engagement level is measured in terms of $level_{engaged}$, the number of periods in which a student submitted a strategy. Since the teaching staff expected that it took about three days for a student to revise a strategy and the duration of the assignment (from day 2 to day 16) is split into five periods of three days each. As a result, the $level_{engaged}$ of a student is formulated as followed.

$$level_{engaged}(student) = \sum_{i=1}^5 engaged_i(student),$$

where $engaged_i = \begin{cases} 1 & \text{if student had submitted strategy} \\ & \text{between day } 3i - 1 \text{ and } 3i + 1 \\ 0 & \text{otherwise} \end{cases}$

The 86 students are divided into three groups according to their $level_{engaged}$. G_{active} contains 23 students whose $level_{engaged}$ is 4 or 5. G_{mid} contains 36 students whose $level_{engaged}$ is 2 or 3. $G_{inactive}$ contains 25 students whose $level_{engaged}$ is 1.

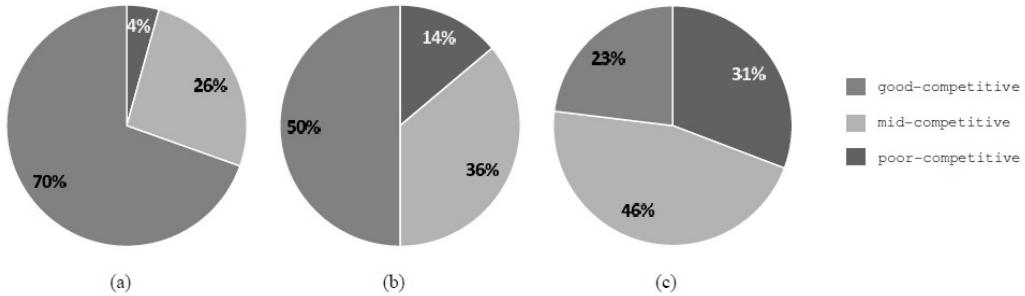


Figure 6. The score distribution in students with different engagement levels over time (a) G_{active} , (b) G_{mid} , and (c) $G_{inactive}$

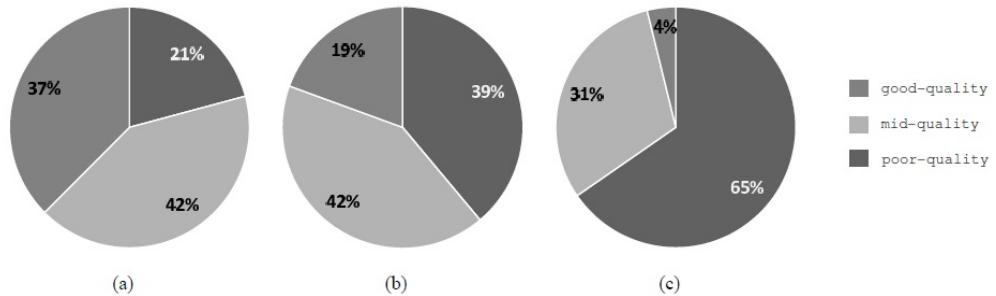


Figure 7. The quality distribution in students with different engagement levels over time (a) G_{active} , (b) G_{mid} , and (c) $G_{inactive}$

Each final submitted strategy was evaluated from two perspectives, *competitiveness* and *quality*. The *competitiveness* of a strategy is represented in terms of the score it attained in the final tournament. The final submitted strategies can be categorized into three different categories: *well-competitive* (with a score higher than 200), *mid-competitive* (between 100 and 200) and *poor-competitive* (less than 100). Figure 6 summarizes the proportions of different competitive categories in three groups. For example, Figure 6(a) shows that there are 70% of students in G_{active}

submitted well-competitive strategies and only 4% with poor-competitive ones. Compared to Figure 6(b) and 6(c), the proportions of students with well-competitive strategies declined along with the engagement level (50% in G_{mid} and 23% in $G_{inactive}$). Students with a higher engagement level produce more competitive strategies.

To assess the quality of the strategies submitted, the following two quality attributes are taken into account: (1) Code structure organization: whether a student defined methods or fields in organizing the code structure of the strategy; and (2) Runtime exception avoidance: whether the submitted strategy performed correctly without any runtime exceptions during execution. The final submitted strategies can thus be categorized into three different groups: *good-quality*, *mid-quality*, and *poor-quality*. A *good-quality* strategy has proper code structure organization and is well implemented to avoid runtime exceptions. A *mid-quality* strategy performs well in either of those two quality attributes. The *poor-quality* strategy is both poor in organizing code structure and in avoiding runtime exceptions. Figure 7(a)-(c) summarizes the proportions of different quality categories in the three groups. The data show that students with higher engagement levels submit strategies with higher product quality. The proportions of *good-quality* in G_{active} , G_{mid} , and $G_{inactive}$ are 37%, 19%, and 4%, respectively. The high proportion of *poor-quality* in $G_{inactive}$ (65%) also indicates that inactive students only focused on developing a workable strategy, without considering the quality.

Summary and discussion

The evaluation results, which are presented along with different stages of the assignment practice, indicate the effectiveness of the WebHat platform. Monitoring student status through WebHat enables a timely identification of students' difficulties. By providing dynamic service adjustment, teaching staff can immediately offer corresponding online assistance. In this study, several quantitative monitoring attributes, such as the successful execution ratio and the number of competitive strategies, can confirm student engagement during assignment practice. This study shows that student difficulties in developing workable strategies can be identified at the early stage of the assignment. Corresponding Error MSG service can be immediately provided to assist in error removals. As shown in the results, the Error MSG service enhances the successful execution ratio of submitted strategies.

The enhancement of student engagement at the early stage leads to the success of the assignment practice. Students are promoted to start their assignment development before day 5 and a number of competitive strategies are developed before day 10. In this situation, the Top Player service can further motivate students in the strategy improvement before final tournament. After releasing Top Player service, the number of daily submissions is highly increased. Finally, the evaluation results show a positive correlation between engagement level and final performance. The effectiveness of WenHat platform is confirmed in enhancing student engagement for the achievement of assignment objectives.

Even though the results are positive and encouraging, two limitations must be clarified. First, the subject assignment practice may not be representative of programming assignment practice in general. This study demonstrates the effectiveness of supporting dynamic service adjustment in the assignment practice designed by integrating specific teaching methods, assignment practice using game (Jiau et al., 2009) and assignment evaluation by a competition (Lawrence, 2004; Guerreiro & Georgouli, 2008). However, the validity of the results may be impaired for other assignment types like traditional programming practice in a problem-solving style (Deek et al., 1999; Daly & Horgan, 2004). Second, the current implementation of WebHat platform mainly supports evaluation on specific input and output of a program. For other assignment practice, the development of additional evaluation services, such as the measurement of code quality, may be required. Such extension is adapted by the design of WebHat platform. Teaching agility is supported during assignment practice using WebHat.

Conclusion

Ensuring that students are engaged in a programming assignment is critical to achieve teaching objectives in computer science education. This paper introduces WebHat platform which applies a service-oriented technique to improve assignment practice of e-learning systems. WebHat supports continuous student status monitoring and dynamic evaluation service adjustment. Teaching staff can therefore assist students promptly, actively and directly during a programming practice. The utilization of WebHat is presented along with an example assignment. The

results of the study show: (1) The dynamic evaluation service adjustment encourages students to start assignment development early and to keep evolving their assignment product in the expected direction. (2) Students with higher engagement levels in WebHat submit better final assignment products with regard to both functionality and quality. The results clearly demonstrate the effectiveness of WebHat in enhancing student engagement to achieve assignment objectives.

WebHat introduces a service-based mechanism to support dynamic evaluation service adjustment and has been applied in *Introduction to Computer Science* course for several semesters in the Department of Electrical Engineering, National Cheng Kung University, Taiwan. Currently, evaluation service development and adjustment in WebHat are still dependent on experience of teaching staff. In the future, the evaluation services and their management will be further patterned in WebHat for specific assignments to accumulate experience of successful teaching. WebHat therefore can provide complete support from assignment design to practice for programming teaching.

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Blogs and Social Network Sites as Activity Systems: Exploring Adult Informal Learning Process through Activity Theory Framework

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ABSTRACT

This paper uses an Activity Theory framework to explore adult user activities and informal learning processes as reflected in their blogs and social network sites (SNS). Using the assumption that a web-based space is an activity system in which learning occurs, typical features of the components were investigated and each activity system then characterized. Data obtained from individual users of a blog (Naver) and a SNS (Cyworld) were analyzed at the individual level and extended into the social level. Based on the findings, commonalities and differences between blog and SNS activities were discussed and different types of the division of labor between the activity systems were identified. This paper furthermore suggests three dimensions of adult informal learning activities in Web 2.0 in terms of learning as (a) an acquisition process, (b) a reflection process, and (c) a practice-based community process. Therefore, its discussion helps advance the understanding of the potential value of using Web 2.0 applications for adult informal learning.

Keywords

Web 2.0, Blog, Social network site (SNS), Activity Theory, Adult learning, Informal learning

Introduction

Web 2.0 is “a collaborative medium that allows users to communicate, work together and share and publish their ideas and thoughts” (Rollett, Lux, Strohmaier, Dösinger, & Tochtermann, 2007, p. 93). Various Web 2.0 applications exist, such as blogs, social network sites (SNS), Wiki, social bookmarking, and more.

Learning is one of main functions of Web 2.0 as ‘places to learn’ for formal and non-formal education as well as informal learning, either self-directed or incidental one (Schugurensky, 2000). Adult learners often benefit by optimizing these web-based spaces as alternative environments for informal learning when these adults navigate through information, network with other people, or produce wanted identities (Selwyn, 2007). There has been, however, a lack of studies that focus on the processes that occur within each web-based space and the possible informal learning outcomes, intended or unintended, while using one of these Web 2.0 applications. It is argued that understanding the processes is important in that doing can make learning more effective.

To examine the adult informal learning process linked with Web 2.0, this study explored adult user activities and the potential nature of informal learning processes and outcomes as reflected in their engagement in the two most popular web-based spaces, blogs and SNS. Under the assumption that a web-based space is an activity system (Engeström, 1987) in which learning occurs, the typical components and features of each activity system were investigated and their characteristics identified. As an expansion of the primary studies (Park, Heo, & Lee, 2008; Park, Heo, & Lee, 2011) on a blog and a SNS, the data obtained from individual users of a blog (i.e., Naver) and a SNS (i.e., Cyworld) at the individual level were analyzed first and then these individuals’ activities were extended into the social level. Therefore, the purposes of this study were to identify any significant commonalities and differences between the components at the individual and the social levels in each web-based space and hence understand different dimensions of informal learning activities that could occur in Web 2.0 to offer implications for adult learners who would like to use one of the Web 2.0 applications for informal learning.

Perspectives of adult informal learning

Informal learning refers to "any activity involving the pursuit of understanding, knowledge or skill which occurs without the presence of externally imposed curricular criteria" (Livingstone, 2001, p.5). It is an important and predominant form of learning in the adult stage because it highlights the learner as agency of learning and happens in the most of the scenes in everyday life, which may surpass the conventional meaning of learning (Livingstone, 2001; Marsick & Watkins, 2001).

To address various processes and outcomes that possibly yield from adult informal learning in web-based spaces, this study depends on Fenwick and Tennant's (2004) four different perspectives of adult learning on its process and outcomes: (a) learning as acquisition of knowledge and/or competencies; (b) learning as reflection and the construction of meaning; (c) learning as practice-based activities of particular communities; and (d) learning as an embodied co-emergent process.

The first perspective, *learning as acquisition process*, suggests that individuals will acquire knowledge, competencies, or strategies to deal with new situations in particular domains, such as academic, work-related and everyday activities. This activity often allows the gaining of new expertise in those domains. This learning process is similar with conventional cognitive and intelligence theories, but the context of learning and the interaction of experience are regarded more important in order to facilitate learning in the learning of adults. The second perspective, *learning as reflection process* interprets learning as a meaning-making process through reflection. Learners may reflect on their own and others' experiences in terms of *content* (i.e., what happened?) or *process* (i.e., how did it happen?), which promote learning. This kind of learning often produces individual transformation (Mezirow, 1991) and sometimes group-based social awareness and action called *praxis* (Freire, 1970). The third perspective, *learning as practice-based activities of particular communities*, brings to learning the concept of communities of practice (CoP) (Wenger, 1998). In a CoP, learners are able to share, negotiate, and create knowledge in relation to their own practice by communicating and collaborating with others with various ranges of experiences, knowledge and expertise. Thus learning is, according to Fenwick and Tennant (2004), entwined with *doing* and the objective of *doing* is to become a full participant in the CoP. Last, the lens of *learning as embodied co-emergent process* challenges the people-centered notions that tend to separate learners from the context of learning. It argues a rather ecological view and explores how cognition, identities, and environment co-emerge, interact, and change simultaneously through the learning process. This view is inherently different from the first three since it argues that individuals should not be separated from the group, learners from context, and subject from object (Fenwick & Tennant, 2004). Therefore, the first three perspectives will be considered to conceptualize adult informal learning since this study tries to capture the varied portraits that individual adult learners create by engaging in Web 2.0.

Nature of learning in Web 2.0: Blog and SNS

Web 2.0 is not technology per se but rather a more interactive technology-based environment that enables users to create, store, publish, and share data freely as the "architecture of participation" (O'Reilly, 2005). Blogs and social network sites (SNS) are the prime examples of Web 2.0 and are widely favored by people. The blog is a medium created by users. Bloggers, people who use blogs, use the medium as a personal log or as a communication tool for the purpose of creating and sharing their personal thoughts and values and interact with other bloggers by leaving comments and interlinking the related posts (Winer, 2003). These actions often form a certain cyber-based agora called a 'blogosphere' (Quick, 2001). SNS, as compared to blogs, is more for establishing and maintaining the social networks of individuals (Boyd & Ellison, 2007), for example MySpace, Facebook, and Cyworld, to name a few. People connect with others in these well-known SNSs mainly to cultivate their networks with people they may already know, but they do also enjoy having strangers connect with them by chance, based on shared interests, views, and activities.

Even though most bloggers and SNS users experience informal learning through their activities, most of the studies on learning with blogs and SNS have focused on formal and non-formal education/learning contexts, which refers to the types of learning that requires assistance of organised curricula and instructors that are different in their degree of formality. In particular, most research on blogs so far has emphasized the learning effectiveness of blogs in classrooms as: (a) a collaborative tool for raising group discussions and knowledge construction between instructors and students as well as among students (Glass & Spiegelman, 2008; Wassell & Crouch, 2008); and as (b) an

instructional tool for teachers and students to use to keep their own learning journals (Johnson, 2004). Studies on the educational application of SNS are comparatively few, but seem about to bloom. Increasingly, many higher education institutions use SNS as a motivating tool to aid learning and this use has produced a burgeoning volume of studies that focus on the function of SNS in higher education (English & Duncan-Howell, 2008; Hinkle & Hersh, 2007; Mazer, Murphy, & Simonds, 2007). Its use supports student identity production and a relationship with instructors and other learners (Bugeja, 2006; Ziegler, 2007). Yet there is a lack of evidence on the significance of blogs and SNS in the everyday digital lives of adult learners (Selwyn, 2007). More studies are needed on the specific potential of blogs and SNS to enhance adult informal learning.

The theoretical framework: Activity theory

Activity Theory (Engeström, 1987, 1999; Leont'ev, 1978) is a psychological and multidisciplinary framework useful for studying human practice by interlinking the individual and social levels (Barab, Evans, & Beak, 2004; Kuutti, 1996).

Engeström (1987) depicts a triangular structure of an activity system with six components (See Figure 1): Subject, Object, Tools, Community, Division of Labor, and Rules. Each of these six components serves a distinct function and work together to set up an activity and relate to other components: *Subject* refers to the actors, which could be individuals or sub-groups, in the analysis. *Object* refers to the objective of an activity as well as the product(s) toward which the activity is directed. The objective is then moulded and transformed into outcomes with the help of mediating artifacts, referring to *Tools*. *Community* as a sociocultural context consists of multiple individuals who share the common general objectives. *Division of Labor* refers to the organization of tasks and responsibilities within the community. Finally, *Rules* refers to the explicit and implicit regulations, norms, and conventions that constrain the actions and interactions within the activity system.

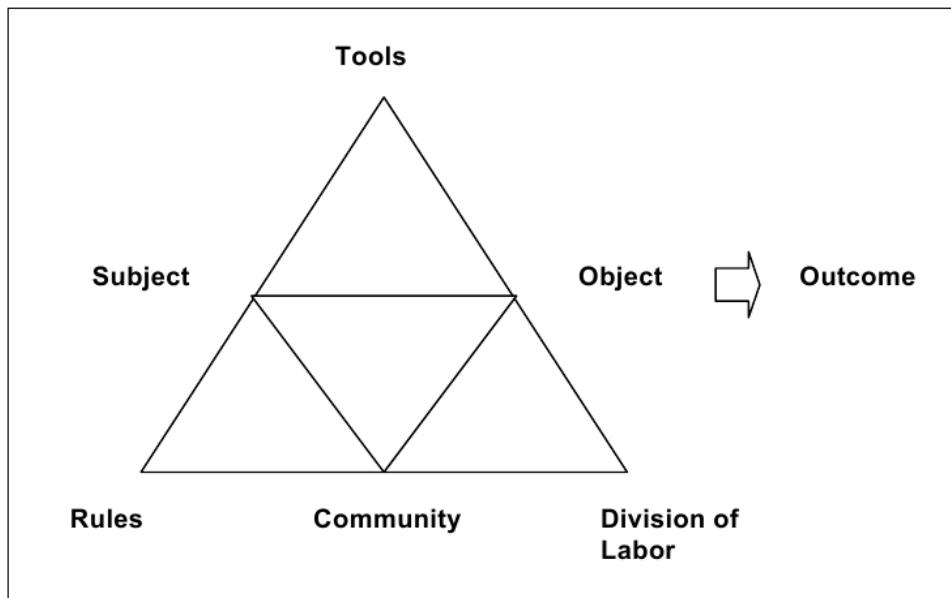


Figure 1. Activity triangle model (Engeström, 1987, p. 78)

Three key principles of Activity Theory are summarized by Kuutti (1996) as follows:

- Activities as basic units of analysis: Individual actions should be situated in a context, which constitutes the activity as a unit of analysis.
- History and development: Activities are not given or static, but instead dynamic unities. The components keep changing and developing unevenly rather than linearly or straightforwardly. Hence, each activity has its own history.
- Artifacts and mediation: An activity consists of various artifacts (see Tools in the activity triangle mode) that mediate between the components of each activity rather than direct it.

Activity theorists understand learning as phenomena generated in a complex, evolving activity system where actors (*subjects*), objectives, and tools interact iteratively (Jonassen & Rohrer-Murphy, 1999). In other words, learning emerges from activity, more specifically, the interaction of human activity within a certain context. Members (*learners*), objectives (*learning objectives*) and tools (*learning tools*) of that particular system are co-dependent and reconstitute each other continuously. That process makes the system alive and engenders learning that is meaningful to learners. Activity Theory explains the learning processes that result from particular actions of learners in a particular context, actions that eventually benefit the learners through expanded knowledge, skills, and attitudes as the final result.

Activity Theory has been applied as a theoretical and methodological framework in various technology-related contexts of learning. Most studies have focused on investigating learning activities in formal and non-formal education systems to monitor and diagnose the processes (e.g., Barab, Schatz, & Scheckler, 2004; Collis & Margaryan, 2004; Jonassen & Rhorer-Murphy, 1999; Lim & Hang, 2003; Mwanza, 2001; Zurita & Nussbaum, 2007). There is, however, no commonly agreed methodology and approach for applying the concepts and principles in the Activity Theory (Barab, Evans, & Baek, 2004; Núñez, 2009). More empirical studies, particularly on informal learning processes, are needed since Activity Theory is still an evolving framework (Engeström, 2008).

In this study, the Activity Theory framework is applied as an analytical tool to investigate adult informal learning processes by characterizing the components of activity in two web-based spaces (i.e., a blog and a SNS) and comparing them. The research questions are as follows:

- What are the characteristics of adult user activities in two activity systems (i.e., blogs and SNS) based on the components of the Activity Theory framework?
- What are the relations between the components as distinguished for blogs and SNS as activity systems?
- What are the main considerations for adults to utilize Web 2.0 applications for informal learning?

Methodology

This study employs a qualitative research approach that is both exploratory and descriptive (Denzin & Lincoln, 2000) to understand in depth the complex phenomena and issues found within natural, real-life contexts (Yin, 2006). A case study was initially conducted in each web-based space (i.e., a blog and a SNS). These two case studies (Park et al., 2008; Park, Heo, & Lee, 2011) were further investigated using the analytical framework of Activity Theory by applying a cross-case analysis “to generalize across several representations of the phenomenon” (Borman, Clarke, Cotner, & Lee, 2006, p.123).

The study data were collected through an online survey questionnaire that included multiple choice and yes/no items and open-ended questions, from each web-based space. The survey questions covered mainly (a) demographic background, (b) personal experiences with a web-based space, and (c) the meanings of activities in a web-based space in relation to their everyday lives and learning. The target participants were adult users (i.e., over 20 years of age) not enrolled in formal education programs since the focus of this study was on the informal learning processes. A snowball sampling strategy was used to recruit participants to increase the response rate and secure quality responses from diverse voices. Hence, 70 bloggers of *Naver*, a renowned portal service and a search engine in Korea that provides a blog service (Park, Heo, & Lee, 2011) and 100 users of *Cyworld*, a representative SNS for Koreans (Park et al., 2008) completed the online surveys.

While the data were analyzed to understand individual adult perceptions and patterns for using each web-based space in relation to informal learning processes in the primary case studies (Park et al., 2008; Park, Heo, & Lee, 2011), this study aimed to extend the analysis of activities in different web-based spaces from the individual level to the social level as an activity system by applying the Activity Theory framework.

First, each component of the activity systems was investigated according to its definition as follows:

1. Subjects: Who is engaging in the activity taking place in a web-based space?
2. Tools: What means are the subjects using to engage in this activity?
3. Object(ive)s: Why are the subjects engaging in the activity?
4. Outcome: What is the outcome of their activity?
5. Community: What is the environment in which the activity is taking place?

6. Rules: What are the cultural norms, rules, or regulations, if any, that govern the activity?
7. Division of Labor (Roles): Who is responsible for what task and how are the different roles organized?

Hence, each activity system was characterized and explored to examine how the combination of these components makes informal learning processes unique in blogs and SNS. The findings for the activity system components were further analyzed to find commonalities and differences between the two activity systems (i.e., Naver and Cyworld) and determine the characteristics of the relations between the components of web-based spaces as an informal learning process. Throughout the whole qualitative research process, a strategy of *investigator triangulation* (Denzin, 1970) was used to enhance the credibility and validity of the findings and the conclusions.

Findings

In this section, each activity system component is articulated according to the Activity Theory framework, and each activity system is then presented graphically using the activity triangle model.

Components of activity systems

Subjects

An agent of the activity taking place in a web-based space is a user of the Web 2.0 application. The subject is identified more specifically herein as adult users who voluntarily use the web-based spaces in their daily lives, namely, a blog (i.e., Naver) and a SNS (i.e., Cyworld).

Tools

The activity is mediated by artifacts, which are features the users can use in the web-based spaces. The Naver blog service provides the typical features of blogs of an individual blog, combining texts, images, videos, and links to other resources. Cyworld also offers features similar to those of blogs for an individual homepage, named “mini-hompi,” consisting of a photo album, a bulletin board, a diary, a jukebox, and a guestbook. The individual space includes interactive functions that correspond to the characteristics of Web 2.0, for example, one can leave a comment to the post, send a message, and reply to a message. In addition, these individual spaces (i.e., the blogs and the mini-hompis) are linked to other user spaces by a connection called “*Neighbor*” in the Naver blog service and “*Ilchon*” (*meaning of kin in Korean*) in Cyworld. These functions enable the users to interact more easily.

Object(ive)s

The activity is directed toward an object, which implies an objective that constitutes motivation for the activity. In this survey, individual users of Naver and Cyworld responded about why they engaged in activities within these web-based spaces (Park et al., 2008; Park, Heo, & Lee, 2011). Considerable differences of these objectives were noticed for the blog and the SNS.

Of the 70 participants, on the one hand, more than half of the Naver bloggers (61.4 %) indicated they used blogs mainly for sharing information with others (see Figure 2).

On the other hand, most users (86 %) used Cyworld mainly to maintain social relationships (See Figure 3). The users perceived Cyworld more as a medium for communication to supplement the traditional communication media, such as telephone, regular mail, and e-mail. In contrast to the results for the blog users, only 19 % of these respondents indicated that they used Cyworld for sharing information (Park et al., 2008).

These results show that users' objectives clearly contrasted for the two web-based spaces. While the main objective of blogging is to share information and knowledge in relation to a user's expertise and interests, the objective for activities within SNS is to cultivate and maintain a social relationship through this new way of interpersonal communication. However, it was also noticed that both users used the spaces to express themselves and also reflect

at an individual level. This finding implies that the differences in the objectives for both web-based spaces lie in the way they interact with others at an interpersonal level.

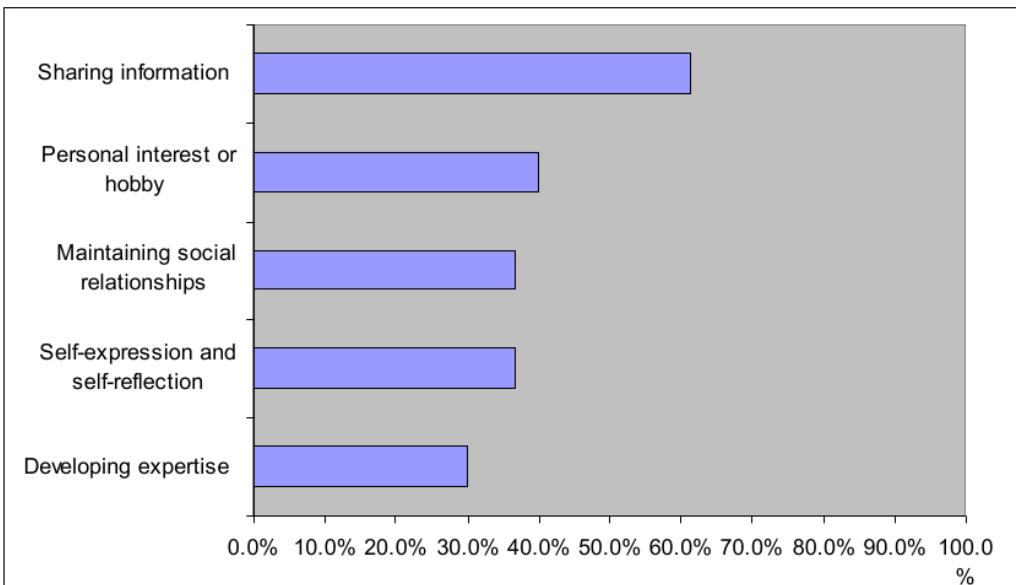


Figure 2. Objectives for using blogs (multiple responses)

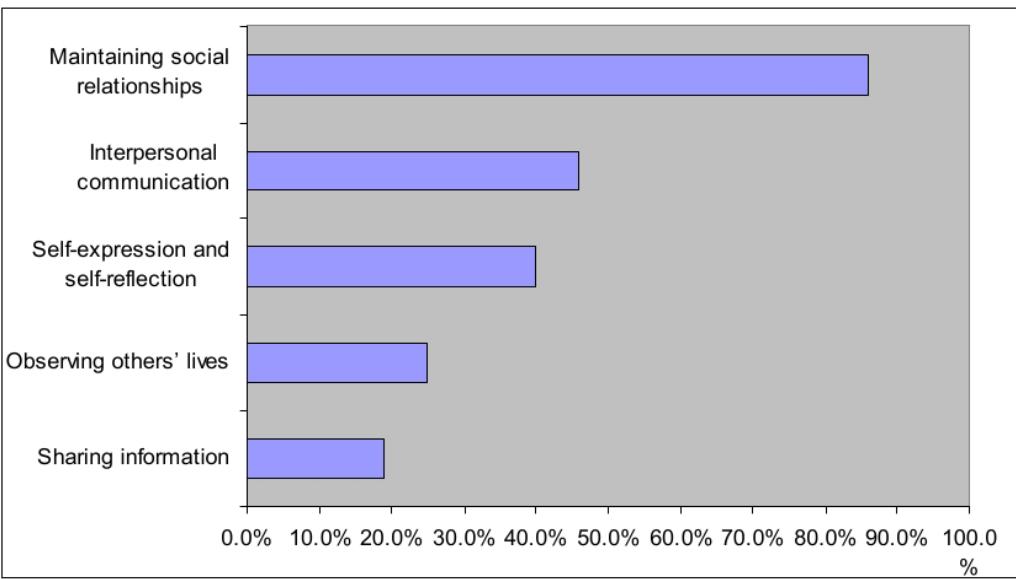


Figure 3. Objectives for using Cyworld (multiple responses)

Outcome

Outcome represents the final state that users achieved through their engagement in activities within the two web-based spaces. Along with the purposes of this study, the outcome inferred the users' perceptions of learning in relation to their individual awareness of learning (Schugurensky, 2000) through the activities they undertook in the Naver blog and Cyworld.

Most of the bloggers (90.0 %) responded that they had experienced some kind of learning through their blogging activities, implying that the bloggers experienced learning even when they did not intend to learn through blogging. One of the main outcomes of blogging that the survey respondents described was knowledge expansion by information sharing. They also interpreted those outcomes positively as *learning*. (see Park, Heo, & Lee, 2011).

On the other hand, 62 % of the Cyworld users indicated that their experiences with the SNS related to learning. They believed that engaging in Cyworld activities did lead them to positive experiences like reflecting on themselves, sustaining social bonds, and acquiring specific knowledge. (see Park et al., 2008).

Overall, the most Naver bloggers and also Cyworld users realized that learning occurred through engaging in activities in each web-based space. However, there is a difference that more bloggers acknowledged learning as an outcome of their activities, while less SNS users related their activities to learning. One of the possible interpretations of this difference could correspond to their own understanding of learning as either acquisition or reflection.

Community

Individual users of each web-based space constitute a community. That community is a sociocultural context in which the activities take place. Within the community, the subjects are related both explicitly and implicitly to one another and exchange influential contributions through the articulated interplay that takes place among the activity system components.

In the Naver blogosphere, the bloggers are connected through the relationship of “*Neighbor*.” Seventy-six percent (76%) of the survey respondents indicated that they had connected to 10 or fewer Neighbors. Regardless of the number of Neighbors, however, the number of visitors to their own blogs ranged from zero to 70,000 visitors, and the number of blogs that they regularly visit ranged between one and 100 blogs. This finding implies that the bloggers are connected by *blogs* in which they could get shared information and knowledge, rather than by *bloggers* who were friends and acquaintances.

On the other hand, SNS users connected to each other and then formed a social network that was like its name of “Cyworld,” which means literally “*relationship world*” in Korean. The relationship of “*Ilchons*” was different from what “*Neighbors*” were connected, this relationship was predominantly based on pre-existing social connections, such as family, friends, and acquaintances, or a relationship that expanded within the Cyworld by them as mediators. The majority of survey respondents (71%) indicated that they interacted regularly with 10 and less Ilchons. In terms of the issue of privacy, only 29% of users kept their sites completely public while the other 71% kept the sites partially open or open only to their Ilchons. Even the Ilchons were grouped according to their degree of openness, thus determining who could access specific contents. This finding implies that the Cyworld users are mainly connected by friends and acquaintances.

Rules

The web-based activities situated into an activity system are governed by various cultural norms, rules, or regulations that are either explicit or implicit.

For the explicit rules, general regulations and codes of conduct were posed by the Naver and Cyworld providers for the purpose of offering safe and respectful environments for the users and their activities in each space. The specific concerns, however, appeared to be somewhat different. On the one hand, the Naver blog service emphasizes the protection of copyrights, appreciation of differences in ideas and thoughts, use of courteous language, and so on (<http://blog.naver.com/post/bloguse.htm>). In contrast, the Cyworld provider places more emphasis on the privacy policy and safety issue, such as no flaming, and respecting others' privacy (<http://www.nate.com/footer/legal/index.html>).

Along with these explicit regulations, individual users (*subject*)' objectives are pursued within the shared ethical concerns, namely, the implicit rules. These are often referred to as “netiquette,” a compounded word of “netizen (net + citizen)” and “etiquette.” These implicit rules are often applied commonly to most web-based spaces since the main features of all these activities are oriented to facilitate social interaction.

Division of labor (roles)

The individual users are connected to others, and these complex links can represent the organization of individual roles or division of labor within the community of each web-based space. Depending on their objectives for using the web-based spaces, individual users differ in terms of their degree of engagement in activities at different levels (i.e., individual and social).

Bloggers are often categorized as either blog writers (Jung, Youn, & McClung, 2007; Nardi, Schiano, Gumbrecht, & Swartz, 2004) or blog readers (Huang, Chou, & Lin, 2008). Based on the survey results here, a third type of blogger appeared, users who spend equivalent times writing and organizing their own blogs and searching and reading others' blogs. 31 Naver bloggers (44 %) spent more time searching, visiting, and reading other blogs. These 'blog readers' use their blogs mainly to collect and gather what they want to keep in one place. Of the survey respondents, 27% indicated, on the other hand, that they spent more time writing on and organizing their own blogs. These 'blog writers' use their blogs mainly to create their own content and develop knowledge by writing their own comments, thoughts, experiences, and reflections to create a knowledge repository. Seventeen bloggers (24 %) indicated an equivalent numbers of hours for both activities, namely, as a writer and a reader.

Due to the scarcity of current research that focuses on SNS usage (Hargittai, 2008), it is difficult to find studies that categorize the types of SNS usage or SNS users. Based on the survey results, the major uses of Cyworld differentiate depending on the users' objectives, for example whether that use is for communication with others (i.e., communicator), self-expression, and/or reflection (i.e., presenter), or observing other lives (i.e., observers) . As discussed in *Object(ive)s*, some users (46 %) used Cyworld as a communication tool. They preferred using the Cyworld guestbook rather than a regular phone or e-mail to drop off a brief 'Hello' message. Forty survey respondents (40 %) indicated they spent more time creating and managing their own postings by uploading photos and writing their own thoughts and experiences. On the other hand, there were Cyworld users (25 %) who just wanted to look at others' lives within their social networks rather than actively engage in those social activities.

Activity systems on blogs & SNS

Each of the activity system components is summarized and presented graphically below using the activity triangle model (see Figure 4 and Figure 5).

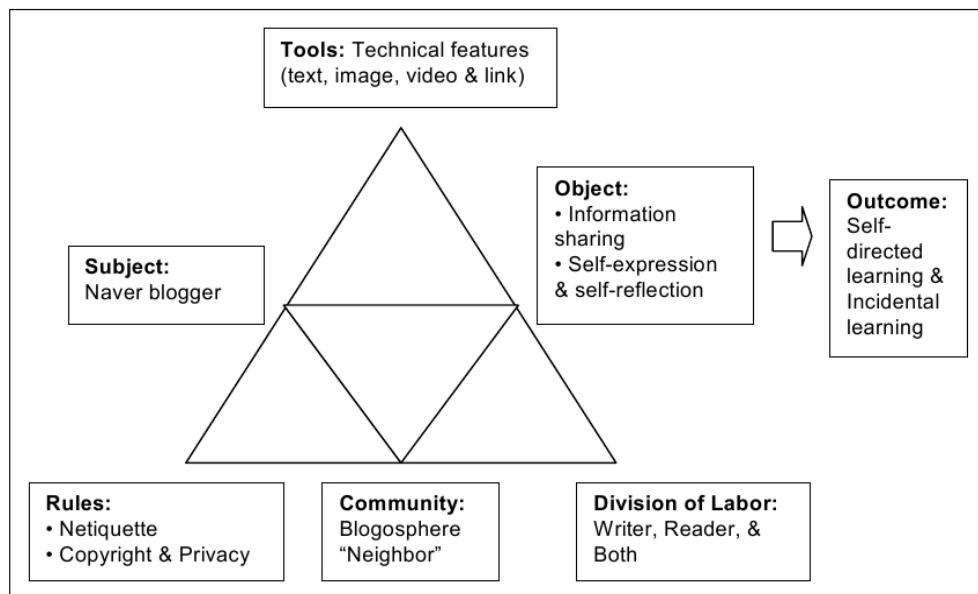


Figure 4. An activity system for a Naver blog

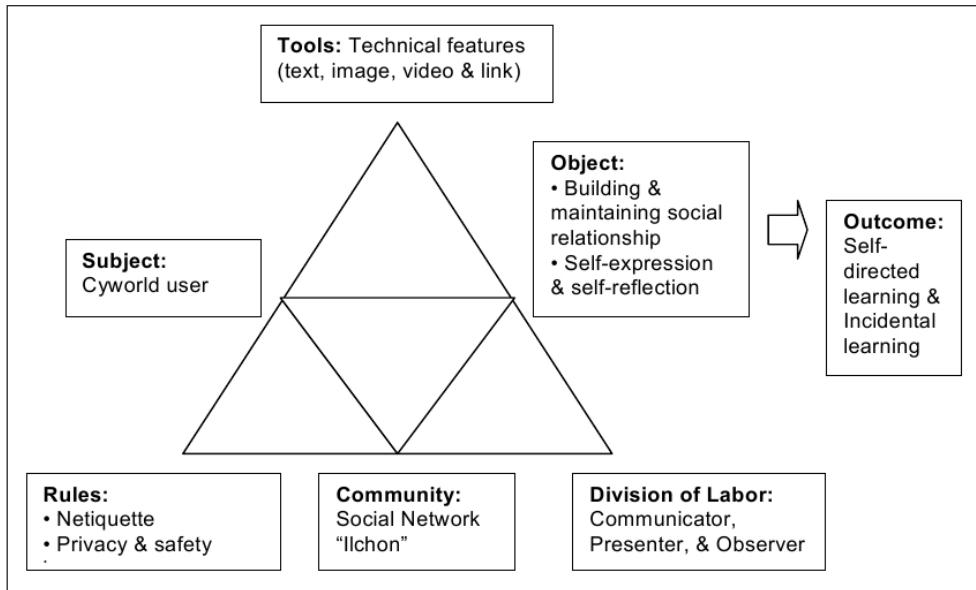


Figure 5. An activity system for Cyworld

From these findings, the general features of these two activity systems can be summarized: Bloggers and SNS users (*Subject*) get into an activity system that contains diverse technical features and services (*Tool*) depending on the individuals' purposes (*Object*), namely, sharing information and/or maintaining social relationships. These individuals then communicate and interact with other bloggers and SNS users, an activity that constitutes a network of subjects (*Community*) in each activity system. Individual activities are governed by explicit regulations as well as implicit rules called as netiquette (*Rules*) and characterized by roles identified with in each community (*Division of labor*). Overall, the adult users of both web-based spaces are able to share information, develop their knowledge, and expand their social relationships by engaging in the specific activities within these activity systems.

On the other hand, specific components distinguish the two activity systems: *Object*, *Community*, and *Division of Labor*. In terms of *objectives*, bloggers mainly aim to share information and knowledge through blogging activities, while SNS users engage in their activities with the main purpose of cultivating and maintaining social relationships. Corresponding to these objectives, for *community*, in blogging practice, a community is mainly formed by *content* of blogs rather than bloggers and hence the blogosphere is considered a publicly open space, whereas a community of SNS is formed by connecting users, namely *people*, through social relationships. Hence it is instead considered to be a rather private and closed space.

Relying on the characteristics of these communities, the roles identified for each activity system are different. Bloggers are categorized into three types based on the range of their blogging activities (i.e., time spent writing and organizing their own blogs or searching and reading others' blogs): Reader, Writer, and Reader & Writer. SNS users can be grouped depending on their objectives for using Cyworld (e.g., interpersonal communication, self-expression / self-reflection, or simply observing others' lives): Communicator, Presenter, and Observer.

Overall, the differences between the two web-based spaces derive from the interpersonal interaction processes that take place between the users at the social level, whereas the common features represent their activities' focusing on personal spaces at the individual level.

Discussion

An activity system consists of multiple components, and the links between these components are complex. Since the components are intimately tied to each other, these multilateral relationships cannot be explained in simple words. Hence, sub-activity triangles between the components in both activity systems were examined closely.

The sub-triangle *Subject-Object-Community*, which is a systemic model (Kuutti, 1996), shows “the systemic relations between an individual and her/his environment in an activity” (p.27). The sub-triangles in the blogs and the SNS represented the characteristic features of each activity system. That is, while the blogs form an open community and the bloggers are linked by content as the main mediator, the SNS is a private community built through social relationships – person to person.

The differences between the sub-triangles *Subject-Object-Community* in the blogs and SNS influence the division of labor accordingly since the division of labor mediates the relationship between *Object* and *Community* (Kuutti, 1996). Based on the roles identified in our findings, in sum, three types of division of labor in each activity system were conceptualized. In the blogs, first, the bloggers' patterns of behaviors were categorized into Knowledge Creator (Writer), Information Organizer (Collector), and Information Seeker (Reader). It should be noted as well that each role does not represent a single blogger. One blogger can play all these roles to different degrees.

- Knowledge Creator: Bloggers who use blogs to post their own writings and materials (e.g., images and videos) based on their own experiences, thoughts, opinions, and knowledge in terms of their own interests and/or expertise and then interact with other bloggers by sharing comments.
- Information Organizer: Bloggers who maintain their own blogs by organizing and updating content collected from other blogs and other resources as they related to their own interests and/or expertise.
- Information Seeker: Bloggers who occasionally visit and read other blogs to seek information as they need it.

In contrast, the types of division of labor in the SNS show different patterns. The behavior patterns of the SNS users can be categorized based on their objectives for using the SNS: Self-reflector (Presenter), Interpersonal Communicator (Communicator), and Lurker (Observer). Again, a single SNS user can present these patterns to different degrees.

- Self-reflector: SNS users who upload new postings (e.g., texts and images) and manage their own space for personal self-expression and self-reflections.
- Interpersonal Communicator: SNS users who use it as a communication tool (e.g., Guestbook) to exchange news and share their feelings and thoughts with others.
- Lurker: SNS users who just look at others without any active social engagement only to get to know what they are doing.

Further, the various types of division of labor in both web-based spaces allowed us to conceptualize different dimensions of adult informal learning activities that could occur in Web 2.0 corresponding to Fenwick and Tennant (2004)'s framework (see Figure 6): Learning as (a) an acquisition process, (b) a reflection process, and (c) a practice-based community process. It should be noted as well that the meaning of these dimensions also imply the range of engagement in the informal learning processes, ranging from narrow to more extended concepts of learning.

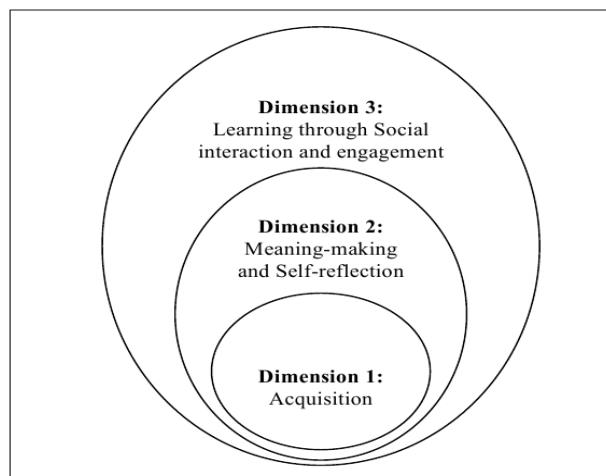


Figure 6. Three dimensions of adult informal learning activities in Web 2.0

- Dimension 1 (Learning as an acquisition process): Learners mainly seek and acquire information and knowledge from others, implying a passive role in the learning process for Web 2.0.

- Dimension 2 (Learning as a reflection process): Learners are more active dealing with and accepting knowledge by making meaning and reflecting on that meaning themselves when using Web 2.0.
- Dimension 3 (Learning as a practice-based community process): Learners create and build their knowledge through interacting with others and engaging in activities in a community, such as a blogosphere or a social network. In terms of sociocultural learning perspectives, users benefit fully from using Web 2.0, as it allows them to share, communicate, and collaborate with others.

Conclusions and educational implications

This paper discusses the processes of adult informal learning activities in blogs and SNS through investigating six components of the Activity Theory framework. The blogs and the SNS are differentiated mainly in terms of their *objectives* – sharing information and knowledge with others vs. retaining and nurturing a social relationship and interpersonal communication. Further, the types of division of labor in each activity system were identified and conceptualized (i.e., Blogs: Knowledge Creator, Information Organizer, and Information Seeker and SNS: Self-reflector, Interpersonal Communicator, and Lurker). This conceptualization allows us to identify the different dimensions of adult informal learning activities available in Web 2.0, corresponding to the different perspectives taken on the adult learning processes (Fenwick & Tennant, 2004): (a) Dimension 1: acquisition from other Web 2.0 users; (b) Dimension 2: meaning-making and self-reflection; (c) Dimension 3: learning through social interaction and engagement.

In addition, this study makes its contributions by illustrating how a methodological approach – the Activity Theory – can be applied to a specific context, web-based spaces. The analytical approach for this study also demonstrates a practical application of the Activity Theory framework and the interpretation of findings from investigating the learning activities engendered in Web 2.0. Although the approach in this study is limited to a certain degree, its conceptual discussion does advance our understanding of the universal and local features of Web 2.0 applications and the potential value of using these applications for adult informal learning. Furthermore, additional work and collection of data representing different contexts would be worthwhile to generalize the findings of this study.

Based on the overall findings of this study, it is confirmed that Web 2.0 as an informal learning environment enables adult learners to engage in different levels of interaction and participation in social activities and hence to experience diverse dimensions of learning depending on their own purposes as self-regulated and self-directed learners. There are education implications of using Web 2.0 for adult informal learning. First, an adult learner should have a clear sense of purpose when choosing Web 2.0 applications. This study shows that the individual level of activities (i.e., self-expression and self-reflection) found in these two web-based spaces can produce different interactive processes and valued outcomes. Recognizing the differences can help adult learners have purposes, in other words, learning objectives, before their engagement in the web 2.0 spaces rather than acknowledging learning happened afterward and plan their learning processes and outcomes. Second, along with the purpose, an adult learner can decide her/his roles and degrees of engagement in the activities found in these web-based spaces. This study identifies the patterns of behaviors as specific roles in both web-based spaces. It presents a spectrum of engagement, from rather passive to active and from rather individual to an interpersonal level. By increasing the level of engagement, s/he can gain more diversity in learning by relating to the different dimensions of learning activities (i.e., learning as acquisition, reflection, and community-based). Hence, more interactive ways of using Web 2.0 may guarantee not only more diverse, but also a better quality of learning.

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A 5E Learning Cycle Approach-Based, Multimedia-Supplemented Instructional Unit for Structured Query Language

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ABSTRACT

With the benefit of multimedia and the learning cycle approach in promoting effective active learning, this paper proposed a learning cycle approach-based, multimedia-supplemented instructional unit for Structured Query Language (SQL) for second-year undergraduate students with the aim of enhancing their basic knowledge of SQL and ability to apply SQL to a database. The students were engaged into the learning unit by using the designed multimedia, were asked to explore SQL syntax errors using a game in the developed instructional multimedia and to share and discuss the cause(s) of the SQL syntax error(s) with the class. They then constructed, practiced, and applied SQL commands, and evaluated their own understanding using the multimedia. Research data were collected through an SQL achievement test, small projects, and a questionnaire. The results showed that the students who participated in this developed instructional unit had better ability to apply SQL to a database compared to other groups of students.

Keywords

Learning cycle approach, Inquiry-based learning, Instruction, Multimedia, SQL, Database

Introduction

A database is a collection of data organized into a structured format defined by metadata. Metadata are data about the data being stored: they define how the data are stored within the database (Sheldon, 2003). Sometimes the data stored in a relation are linked to the data stored in another relation. If one of the relations is modified, the other must be checked and perhaps modified to keep the data consistent. Database query languages provide access to information in a database. Such queries may be composed via menus, command languages, or direct manipulation, but at last appear as Structured Query Language (SQL) queries (Smelcer, 1995).

SQL is today the de facto standard language for relational and object-relational databases (Brass & Goldberg, 2006), and is the most important language used to support the creation and maintenance of a relational database and the management of data within that database (Sheldon, 2003). Because of SQL importance, students would benefit more if the teachers could demonstrate the queries and ill-defined errors present in those queries and allow the students to practice by themselves instead of following an example from a textbook (Rob & Coronel, 2007; Wilton & Colby, 2005).

In recent years, multimedia has afforded an opportunity to implement an active, student-centered instructional approach in which learners can select relevant words and images, organize them into coherent verbal and visual models, and integrate them into a whole conceptual structure (Mayer, 2005). Such an approach can enhance students' learning when appropriate principles are taken into account (Mayer & Moreno, 2003). Multimedia teaching-learning tools are changing the way students from all levels are taught in the educational arena. Multimedia learning tools have also been successfully adopted in related areas such as data communications and networking (Asif, 2003; Elkateeb & Awad, 1999; Yaverbaum & Nadarajan, 1996), operating system concepts (Rias & Zaman, 2008, 2010), multimedia learning (Lahwal, Amaimin, & Al-Ajlan, 2009; Neo & Neo, 2009; Teoh & Neo, 2006), computer algorithms and design patterns (Byrne, Catrambone, & Stasko, 1999; Dukovich & Janzen, 2009), or even merging

skills for learning English (Lai, Tsai, & Yu, 2009; Tsai, 2009). Nevertheless, it is not easy to find studies who demonstrate their effectiveness for SQL learning.

Simply implementing multimedia tools in classrooms is not enough. Moreover, teachers should select appropriate ways to used multimedia tools for enhancing students' learning effectively. The 5E learning cycle model, which is one of the learning and teaching approach based on the concept of inquiry-based learning (Renner & Lawson, 1973), is seen as effective active learning, inquiry-based scientific pedagogy, especially in enhancing students' understanding of the nature of the world (Bybee, 2006; Stamp & O'Brien, 2005). The idea of the 5E learning cycle model has been applied to promote students' understanding in several areas such as life science, biology, and physics (Dibley & Parish, 2007; Kaynar, Tekkaya, & Cakiroglu, 2009; Krall, Straley, Shafer, & Osborn, 2009).

To our knowledge, there is no research concerning the integration of multimedia into the 5E learning cycle-based activities for SQL learning. With the benefit of multimedia tools and the 5E learning cycle model in enhancing students' understanding, in this study, it is a challenge to develop SQL instructional multimedia based on the 5E learning cycle to support second-year undergraduate students' learning.

The 5E learning cycle model–based learning environment

The 5E learning cycle model has five instructional stages, i.e., engagement, exploration, explanation, elaboration, and evaluation (Bybee, 2002, 2006).

- **Engagement phase (E1):** Teachers access students' prior knowledge and help them become engaged in a new concept through the use of short activities that generate enthusiasm and access prior knowledge. The activities should make connections between what students know and can do, expose prior conceptions, and organize students' thinking toward the learning outcomes of the current topic.
- **Exploration phase (E2):** Exploratory experiences provide students with a common set of experiences within which present concepts (i.e., misconceptions), processes, and skills are reflected and conceptual change is facilitated. Students have the opportunity to compare ideas that identify inadequacies of current concepts. Learners are not just passive receptors: they also have the chances to acquire knowledge actively. They may manipulate materials using existing knowledge to generate new ideas, explore questions and possibilities, and execute a preliminary investigation.
- **Explanation phase (E3):** In this phase, there are more interactions between teachers and students. The explanation phase focuses students' attention on a specific aspect of their engagement and exploration experiences and provides opportunities for students to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to use direct instruction. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them to modify and enhance their conceptual understanding.
- **Elaboration phase (E4):** Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, students learn to develop broader and deeper understanding and adequate skills, and perhaps acquire additional information. Students apply their understanding of the concept by performing additional activities.
- **Evaluation phase (E5):** The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate students' progress toward achieving the learning goals (Bybee, 2002, 2006).

The 5E learning cycle model is a realistic, constructivist method of leading students through a learning sequence in which they become engaged in a topic, explore that topic, are given an explanation for their experiences, elaborate on what they have learned, and are then evaluated (Wilder & Shuttleworth, 2005). The idea of the 5E learning cycle model has been applied to promote students' understanding in several areas. For example, in 2007, Beffa-Negrini, Cohen, Laus, and McLandsborough applied the 5E learning cycle model to a teacher development program in a food safety curriculum. They recruited seventy-one secondary teachers to register for the program, which designed online food-safety training activities rooted in the American National Science Education Standards and the Biological Sciences Curriculum Study. The participants went through 3 modules, each with 15 hours of web-based instruction,

interactive discussion, and tools for conducting experiments or for critically evaluating food safety. After analyzing 38 pre-tests and post-tests, they found that the teachers were satisfied with the program and that most of them felt more capable of critically evaluating food safety information on the Internet. By experiencing the 5E instructional strategy on the food safety topic, and by using an inquiry-based approach, these teachers could continue to effectively instruct in this topic. Krall, Straley, Shafer, and Osborn (2009) evaluated a unique series of physical-science, distance-learning courses in a professional development program for middle-school teachers in a rural region. The lesson followed the 5E learning cycle model and incorporated key tenets from conceptual change research. Instruction through active learning, inquiry-based investigations distinguish this program from other distance-learning programs. The results from the pilot study indicated that the 43 teachers' content knowledge was higher for six out of nine temperature and heat concepts. The teachers' views toward the distance-learning medium and the course in general were positive. Gerdprasert et al. (2010) developed a web-based learning unit based on integrating the principles of the mechanism of labor with the 5E learning cycle model. The results showed that supplementing the conventional lecture with the learning unit made learning significantly more effective than the traditional lecture alone and students responded positively toward this learning unit.

The developed multimedia-supplemented instructional unit based on the 5E learning cycle model

Two lessons of the SQL instructional unit were developed: Lesson I—SQL for defining and manipulating data, and the rules related to keys in a relational database—focused on SQL's data definition language (DDL), which relates to creating tables, and on the part of the data manipulation language (DML) that relates to inserting, updating, and deleting data, and integrity rules. Lesson II—SQL for retrieving data—focused on DML statements related to data retrieval. These lesson plans were designed based on Bybee's (2006) 5E learning cycle approach—engagement, exploration, explanation, elaboration, and evaluation. Each lesson was divided into two parts: a two-hour computer laboratory with the use of the developed multimedia tool and a one-hour lecture. These instructional plans provided students with experiences in the computer laboratory before attending the lectures. The overall activities of each lesson were as follows:

Phases/Description	Objectives	Student Activities
Lesson I: SQL for defining and manipulating data and the rules related to keys in a relational database		
Engagement I (10 mins)	1. To introduce students to SQL commands	Students were engaged into the learning unit by using the designed multimedia animation.
Exploration I (30 mins)	1. To expose students to SQL commands and syntax: defining tables, manipulating data, and integrity rules 2. To predict the output of SQL commands 3. To practice writing SQL commands to generate output 4. To investigate the cause(s) of SQL syntax error(s)	Game investigation: students predicted SQL statements, both the DDLs (create, alter, and drop a table) and the DMLs (insert, update, and delete data from a database). Content investigation: students tried to write SQL commands with the designed multimedia as shown in Figure 1 by using an SQL manual, used the Microsoft Office Access program in a computer laboratory for observing SQL syntax errors, communicated their results with peers, and discussed the results of game and content investigation with the class.
Explanation I (20 mins)	1. To summarize the objectives of DDL commands, and relate DML commands (manipulating data in a database) to integrity rules	The teacher encouraged students to share and discuss the cause(s) of SQL syntax error(s) they faced, summarized the objectives of DDL commands, DML commands (except query commands), and related DML commands to integrity rules. Also students were encouraged to construct the whole SQL command concepts. The teacher taught in-depth

Phases/Description	Objectives	Student Activities
Elaboration I (20 mins)	1. To elaborate by applying knowledge to new situations	Students practiced and applied DDL and DML commands by using the multimedia animation and used the Microsoft Office Access program to learn from error message responses. The teacher provided results and additional information on practicing SQL commands.
Evaluation I (10 mins)	1. To evaluate their understanding and perceptions	Encourage students to evaluate their understanding, findings, explanation, and elaboration.
Lesson II: SQL for retrieving data		
Engagement II (10 mins)	1. To introduce students to more SQL commands	Students were engaged into the learning unit by using the designed multimedia animation.
Exploration II (30 mins)	1. To experience data query 2. To predict the output of SQL commands 3. To practice writing SQL commands to generate output 4. To investigate the cause(s) of SQL syntax error(s)	Game investigation: students predicted SQL's DML statements (query commands). Content investigation: students tried to write SQL commands with the designed multimedia animation as shown in Figure 2 by using an SQL manual, used the Microsoft Office Access program in a computer laboratory for observing SQL syntax errors, communicated their results with peers, and discussed the results of game and content investigation with the class.
Explanation II (20 mins)	1. To summarize the objectives of DML (query commands)	The teacher encouraged students to share and discuss the cause(s) of SQL syntax error(s) they faced, and summarized the objectives of DML (query commands). Also students were encouraged to construct the whole SQL command concepts
Elaboration II (20 mins)	1. To elaborate by applying knowledge to new situations	Students practiced and applied DML commands (query commands) by using the multimedia animation and used the Microsoft Office Access program to learn from error message responses. They shared and collected results with peers. The teacher provided results and additional information on practicing SQL commands.
Evaluation II (10 mins)	1. To evaluate their understanding and perceptions	Encourage students to evaluate their understanding, findings, explanation, and elaboration.

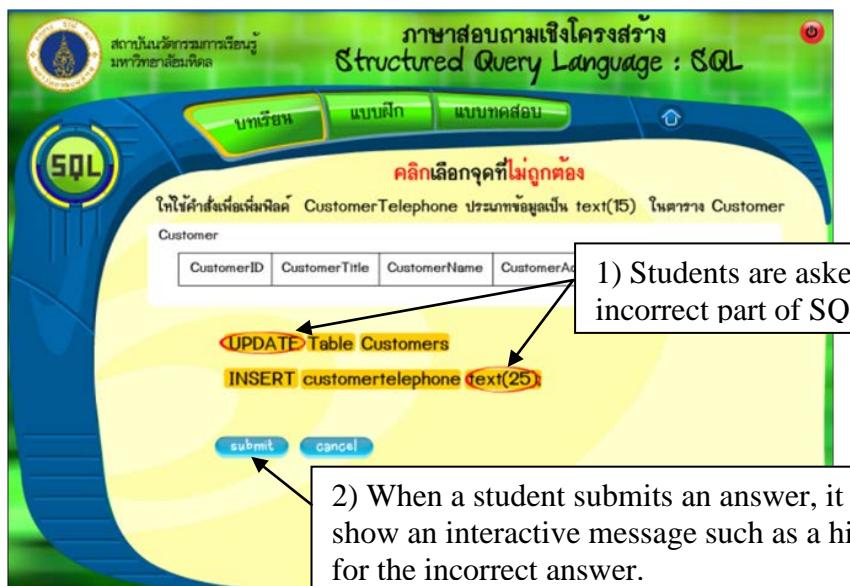


Figure 1. An SQL interactive game that asks the students to find and click on each incorrect part of an SQL statement in the phase Exploration I

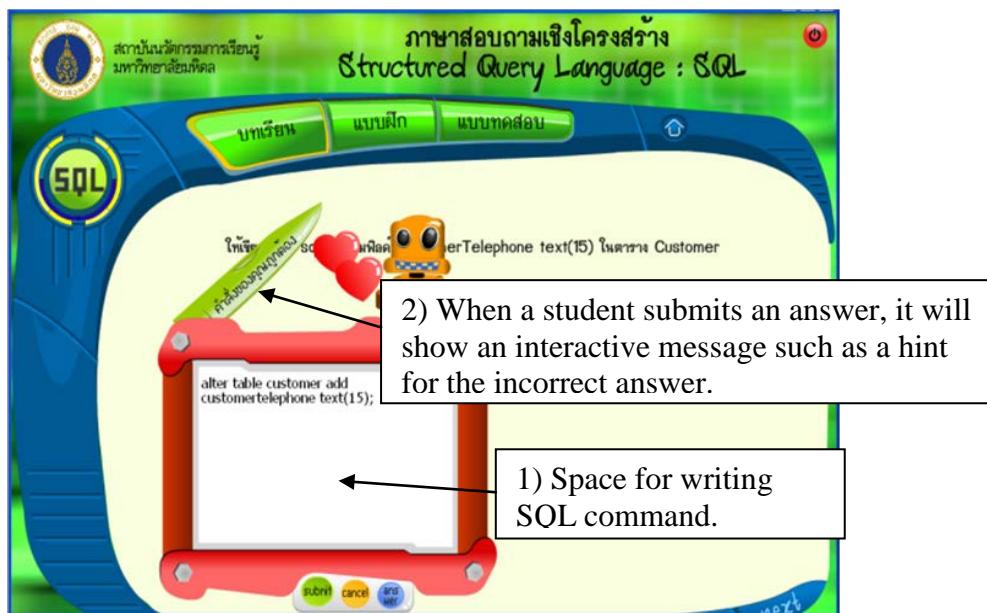


Figure 2. An interactive game for writing SQL commands in the phase Exploration II

The development of the SQL learning unit started from planning the instruction, consulting with the curriculum experts, conducting the pilot study, and revising the draft. The next step was implementation and data collection. Finally, the SQL learning unit was evaluated from all the data.

Research objectives

1. To investigate the students' learning achievement on SQL after participating in the learning unit based on 5E learning cycle model supplemented with interactive multimedia.
2. To investigate the students' learning attitude after participating in the interactive learning unit based on 5E learning cycle model supplemented with interactive multimedia.

Research questions

1. To what extent can the learning unit based on 5E learning cycle model supplemented with interactive multimedia promote undergraduate students' learning achievement on SQL?
2. What is undergraduate students' attitude toward the innovative SQL learning unit based on 5E learning cycle model supplemented with interactive multimedia?

Methods

This study is experimental research. The faculty teacher in the university who teaches SQL did all teaching in this study. Researchers by ourselves constructed the pre- and post-test (open-ended questions), questionnaire, and set criteria of rubric scores for evaluating students' projects. Researchers asked another faculty teacher (who did not teach in this study) to score pre- and post-tests and evaluate students' projects based on the rubric scores. The details of participants and research instruments (i.e., pre-post tests, criteria of rubric scores, and questionnaire) are included in this section.

Participants

Ninety-five second-year undergraduate students (fifty-two males, forty-three females), aged 18–20, were recruited to participate in this study. They were taught by the same teacher. After learning fundamental database concepts in the database course, all students took a pre-test to ensure whether they had equivalent prior knowledge about the fundamental database concept and they then were randomly divided into three groups, namely a control group (thirty-three students), an experimental group 1 (thirty students), and an experimental group 2 (thirty-two students). The students in the control group (CG) participated in the traditional lecture without interactive multimedia as a supplementary material. The teacher guided them to follow SQL commands step-by-step by the textbook in three-hour lectures without any supporting activities or discussion with their classmates. Those in the experimental group 1 (E1) were given the developed 5E learning cycle model-based learning unit without interactive multimedia as a supplementary material. They participated in the active learning activities based on the 5E learning cycle model and discussed with their classmates and the teacher in three-hour sessions. Those in the experimental group 2 (E2) participated in the developed 5E learning cycle model-based learning unit with the instructional interactive multimedia. They manipulated the animation in the interactive multimedia to engage their prior knowledge before learning SQL and playing the game in interactive multimedia to explore and observe the cause(s) of SQL command error(s) by discussing with their classmates and receiving the guidance from the teacher in three-hour sessions after experiencing learning activities, all participants were assessed by a small project and a post-test on the database system to examine learning achievement in SQL. To measure the students' attitude with the 5E learning cycle model-based learning unit supplemented by the instructional interactive multimedia, a questionnaire was administered after finishing the post-test to the students who followed the developed learning instruction. The complete procedures for experimental designing are shown in Figure 3.

Research instruments

To evaluate undergraduate students' learning achievement on SQL and attitude toward learning activities, we constructed research instruments including (1) pre-post tests, (2) criteria of rubric scores, and (3) a questionnaire. The pre-test was a ten open-ended question test, in which each item scored three points with the aim of testing students' prior knowledge about the fundamental database concept before learning SQL commands. In this test, the KR-20 reliability was .79, indicating that the items were useful.

The post-test was intended to compare the SQL commands knowledge of the three groups of students after taking the different learning activities. The test, different from the pre-test, was a ten open-ended question on two categories: three items on the basic knowledge of SQL and seven items on the ability to apply SQL. In this test, the KR-20 reliability was .75, indicating that the items was useful.

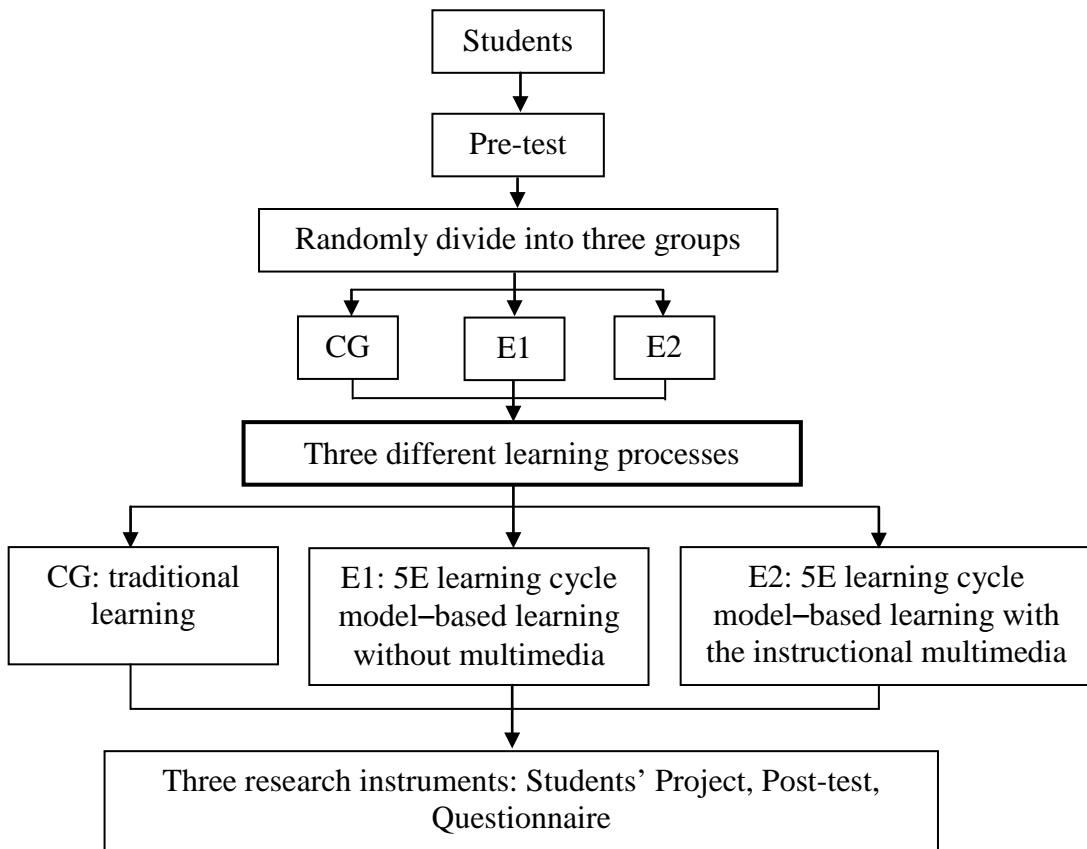


Figure 3. Work flow of experimental design of the second study

The criteria of rubric scores were carefully set for evaluating students' ability to apply SQL-related database concepts on students' project after experiencing the learning activities. The rubric score consisted of five criteria: (1) database design; (2) framework of database system; (3) user interface design; (4) data preparation; and (5) applying SQL, where 0–1.5 represents “beginning”, 1.51–2.50 represents “developing”, 2.51–3.50 represents “accomplished”, and 3.51–4.00 represents “exemplary” as shown in Table 1.

The questionnaire was administered to the students in three groups after finishing the instructional process. The questionnaire was employed to investigate students' attitude toward the learning activities using a 5-point Likert scale, where 1 represents “strongly disagree”, 2 represents “disagree”, 3 represents “uncertain”, 4 represents “agree”, and 5 represents “strongly agree.” The Cronbach's alpha of this questionnaire was .87, implying that this questionnaire is reliable.

Table 1. Scoring rubric for analyzing students' projects

Criterion	Descriptions			
	4 (Exemplary)	3 (Accomplished)	2 (Developing)	1 (Beginning)
1. Database design	Designed database cover 5 conditions: 1. Remove data redundancy 2. Setting primary key 3. Setting foreign key 4. Setting relationship 5. Determine appropriate attribute in each table	Designed database defined cover 4 conditions from all 5 conditions	Designed database defined cover 3 conditions from all 5 conditions	Designed database defined cover 2 conditions from all 5 conditions

Criterion	Descriptions			
	4 (Exemplary)	3 (Accomplished)	2 (Developing)	1 (Beginning)
2. Scope of application system	Scope of designed application cover 4 conditions: 1. Completely scope 2. Simulate the real system 3. Complexity of system 4. Useful system	Scope of designed application defined cover 3 conditions from all 4 conditions	Scope of designed application defined cover 2 conditions from all 4 conditions	Scope of designed application defined cover only one condition
3. User interface	Designed user interface cover 5 conditions: 1. User friendly 2. Appropriate to use 3. Well fineness designed page 4. Designed data access system 5. Accuracy of data displaying in interface	Designed user interface defined cover 4 conditions from all 5 conditions	Designed user interface defined cover 3 conditions from all 5 conditions	Designed user interface defined cover 2 conditions from all 5 conditions
4. Data preparation for system testing	Data preparation cover 4 conditions: 1. Fundamental data 2. Operational data 3. Completely data 4. Reasonable data	Data preparation defined cover 3 conditions from all 4 conditions	Data preparation defined cover 2 conditions from all 4 conditions	Data preparation defined cover only one condition
5. Applying SQL command in application	Applying SQL command cover 4 conditions: 1. Updating data 2. Querying from one table 3. Querying from more than one table 4. Querying by condition	Applying SQL command defined cover 3 conditions from all 4 conditions	Applying SQL command defined cover 2 conditions from all 4 conditions	Applying SQL command defined cover only one condition

Results

In this study, the results from the pre-test, the post-test, the small projects, and the questionnaire were analyzed to find out whether the developed learning unit helped enhance learning achievement.

Students' achievement

The pre-test aimed to examine the prior knowledge of the control and the two experimental groups while the post-test explored how the three groups were affected by the treatments in terms of students' basic and applied knowledge of SQL after the implementation of the developed learning units. Table 2 shows that there was no significant difference in the average pre-test scores of CG (2.70 ± 3.56), E1 (3.42 ± 3.72), and E2 (4.52 ± 1.98). The results suggested that the three groups of the students had similar prior knowledge regarding SQL. However, for the average post-test scores, the score of E2 (19.44 ± 6.04) was significantly higher than those of E1 (12.17 ± 8.27) and CG (7.75 ± 4.58).

Table 2. One-way analyses of variance (ANOVA) for the pre-test and post-test results

Pre-test	Group	Number of students	Average score	Standard deviation	F(2, 92)	Post hoc test (Scheffe)
Overall (Total Score: 30)	(a)	33	2.70	3.56	2.697	-
	(b)	30	3.42	3.72		-
	(c)	32	4.52	1.98		-
Post-test						
Overall (Total Score: 30)	(a)	33	7.75	4.58	27.394	(c) > (a)*
	(b)	30	12.17	8.27		(c) > (b)*
	(c)	32	19.44	6.04		(b) > (a)*

* $p < .05$

(a) Control group CG: traditional learning; (b) Experimental group E₁: 5E learning cycle model-based learning without interactive multimedia; (c) Experimental group E₂: 5E learning cycle model-based learning with the instructional interactive multimedia.

Moreover, Table 3 shows that, regarding basic knowledge of SQL, there were significant differences in the average post-test scores between E₂ and E₁, E₂ and CG, and E₁ and CG. Similar results were found for the ability to apply SQL. These results suggested that the SQL learning unit based on the 5E learning cycle model supplemented with the interactive multimedia is more helpful than other learning units for students in learning SQL.

Table 3. One-way analyses of variance (ANOVA) for the post-test results of the three groups regarding basic knowledge of SQL and ability to apply SQL

Category	Group	Number of students	Average score	Standard deviation	F(2, 92)	Post hoc test (Scheffe)
Basic knowledge of SQL (Total Score: 10)	(a)	33	4.55	1.68	28.304	(c) > (a)*
	(b)	30	5.64	1.97		(c) > (b)*
	(c)	32	7.69	1.45		(b) > (a)*
Ability to apply SQL (Total Score: 20)	(a)	33	3.21	3.58	21.576	(c) > (a)*
	(b)	30	6.53	6.71		(c) > (b)*
	(c)	32	11.75	5.21		(b) > (a)*

* $p < .05$

(a) Control group CG: traditional learning; (b) Experimental group E₁: 5E learning cycle model-based learning without interactive multimedia; (c) Experimental group E₂: 5E learning cycle model-based learning with the instructional interactive multimedia.

Results of students' small projects

Table 4 shows the overall student-project results. Students' projects in the experimental group 2 (E₂) regarding the database design, the framework of the database system, the user interface design, and the data preparation were exemplary. Moreover, they were exemplary in applying SQL commands to update and query data from multiple tables, and in querying data by using correct conditions. The projects in the experimental group 1 (E₁) were exemplary in the framework of database system and in applying SQL. As a comparison, students' projects in the control group were only exemplary in the framework area. These results confirmed that our innovative learning unit was able to promote students' understanding of SQL, particularly in applying SQL to develop small projects.

Table 4. The overall rubric scores of students' projects

Criteria (Total scores: 20)	Results of students' projects		
	(a)	(b)	(c)
Database design (4)	Accomplished	Accomplished	Exemplary
Framework of database system (4)	Exemplary	Exemplary	Exemplary

Criteria (Total scores: 20)	Results of students' projects		
	(a)	(b)	(c)
User interface design (4)	Accomplished	Accomplished	Exemplary
Data preparation for system testing (4)	Accomplished	Accomplished	Exemplary
Applying SQL (4)	Accomplished	Exemplary	Exemplary

(a) Control group CG: traditional learning; (b) Experimental group E₁: 5E learning cycle model-based learning without interactive multimedia; (c) Experimental group E₂: 5E learning cycle model-based learning with the instructional interactive multimedia.

Students' attitude: Results of the questionnaire

The questionnaire was employed to investigate students' attitude after experiencing the learning activities. As shown in Table 5, the students in the experimental group 2 (E₂) who followed the proposed learning unit based on the 5E learning cycle model-based learning with the instructional interactive multimedia were satisfied with the engagement method. Moreover, the experimental 1 (E₁) and 2 (E₂) groups felt that they had the opportunities to explore the SQL commands and explain their knowledge in the classroom during the proposed learning activities. Furthermore, these two groups agreed that they could discuss with their peer from the active learning activities. Thus, the experimental group 2 (E₂) realized that they could assess and evaluate their knowledge according to the learning objectives.

Table 5. Students' responses to the questionnaire (N = 95)

Items	Mean			SD		
	(a)	(b)	(c)	(a)	(b)	(c)
Engagement						
1. These learning-teaching activities can increase encouraging in learning	3.85	4.06	4.15	0.66	0.51	0.51
2. These learning-teaching activities can help learners to relate prior knowledge to the current topics						
3. These learning-teaching activities can engage learners to the content						
Exploration						
4. I learn by manipulating via these learning-teaching activities	3.69	4.02	4.03	0.73	0.61	0.61
5. There are many encouraging questions along the active learning activities via these learning-teaching activities						
6. These learning-teaching activities help learners self-performing						
Explanation						
7. These learning-teaching activities concern the learners' explanation and share learning concepts by self practicing	3.68	3.91	4.01	0.73	0.52	0.71
8. There are many encouraging questions for evaluating the individual understanding via these learning-teaching activities						
9. I understand the additional concept from teacher explanation						
Elaboration						
10. There are many exercises for learners practicing and learning via these learning-teaching activities	3.74	3.90	3.94	0.67	0.52	0.63
11. I can learn from sharing, observing, and problem solving with my classmates						
12. I can learn from asking and suggesting from teacher						
13. I can link the learning concepts with real situation						

Items	Mean			SD		
	(a)	(b)	(c)	(a)	(b)	(c)
Evaluation 14. I have assessed my knowledge and understanding after learning this topic 15. The learning evaluations are relevant to learning objectives 16. The evaluations are clear, suitable and able to measure	4.03	4.01	4.29	0.71	0.60	0.64

(a) Control group CG: traditional learning; (b) Experimental group E₁: 5E learning cycle model-based learning without interactive multimedia; (c) Experimental group E₂: 5E learning cycle model-based learning with the instructional interactive multimedia.

Discussion

This study was conducted to investigate the effectiveness of the three methods of learning SQL (5E learning cycle model with instructional interactive multimedia, 5E leaning cycle instruction, and traditional instruction) for the second-year undergraduate students. From previous research, there was no report of applying the 5E learning cycle approach supplemented with interactive multimedia for SQL learning. The overall results of this study indicated that the 5E learning cycle model-based learning unit with the instructional interactive multimedia significantly outperformed the 5E learning cycle model instruction and the traditional method in promoting students' understanding of key aspects and concepts involved in SQL, especially regarding basic knowledge of SQL and ability to apply SQL on the students' projects on the database system. The students could explore SQL syntax errors via the game in the interactive multimedia and came to understand the concepts of SQL commands. This study thus could be an original contribution to the 5E learning cycle-based instruction supplemented with interactive multimedia.

Possible reasons for this observed difference might include the value associated with alternative ways of acquiring knowledge in science, particularly inquiry, and the confirmation value of active learning activities. During the 5E learning cycle instruction, the students learned through their own actions and reactions by being involved in the active learning activities. They were engaged by the SQL game and the responses from dragging, dropping, and clicking the exemplified statements encouraged them to modify and mark parts of the commands in order to find the correct answers. They explored SQL commands and the responses from running the given statements encouraged them to modify the commands to find the correct answers. Students' explorations involved trying out and learning from errors. The students in the 5E learning cycle instruction group were also involved in active learning activities that helped them to examine the adequacy of their prior conceptions and encouraged them to discuss about those conceptions. This led to disequilibrium where predictions based on their prior beliefs were contradicted and provided the opportunity to construct more appropriate concepts. The 5E learning cycle model-based, interactive multimedia-supplemented SQL instructional unit incorporated a teaching strategy in which students had enough time to identify and express their preconceptions and examine their usefulness, before a group of related new concepts was introduced and explicated. Students elaborated by applying and extending newly constructed knowledge to other database case studies and small projects. The evaluation in the 5E learning cycle model-based instructional interactive multimedia required the students to evaluate what they have done. The students in the 5E learning cycle instruction went through the same teaching strategy as those in the 5E learning cycle model-based, interactive multimedia-supplemented instructional unit except for the engagement stage wherein these students were engaged by reviewing the database concepts related to SQL commands. Meanwhile, the students in the traditional group mainly focused on concepts related to the subject, the process that required less conceptual restructuring.

The findings in this study regarding better performance of students in the 5E learning cycle model-based, interactive multimedia-supplemented group were consistent with the view claiming that correct use of the 5E learning cycle instruction accomplished both effective learning of concepts and an ability to apply concepts. The positive effect of 5E learning cycle instruction on students' achievement was supported by previous studies in the literature (Gerdprasert et al., 2010; Kaveevivitchai et al., 2009; Kaynar Tekkaya, & Cakiroglu, 2009; Liu et al., 2009). For example, Kaynar et al. (2009) revealed effectiveness of the 5E learning cycle model over traditional learning on

students' achievement in cell concepts. Studying the achievement of third-year university nursing students and midwifery, Gerdprasert et al. (2010) showed that supplementing the conventional lecture with the developed web-based learning unit made learning significantly more effective than the traditional lecture alone and students responded positively toward this learning unit. They developed the web-based learning unit by integrating the principles of the mechanism of labor with the 5E inquiry cycle model. The results of the present study were also consistent with the results reported by earlier studies that indicated positive effect of 5E learning cycle instruction on students' ability to apply their knowledge. For example, Van Hook and Huziak-Clark (2007) implemented the 5E learning cycle model in which students used the understanding gained in the previous learning steps to apply their ideas about how things work through collaborative active learning inquiry guided by a knowledgeable teacher. Students in the constructivist classroom were able to adopt their learned concept and used active learning materials to describe how multiple magnets would interact with each other.

This study indicated the positive effect of integrating interactive multimedia with a learning approach on students' understanding and their motivation. The present study is also consistent with the study by Murray and Guimaraes (2008) who found a positive rating on the value of animated courseware by students and faculty. This learning tool could help students find a pathway to increase understanding and generate a high level of learning. In another study, Valdés et al. (2000) provided multimedia resources for students as alternative study tools. Their work showed that students found the learning tools easily understandable and were motivated to learn. Overall results of this study suggested that when students participated in appropriate instruction which helped them understand relevant ideas, sound understanding of SQL concepts could be achieved.

Conclusions

The finding of the present study indicated that the 5E learning cycle model-based, interactive multimedia-supplemented instructional unit caused significantly better acquisition of principal conceptions related to SQL commands than traditional instruction. For the students who followed the 5E learning cycle model supplemented by the instructional interactive multimedia activities, the emphasis was on practicing and learning from errors found. The students were involved in the activities that helped them activate their prior knowledge and allowed them to struggle with their own practices. These activities also provided evidence that the students' initial conceptions were insufficient to write SQL commands. To deal with these errors found by practicing, for instance, SQL syntax errors, students became dissatisfied with their existing conceptions. This dissatisfaction led them to accept better explanations for the situations that were introduced. In this way, students were allowed to think about their prior knowledge and reflect on it. The important part in the implementation of the SQL-concept instruction was the intensive teacher-student interaction. The use of the 5E learning cycle model-based instructional interactive multimedia activities could clarify students' thought processes and corrected their errors found by practicing. When students dealt with a new concept through an exploration, their new experiences caused them to reevaluate their past experiences. This produced disequilibrium in the students, and they needed to accommodate the new concept to reach new equilibrium. They had the opportunity to explain, to argue, and to debate their ideas, which allowed them to accommodate the concept. In the elaboration phase, students became familiar with the introduced concept and either assimilated or accommodated the new concept into their schemata. The persistence of inadequate cognitive structures was attacked by applying the new concept to a broad range of new examples. The study presented here revealed that teacher-centered and textbook-oriented science instruction did less to improve students' conceptual understanding and leaved many errors found by practicing unchanged.

To apply the proposed 5E learning cycle model-based, interactive multimedia-supplemented instructional unit, several points need to be taken into consideration:

1. The 5E learning cycle model supplemented with interactive multimedia can be applied as an alternative method to traditional instruction. It is important to be aware of students' prior knowledge and to manage the classroom activities accordingly.
2. Various assessment tools allow teachers to assess students' abilities to apply their knowledge in the information system area.
3. Since the learning process in this study enables students to learn based on their own exploration and explanation, formative assessment to follow students' progress during the learning process should be considered.

In addition, to introduce the proposed 5E learning cycle model-based instructional interactive multimedia into the classroom, a step-by-step guideline for the teachers/ practitioners/ researchers is as follows:

- Step 1: Introduce SQL commands to the students by showing the animation in the interactive multimedia. This step will take 10 minutes.
- Step 2: Ask the students to play a game in the interactive multimedia program to investigate the cause(s) of SQL syntax error(s). Usually the Microsoft Office Access program has a guideline that shows all command errors. This step will take 30 minutes.
- Step 3: Encourage the students to share and discuss the cause(s) of SQL syntax error(s). This step can be carried out in groups or individually, depending on the practical needs.
- Step 4: Ask the students to practice SQL commands using the animation in the interactive multimedia. Usually the Microsoft Office Access program has a guideline that allows the teachers and students to learn about the error message responses. This step will take 20 minutes.

For researchers who would like to compare students' learning achievement before and after receiving the learning activities supplemented with the interactive multimedia, a post-test is needed. If the objective of the research is to investigate the effectiveness of the treatment, control groups might be needed to compare the performance of the students who participate in different treatments. Furthermore, for those teachers/practitioners/researchers who have difficulty in implementing their own learning activities supplemented with the interactive multimedia, the authors are willing to provide a lesson plan, a manual of the interactive multimedia, the multimedia source code, or technical assistance upon request.

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Understanding New Media Literacy: An Explorative Theoretical Framework

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ABSTRACT

With the advent of new media technologies, the role of media in a society has been changed that leads researchers to re-construct the meaning of literacy from classic literacy to new media literacy. There have been continuing efforts to understand new media and promote the importance of becoming new media literate among researchers, educators, and policy makers. Fundamental understanding to what is new media literacy still remains unclear. There is only one paper providing the preliminary work in unpacking the framework of new media literacy. Although the developed framework has its merit, more details and information need to further elaborate and refine. In this paper, we acknowledge the two continua framework and endorse four types of literacy comprising of this two-continua. Moreover, we provide ten fine-grained indicators to reflect these four types of literacy. We also propose another new divide that distinguishes Web1.0 from Web2.0.

Keywords

New media literacy, Web 2.0, Consuming, Prosuming

Introduction

With the advent of new media technologies, the landscape of media has been changed drastically and dramatically. Although there are various terms such as ICT and digital technologies to name these technologies, we choose the term, ‘new media’ technologies, as ICT and digital technologies could be embedded in it. As Eshet-Alkalai & Soffer (2012, p. 1) argued in an editorial, ‘digital technologies (social media, multimedia and communication technologies) have penetrated almost every aspect of our lives’. These changes cause new forms of cultural practice in working, learning and personal domain. The appearance of Web 2.0 is an example (Berger & McDougall, 2010). These new technologies make the media even more significant and influential than ever in human history. Therefore, individuals need to be new media literate to be able to fully function in the society. This paper aims at providing an explorative theoretical framework to define and understand the ‘new media’ literacy. Based on existing literature and the new media ecology, this framework is developed to help understand the new media literacy among the public. In the rest part of introduction, we discuss the characteristics of new media and the development of media literacy which is precedent and a part of our new media literacy framework. Then, we examine an existing framework proposed by Chen, Wu, & Wang (2011) and point out the limitations of their framework. In the third part of this paper, we suggest a refined framework that works better on explaining the elements of new media literacy. While developing this theoretical framework, there are some difficulties and challenges which we document them in the conclusion with our suggestions for further developing the theory of new media literacy.

The term ‘new media’ broadly refers to computer and communication technologies (Chen, Wu, & Wang, 2011; Rice, 1984), or ‘a wide range of changes in media production, distribution and use’ (Lister, Dovey, Giddings, Grant, & Kelly, 2003, p. 13). A majority of researchers tend to define new media by highlighting its technical characteristics including digitality (i.e., numerical representation), hypertextuality, dispersal, virtuality, modularity, multimodality, hybridity, interactivity, automation, and variability (see Anderson & Balsamo, 2008; Lister et al., 2003; Manovich, 2001; Nichols, 2008; Pratt, 2000). Meanwhile, some researchers have begun to address the socio-cultural characteristics of new media. Specifically, they advocated four key points: (a) each medium has unique language; (b) media messages are constructed; (c) media have embedded value and ideology; and (d) media serve various purposes (e.g. Aufderheide & Firestone, 1993; Blau, 2004; Ito et al., 2008; Newby, Stepich, Lehman, & Russell, 2000; O'Reilly, 2005; Pink, 2005; Pungente, Duncan, & Andersen, 2005). More details on these points will be discussed later in this paper. As suggested by Gee (2001), Jenkins (2006) and Lievrouw & Livingstone (2006), the socio-

cultural characteristics should be greatly underlined rather than the technical issues in the context of 21st century new media era.

Literacy for the 21st century: from media literacy to new media literacy

The notion of media literacy has existed in the Western for a long time. It is not only the precedent of new media literacy but also covered by the new media literacy framework in this paper. Therefore, it is worth of discussing the development of media literacy before introducing our framework of new media literacy as there are some common assumptions and arguments.

The beginning of media literacy can be traced back to the first half of the 20th century when Leavis & Thompson (1933) proposed to teach students how to distinguish the high culture and the popular culture through education in the UK. In this early protectionist approach, these advocates aim at promoting high culture to fight against the increasing growth of popular culture in printing media era (Buckingham, 2003). In 1950s, media literacy was introduced to the United States with the acknowledgement of the increasing impact of mass media such as radio and television on people's daily life and schooling (Schwarz, 2005). A general trend of the development of media literacy as well as new media literacy is that the importance of media literacy is brought back to the educational agenda when there is a new media technology that causes collective anxiety in the society (Lin, 2010). The appearance of new media also raised concerns among the public in various countries. For example, the recently growing interests in media literacy in various East Asian countries such as China (including Hong Kong), Taiwan, Japan and Korea since late 1990s (Cheung, 2009) comes from an emerging new media technology, the internet, that causes cyber cafe phenomenon. The birth of internet is a milestone in the development of media literacy because it 'changed the whole media landscape' and starts a debate on the different approaches to media literacy (Gauntlett, 2011). This is also the starting point for us to propose a framework that can both suit the need of conventional media such as television, newspaper and radio and new media such as internet and the Web 2.0 technology.

With the emerging new media technologies in the beginning of 21st century, traditional literacy is no longer sufficient for an individual to competently survive in this new media ecology. Wu and Chen (2007) argued that media is not merely shaping our culture; it is our culture. In other words, new media plays an indispensable role in human societies and individuals need to equip with new literacies (e.g., Cope & Kalantzis, 2000) to be able to fully engage in the new media environment. All the above arguments represent the necessity and importance of new media literacy.

As aforementioned, there are similarities between media literacy and new media literacy regarding the approaches to understand media, the role of media in a society and the purposes of media literacy. Cappello, Felini & Hobbs (2011) indicated that the current media literacy education strikes a balance between discrimination/protection and empowerment approaches and the recognition of media as an aspect of social environment is a pushing force for the recent development of media literacy in the world. The moving away from extreme protectionist approach and acknowledging the great socio-cultural impact of media have also offered a solid foundation for the development of new media literacy. Detail discussion on various approaches of media literacy education can be referred to Buckingham (2003), Leaning (2009) and Lin (2010). Livingstone, Van Couvering & Thumin (2004) revealed three purposes of implementing media literacy: (a) democracy, participation and active citizenship, (b) knowledge economy, competitiveness and choice, and (c) lifelong learning, cultural expression and personal fulfillment. Similar emphases on the role media literacy are also evident and advocated in the media literacy documents/standards of US (National Association for Media Literacy Education, 2007), UK (Ofcom, 2004), Singapore (Lin, 2011; National Institute of Education, 2009), and Taiwan (Lin, 2009; Ministry of Education, 2002).

Meanwhile, research on media literacy has also suggested a progressive shift in its meaning. As it is suggested in a review by Cervi, Paredes, & Tornero (2010), literacy has developed generally from classic literacy (e.g. reading and writing) to audiovisual literacy (e.g. related to electronic media) to digital literacy (e.g. related to digital media) and recently to a more comprehensive new media literacy (e.g. related to Internet and Web 2.0). Moreover, Cappello, et al. (2011) applied the concept 'expanded literacy' (p. 68) to underline the shift from the literacy strictly related to alphabetic and written texts to another literacy focused more on social communication and ideology. Besides, Chen et al. (2011) argued that an individual needs to become new media 'literate' in order to participate responsibly in the new century society.

Considering the importance of new media literacy, it seems necessary to explore the content and theoretical framework of ‘new media literacy (NML)’. However, there are very few applicable frameworks that provide a comprehensive understanding about how NML can and should be like. There is only one paper documenting the attempt to develop a framework to unpack NML (Chen et al., 2011) with a focus on technical and socio-cultural characteristics of new media. In next section, we discuss this framework and indicate some limitations. Then, we argue for a need to further elaborate and refine the framework to make it work better in explaining the socio-cultural consequence and the daily practices of new media.

Attempt to unpack NML: A preliminary framework and its limitations

A preliminary framework

As Chen et al. (2011) pointed out, most researchers perceived NML ‘as a combination of information skills, conventional literacy skills, and social skills’ (p. 84) or *multiliteracies*. That is, relevant definitions generally overlooked the significance of both the technical and socio-cultural characteristics of new media in shaping what NML can and should be. To address this gap, Chen et al. (2011) proposed a promising framework that unpacks NML as two continua from consuming to prosuming literacy and from functional to critical literacy (see Figure 1). Specifically, the ‘consuming’ literacy was defined as the ability to access media message and to utilize media at different levels, while ‘prosuming’ literacy ability to produce media contents (e.g. messages and artifacts). According to Chen et al. (2011), the consuming aspect should be integrated and implied in the prosuming aspect. For instance, an individual have to read and understand others’ ideas before they create media contents to respond. On the other hand, the ‘functional’ literacy refers to individuals’ ‘textual meaning making and use of media tools and content’ (Chen et al., 2011, p. 86), while ‘critical’ literacy their ability to analyze, evaluate, and critique media. Similarly, the functional aspect provides an essential basis for the critical aspect. For example, individuals may fail to make their great grasp of socio-cultural contexts of the media explicit due mostly to their unfamiliarity with the technical characteristics of new media tools/languages.

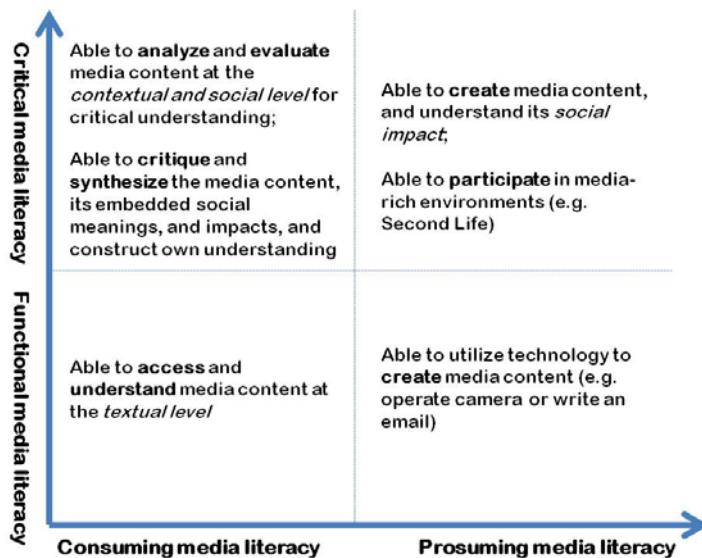


Figure 1. Framework for new media literacy (cited from Chen et al. (2011))

Based on the above two continua, four types of NML can be recognized. They are (a) functional consuming (FC, the lower left quadrant of Figure 1), (b) critical consuming (CC, the upper left quadrant), (c) functional prosuming (FP, the lower right quadrant), and (d) critical prosuming (CP, the upper right quadrant). Accordingly, FC requires individuals’ abilities to access media content and understand its textual meaning. CC involves abilities to interpret the media content within specific social, economic, political and cultural contexts. FP focuses on abilities to participate in the creation of media content, while CP underlines individuals’ contextual interpretation of the media content during their participation activities. As Chen & Wu (2011) suggested, CP should be advocated as an important goal in the 21st century information society.

In brief, Chen et al.'s (2011) two-continuum framework indeed provides a better understanding of the notion NML. However, such framework still can be further developed, which constituted the main concern of this paper. More discussion on Chen et al.'s (2011) framework is detailed in the following section.

Limitations of existing framework

There are, at least, two limitations in the framework by Chen et al. (2011). First, the framework has characterized the four types of NML in a relatively coarse manner. As seen in Figure 1, it provides certain indicators/keywords for understanding each type of NML. For example, it is expected that functional media consumer be 'able to *access* and *understand* media contents at the textual level' (p. 85). Additionally, critical media consumers should be able to *analyze*, *evaluate*, *critique*, and *synthesize* the media content by pondering its embedded socio-cultural meanings/values. However, what these keywords refer to remain unclearly defined. This may further make unspecified the boundaries among the four types of NML. For instance, how great is the difference between 'understand' (from the functional consuming literacy) and 'analyze' (from the critical consuming literacy)? All these indicate the necessity of developing a more fine-grained framework of NML.

Second, the framework did not distinguish Web 1.0 from Web 2.0, which plays a pivotal role in shaping a distinct culture of media. In Figure 1, Chen et al. (2011) has unpacked the prosuming media literacy into students' abilities to *create* media contents and to *participate* in media-rich environment. This understanding of the prosuming literacy reflects their consideration of both the Web 1.0 and Web 2.0 environments. Within the Web 1.0 environment, students are allowed to create media contents, such as turning hardcopy into digital format, composing an email, and editing a photo. However, the Web 1.0 does not provide opportunities for students to participate as a group to share and negotiate their perspectives, which can be accomplished within the Web 2.0 environment instead (Berger & McDougall, 2010). More importantly, a number of scholars have recently emphasized that the Web 2.0 plays an essential part in encouraging adolescents to (a) make their voice heard, (b) embody their ideology, attitude, values through different identities, (c) grasp various social norms, and (d) participate responsibly in critical exchange/co-construction of ideas (e.g. Thoman & Jolls, 2008; Gee, 2001; Jenkins, Purushotma, Clinton, Weigel, & Robison, 2006). All these benefits are hardly expressed by the Web 1.0 environment. Therefore, it is necessary to make a divide between the Web 1.0 and 2.0 when discussing the prosuming media literacy. To tackle this issue, a refined framework is proposed in the next section.

A refined framework of NML

Our attempt is to propose a refined framework (see Figure 2) that aims to address the two limitations of Chen et al.'s (2011) framework. Like Chen et al.'s framework, our framework acknowledges NML as indicated by two continua (i.e., *functional-critical* and *consuming-prosuming*) that consist of four types of literacy: FC, CC, FP, and CP. Furthermore, our framework further unpacks the four types of NML into ten more fine-grained indicators, and proposes another new divide that distinguishes Web 1.0 from Web 2.0.

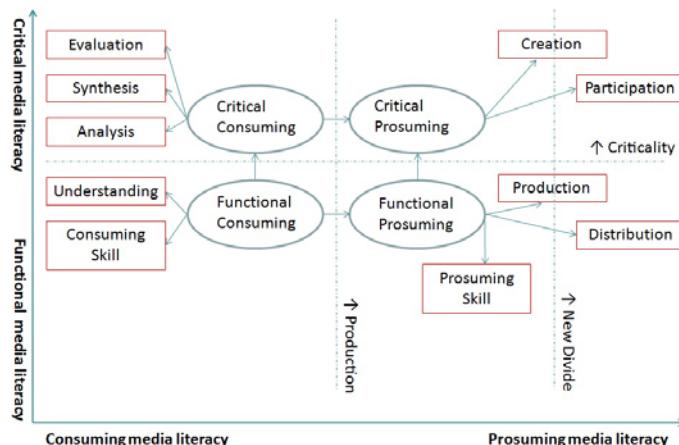


Figure 2. A refined framework of new media literacy

Framing NML: A refined framework with indicators

Our framework suggests that the four types of NML can be generally represented by ten more fine-grained indicators (shown in the red squares in Figure 2). In the following paragraphs, each indicator is introduced, elaborated, and discussed. Specifically, we firstly define and illustrate each indicator, and then discuss the similarities and/or differences between our definitions and others from the literature.

Consuming skill. The *consuming skill* refers to a series of technical skills necessary for an individual when an individual consumes media contents. For example, it requires an individual to know how to operate a computer, how to search/locate information, how to use information technology (e.g. Internet), and so on. This indicator bears some resemblance with Buckingham et al.'s (2005) *access*, which focuses on the ability to manipulate hardware and software and to gather information. Besides, the indicator also encompasses Chen and Wu's (2011) *access*, which addresses the ability to use different format/modality of media.

Understanding. This indicator refers to individuals' ability to grasp the meaning of the media contents at a *literal* level. Examples include individuals' ability to capture others' ideas that published on different platforms (e.g. book, video, blog, Facebook, etc.), and to interpret the meaning of new short forms or emoticons. Besides, four (out of 11) media literacy skills proposed by Jenkins et al. (2006) are other representative illustration as well. Specifically, individuals should be able to experiment with their surroundings to solve problems (i.e., *play*), to interpret and construct dynamic models (i.e., *simulation*), to scan their environment and shift flexibly onto salient information (i.e., *multi-tasking*), and to handle the flow of information across various modalities (i.e., *transmedia navigation*). Notably, the indicator *understanding* is distinct from but part of both Ofcom (2004) and Buckingham et al.'s *understand*. That is, their indicator involves not only individuals' textual understanding of, but also their critical stance towards the media content. Similar to Chen and Wu (2011), we tend to define *understanding* at the *textual* level only. On the other hand, we attempt to further unpack the *critical* level of Buckingham et al.'s (2005) *understand* into three more fine-grained indicators (i.e., *analysis*, *synthesis*, and *evaluation*), which are elaborated as follows.

Analysis. This indicator refers to individuals' ability to deconstruct media messages. Unlike *understanding* discussed above, this indicator can be seen as a semiotic 'textual analysis' (Share, 2002, p. 144) that focuses on language, genres, and codes of multiple modalities (e.g. print based, digital, etc.). As Thoman and Jolls (2008) illustrated, individuals need to be aware of the authorship (e.g. all media messages are constructed), format (e.g. the construction of media messages involves using a creative language with certain rules), and audience (e.g. interpretations of media messages vary across individuals) when they deconstruct media messages. Generally, the indicator shares similar meaning with Chen et al.'s (2011) *analyze* and Buckingham et al.'s (2005) *representation* (belonging to their indicator *understand*). All these indicators consistently stress that individuals should not simply perceive media contents as neutral conveyors of reality, but recognize the construction of media messages as a subjective and social process (e.g. Pungente et al., 2005).

Synthesis. This indicator refers to individuals' ability to remix media content with integrating their own viewpoints and to reconstruct media messages. For example, individuals are expected to compare news with the same theme from different sources. As shown in Figure 2, the indicator *synthesis* is categorized in the consuming rather than the prosuming literacy. This is based on the argument that synthesis itself does not necessarily imply prosuming. For instance, one might compare the number of people reported for rally from different media and notice the difference. It does not necessarily imply that the individual knows which number is closer to the 'truth' or that an individual has submitted a new item (e.g. posting one's own ideas). This indicator bears much resemblance with Jenkins et al.'s (2006) *appropriation*, which refers to the ability to sample and remix media content in a meaningful manner. Strictly speaking, as Jenkins et al. (2006) implicitly suggested, *appropriation* also involves *analysis* discussed above. When individuals remix media contents, they need to appreciate the 'emerging structures and latent potential meanings' (Jenkins et al., p. 33) of the message/language.

Evaluation. This indicator includes individuals' ability to question, criticize, and challenge the credibility of media contents. Compared to *analysis* and *synthesis* above, this indicator represents much higher-order criticality though they all acknowledge that media contents are merely human-constructed representation. It requires individuals to interpret the media contents by considering issues such as identity, power relation, and ideology (e.g. Chen et al., 2011). More importantly, *evaluation* also involves decision-making process which *synthesis* (and *analysis*) may not explicitly underline. For example, comparing prices from different vendors over the internet is an action of *synthesis*,

while making a decision of which vendor to buy from an action of *evaluation*. The indicator *evaluation* seems to echo other similar terms used by the literature. These terms include Jenkins et al.'s (2006) *judgment* that requires 'the ability to evaluate the reliability and credibility of different information sources' (p. 43) and Share's (2002) *representation* that underlines that 'media have embedded ideologies, discourses, and points of view that convey hierarchical power relations' (p. 144). Furthermore, this indicator also gains supports from other scholars who similarly advocated that media contents have embedded values and serve various purposes (e.g. Aufderheide & Firestone, 1993; Ito et al., 2008; Lievrouw & Livingstone, 2006; Thoman & Jolls, 2008)

To sum up, the above five indicators are representing the consuming media literacy, which we propose a media consumer should express. With the development of technology, the gap between media producers and consumers has been converging (Jenkins, 2006). As Buckingham (2009) suggested, such convergence tends to result in the appearance of a new breed of *media prosumers*. More importantly, the new forms of cultural expression and exchange, which are organized democratically and collectively, also motivate individuals to participate in media production and to have their voice heard (Blau, 2004; Chen et al., 2011; Jenkins et al., 2006; Pink, 2005). In the following paragraphs, we continue to introduce the other five indicators for the prosuming media literacy.

Prosument skill. This indicator refers to a set of technical skills necessary for an individual to produce/create media contents. For example, it involves individuals' ability to set up an online communicative account (e.g. MSN, Skype, Blog, Gmail, and Facebook), to use software to generate various digital artifacts (e.g. picture, video clip, and flash), and to do programming (e.g. for computer or hand phone devices). Together with the next two indicators (i.e., *distribution* and *production*), it constitutes Thoman and Jolls' (2008) *create* that underlines the use of various technologies to create, edit, and disseminate media messages.

Distribution. This indicator refers to individuals' abilities to disseminate information at hand. We considered this indicator mainly based on Buckingham's (2009) insightful viewpoint 'that the most significant developments in recent years have been to do with technologies of distribution rather than of production' (p. 235). In other words, distribution of information can be seen as another (or even more effective) means to prosume media. Compared to *prosuming skill*, *distribution* usually involves the process of sharing. Relevant examples include individuals' abilities to use build-in function on social network websites to share their feelings (e.g. like/dislike), to share media messages, and to rate/vote for products/services. Along with the aforementioned *computer skill* and *synthesis*, this indicator belongs to Jenkins et al.'s (2006) *networking* literacy that focuses on 'the ability to search for, synthesize, and disseminate information' (p. 49).

Production. This indicator involves abilities to duplicate (partly or completely) or mix media contents. Actions of *production* include scanning (or typing) a hardcopy document into digital format, producing a video clip by mixing images and audio materials, and scribble online through blog or Facebook. The indicator generally shares many similarities to Jenkins et al.'s (2006) *distributed cognition* and *transmedia navigation*. One refers to 'the ability to interact meaningfully with tools that expand mental capacities' (p. 37), while the other 'the ability to deal with the flow of stories and information across multiple modalities' (p. 46). In brief, the above three indicators (i.e., *prosuming skill*, *distribution*, and *production*) jointly provide a more fine-grained understanding of Chen et al.'s (2011) functional prosument literacy.

Participation. Unlike the above three prosument indicators, participation requires more criticality from individuals. We propose this indicator based mainly on Chen et al.'s (2011) framework and Jenkins et al.'s (2006) 'participatory culture'. Specifically, it refers to abilities to participate interactively and critically in new media environments. By interactively, we emphasize the bi-lateral interactions among individuals (or participants). For example, individuals are expected to actively co-construct and refine one another's ideas within certain media platform (e.g. blog, chat room, Skype, Facebook, etc.). It can be also illustrated by Jenkins et al.'s (2006) *collective intelligence*, that is, 'the ability to pool knowledge and compare notes with others towards a common goal' (p. 39). By critically, we focus on individuals' awareness of the socio-cultural values, ideology, and power relation embedded in their media participation. For example, individuals are required to effectively handle with different ideas within a social community and even across communities. Jenkins et al.'s (2006) *performance* and *negotiation* also provide alternative understanding about such criticality. Specifically, performance refers to 'the ability to adopt alternative identities for the purpose of improvisation and discovery' (p. 28); while negotiation 'the ability to travel across diverse communities, discerning and respecting multiple perspectives, and grasping and following alternative sets of norms' (p. 52). The *participation* here also share similar meaning with Thoman and Jolls' (2008) *participate* that requires individuals' constant engagement and interaction for media construction. Compared to all the eight indicators

introduced above, *participation* seems to focus explicitly on social connection that values each individual's contribution. According to Jenkins et al. (2006), active media participation should be underscored in the media education, especially within the Web 2.0 environment popular in the 21st century. We will continue to elaborate this viewpoint in the next section.

Creation. This indicator refers to abilities to create media contents *especially* with a critical understanding of embedded socio-cultural values and ideology issues. Compared to *distribution and production*, *creation* involves much more criticality from individuals. Although both involve criticality, the difference between *creation* and *participation* should be noted. Unlike *participation*, creation usually requires an individual's own initiative rather than bi-lateral interaction among individuals. For example, the first initiation of a thread with criticality would be creation; while the subsequent reflections would be seen as actions of participation. Besides, this indicator can be illustrated as individuals' ability to critically create a blog or webpage, to post original artwork online, or to remix online content into their own creations (Jenkins et al., 2006).

New divide: From Web 1.0 to Web 2.0

Apart from proposing the above ten indicators to understand NML in a more detailed way, our framework also suggests another new divide that distinguish Web 1.0 from Web 2.0. We first discuss the emergence of Web 2.0 and the differences between Web 1.0 and Web 2.0. Then, we explicate why our framework place more emphasis on Web 2.0. These two parts jointly indicate the necessity of the new divide from Web 1.0 to 2.0. Based on this new divide, we explain the categorization of the five prosument indicators (i.e.: *prosuming skill*, *distribution*, *production*, *participation*, and *creation*) from the Web 1.0 as well as Web 2.0 perspective.

The emergence of Web 2.0

At least two major factors have contributed to the emergence of Web 2.0. First, the recent development of technologies has contributed a lot to the emergence of Web 2.0. The term, Web 2.0, was firstly generated by the O'Reilly (2005) to expound the significant change in the nature of web-based services. That is, as Postigo (2011, p. 182) maintained, 'Web 2.0 describes Web-based technologies, such as wikis, blogs, social networking sites (SNS), and RSS feeds, meant to facilitate and coordinate massively produced knowledge and content'. Moreover, Gauntlett (2011) described 'Web 2.0' as a way of expanding existing systems (i.e. the World Wide Web (WWW)) in a new way to bring people together creatively rather than replacing the Web 1.0. Compared to Web 1.0 (WWW technologies), Web 2.0 seems to be more user-friendly and require less technical skills from users. In other words, Web 2.0 has made it easier and more convenient for individuals to *produce* rather than consume media contents only (e.g. Boyd, 2008; Chen et al., 2011; Hardey, 2007). For example, equipped with Web 2.0 technologies, individuals do not need to know HTML if they attempt to design and post professional-looking websites (Postigo, 2011).

Second, Individuals' gradual desire/tendency to share their ideas with others also facilitates the emergence of Web 2.0. As Lim and Nekmat (2008) argued, media consumers today tend to enjoy various avenues by which they can produce and share content (p. 260). With the affordance of new media, media consumers may also enjoy infusing their own values into existing media content to make their voice heard (e.g. Shih, 1998; Turkle, 1995). For example, with Web 2.0 technologies, individuals can freely share and discuss their own viewpoints with others. These practices are generally not well supported by Web 1.0, which focuses more on an individual's sole authorship of media content (e.g. ideas or artifacts).

The emergence of Web 2.0 depends mostly on its relative advantages (compared to Web 1.0) in meeting individuals' needs in the contemporary society (also see O'Reilly, 2005). This in some degree supports the proposed new divide from Web 1.0 to 2.0 in our framework (see Figure 2). To further demonstrate the significance of this new divide, more discussion about our emphasis on Web 2.0 in the framework is presented below.

Rationales of our emphasis on Web 2.0

We put much emphasis on Web 2.0 in our framework based on at least three reasons. First of all, Web 2.0 benefits the establishment and development of Jenkins et al.'s (2006) 'participatory culture'. Specifically, the relatively low barriers to artistic expression and civic engagement are evident within the Web 2.0 environment. More importantly,

Web 2.0 allows individuals to contribute valuable and creative works within certain social communities, or called ‘affinity groups’ (see Gee, 2001). The communities themselves, in turn, provide ‘strong incentives for creative expression and active participation’ (Jenkins et al., 2006, p. 7). Accordingly, more productive exchange and co-construction of ideas are facilitated. According to Chen et al. (2011), such active (or responsible) participation may facilitate more enabled individuals to become more new media literate.

Web 2.0, secondly, is conducive to the development of ‘folksonomy’ (Blau, 2004) as opposed to taxonomy by authoritative figures. According to Postigo (2011), information production in the Web 2.0 environment blurs the distinctions between experts and non-experts. Within the Web 1.0 environment, folk people generally act as consumer of media content produced by experts. In contrast, they are both consumers and producers (or called prosumers) in the mode of Web 2.0. They can even collectively criticize the bias or credibility of the media content from the authoritative institutions. For example, folk people can freely express their own ideas and extend/challenge others’ (including experts’) ideas on the platform of Facebook and Wikipedia. In this sense, both experts and non-experts are authors of the media content.

Then, Web 2.0 allows individuals to embody/interpret one another’s values, identities, and/or ideologies when they prosume media. This shares many similarities with Postigo’s (2011) perceptions about Web 2.0 as a set of social relations and values. More specifically, individuals may play various roles (e.g. fans, contributors, editors, experts, and critics) during their participation in the Web 2.0 communities. The dynamics of the participation may further enable individuals to better recognize/interpret one another’s multiple ‘identities’ (Gee, 2001) or ‘social roles’ (Postigo, 2011). As also noted previously, Web 2.0 empowers individuals to remix media (e.g. infuse their own values/ideologies into the existing media content) and participate in co-constructing ideas (e.g. including extend and criticizing others’ ideas). Generally, individuals are actually embodying their own values/ideologies during these practices, and such embodiment mostly requires their awareness of other values embedded in the existing media content.

It is necessary to point out that there are some debates on the use of Web 2.0. Advocates of Web 2.0 (e.g. Gauntlett, 2011) suggested that media studies needed to be refreshed to respond to a new era of media participation. Unlike Web 1.0 that follows the traditional ‘broadcasting’ model, Web 2.0 can be ‘described as a huge communal garden, with everyone joining in and adding to it’ (Berger & McDougall, 2010, p. 7). However, the prosumption that Web 2.0 brings about connected participation has been challenged by opponents of Web 2.0. Major arguments include (a) not sufficient people are participating in Web 2.0 communities (Buckingham, 2010), and (b) relative less concern is put on the Web 2.0 artifacts (Laughey, 2011). Although Web 2.0 is underlined in our framework (Figure 2), we do not suggest the sole use of Web 2.0 or the abolishment of Web 1.0 in the future. This can be elaborated through the following categorization of the five prosuming indicators (*prosuming skill, distribution, production, participation, and creation*).

Categorization of the five prosuming indicators

As seen in Figure 2, the indicator *prosuming skill* was assigned as Web 1.0 literacy, while both *distribution* and *participation* as Web 2.0 literacy. Besides, two indicators (*production* and *creation*) were proposed to indicate both Web 1.0 and 2.0 literacies. Based on the definition of *prosuming skill* in this paper, this indicator focuses more on individuals’ own media production, which does not involve others’ engagement. In other words, individuals have the *unique* authorship of what they produce. Considering this great match with the ‘broadcasting’ characteristics of Web 1.0, we assigned it to the category of Web 1.0 literacy. As discussed above, both *distribution* and *participation* focus mainly on individuals’ social sharing in ideas and/or artifacts. Others are also allowed to make further contribution/revision to the existing media content. In this sense, every participant owns the authorship of the ideas/artifacts. Individuals may be able to embody/interpret one another’s values, identities, and/or ideologies during these activities. All these can be well supported within the Web 2.0 rather than Web 1.0 environment. Thus, we decided to assign both *distribution* and *participation* into the category of Web 2.0 literacy. According to the aforementioned definitions of *production* and *creation*, both indicators involve not only individuals’ own construction of ideas/artifacts (i.e., more Web 1.0 oriented), but also sometimes their incorporated/shared ideas and/or values (more Web 2.0 oriented). In this light, we suggested that they can reflect both Web 1.0 and 2.0 literacies. These categorizations are also represented by the proposed new divide in our framework (see the right dotted line).

Conclusion

Given the technical and socio-cultural characteristics of new media, individuals nowadays are expected to express satisfactory new media literacy. Grounded on Chen et al.'s two-continua (consuming-prosuming and functional-critical) framework, we have proposed ten fine-grained indicators to represent the concept of NML. Given the limited space issue, we do not elaborate more information here. More significantly, our framework proposed another new divide that distinguishes Web 1.0 from 2.0, with the latter well responding to a new era of media participation. However, a limitation of the current framework needs to be noted. In our framework, *creation* was used as an indicator for NML. However, we acknowledged the important role of creation and creativity in our framework and tried to define creation. During the development of instrument to measure creation, the research team encounters difficulties in self-report survey. Future research may consider alternative means to examine the *creation* dimension of NML if this framework is applied.

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Self-Regulation in e-Learning Environments: A Remedy for Community College?

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ABSTRACT

A mixed-methods study was conducted to examine the effects of self-regulated learning (SRL) strategy training on learners' achievement, motivation and strategy use in a web-enhanced College Success course at a community college in southeast US. It was found that training assisted with students' overall course performance and accomplishment of long-term tasks, enhanced students' self-satisfaction, and persistence. This study empirically tested the effects of a technology-enabled strategy training intervention in a field setting; it contributes to the understanding about SRL and persistence in the community college population; and it is a pioneering trial of conducting learning strategy research using mixed methodologies. Results and implications for future research and instructional design are also discussed.

Keywords

Self-regulated learning, Web-enhanced instruction, Mixed-methods study, Achievement, Motivation

Introduction

With about 42% (7.8 million students) of all undergraduates in the country on their rosters (Knapp, Kelly-Reid, & Ginder, 2012), community colleges are considered essential providers of postsecondary education in the United States. Yet, student retention in community colleges is a concern for many educational researchers and administrators because the problem of high attrition rates has come despite the affordable expense and open-access policies of community colleges. A large number (30 to 50 percent) of students who started their postsecondary education in community colleges never complete it (Horn & Nevill, 2006; Knapp, Kelly-Reid, & Ginder, 2012).

Various interrelated causes for students' early departure from community colleges have been documented. In addition to demographic characteristics such as old age, family responsibilities, working full-time, and part-time enrollment, which inherently make it harder for community college students to succeed in their academic career (Horn & Nevill, 2006; Schmid & Abell, 2003), many of these students are identified with poor educational preparation (Wirt, Choy, Rooney, Provasnik, Sen, & Tobin, 2004), low first-year achievements (Bradburn & Carroll, 2002; Horn & Nevill, 2006), and a lack of learning strategies (Byrd & MacDonald, 2005; Schmid & Abell, 2003).

It was found that remedial or study skills courses could provide under-prepared students with math, reading, and study skills to enhance achievement (Tuckman, 2002; 2003), and to improve retention (Stovall, 2000; Tuckman, 2003). Therefore, researchers (Byrd & MacDonald, 2005; Schmid & Abell, 2003) pointed out the need for interventions that concentrate on the academic needs of students, and proposed the use of remedial education and study skills courses. Numerous remedial or study skills interventions have been developed using the research on academic self-regulation (Shafer, Lahner, Calderone, Davis, & Petrie, 2002; Tuckman, 2003) as a theoretical framework.

This mixed-methods study attempted to investigate the effects of an intervention, which included a web-based tutorial on SRL and online Study Plans and Self-Evaluations, on students' achievement, motivation and self-reported use of strategies in a College Success course. This was another endeavor, hoping to facilitate student retention through the teaching of SRL strategies.

Self-regulated learning

Over the last decade, learners' self-regulation of their cognition, motivation, and behaviors to promote academic achievement has received increasing attention in the field of education. Driscoll (2005) refers to self-regulation as skills that learners use for goal setting and managing their own learning and performance.

Pintrich (1995) emphasizes the regulation of three general aspects of learning in his interpretation of SRL. First, learners self-regulate their behavior including the control of various resources, such as time, study environment, and students' use of peers and faculty members for help (Garcia and Pintrich, 1994); second, learners self-regulate motivation and affect through controlling and modifying motivational beliefs such as efficacy and goal orientation to adapt to the demands of a course; third, learners self-regulate their use of various cognitive strategies to achieve learning outcomes.

Furthermore, SRL is particularly appropriate to the college context. Traditional academic environment rarely encourages the use or development of self-regulatory skills (Orange, 1999). It may be hard for busy college students, especially those with jobs and family responsibilities, to find time to learn to use self-regulation strategies. This is why it is suggested (Orange, 1999; Pintrich, 1995) that self-regulation strategies should be taught at all levels of education.

Recently, Wolters (2010) identified the connection between SRL and the 21st Century Competencies (CC) (Partnership for 21st Century Skills, 2011) in that self-direction and individual adaptability are key aspects of the 21 CC framework, which have the closest fit to concepts within the SRL context.

Importance of the study

Decades ago, McKeachie, Pintrich, & Lin (1985) conducted a study to evaluate a semester-long introductory cognitive psychology course that taught both concepts of cognitive psychology and their application to learning strategies with intact groups of students. Their study found that the learning strategies course was substantially successful in affecting students' self-reported study habits and modestly successful in affecting students' achievement in the two semesters following the study.

Normally, providing comprehensive training on SRL strategies to students in various traditional classroom settings led to improved task performance (Hofer & Yu, 2003; Weinstein, Husman, & Dierking, 2000) and metacognitive understandings (Ching, 2002), more positive motivation (Ching, 2002; Weinstein et al., 2000), more strategy use (Hofer & Yu, 2003), and even a better retention rate (Weinstein et al., 2000).

New learning environments, such as web-based or -enhanced instruction, require more proactive learning to construct knowledge and acquire skills. As Schunk & Zimmerman (1998) mentioned that "an area that lends itself well to self-regulation is distance learning, where instruction originates at one site and is transmitted to students at distant sites... Self-regulation seems critical due to the high degree of student independence deriving from the instructor's physical absence" (p. 231-232).

Bandura's (2000) social cognitive theory has been successfully used with Internet-delivered interactive guidance for self-management of health issues, such as weight-control (Taylor, Winzelberg, and Celio, 2001) and Dietary changes (Clark, Ghadour, Miller, Taylor, Bandura, & Debusk, 1997).

Azevedo and Cromley (2004) conducted a study to provide students with a 30-minutes training on SRL in order to facilitate their learning about the circulatory system with hypermedia. They found that SRL training did foster more sophisticated conceptual understanding and use of learning strategies.

According to the 2009 Faculty Survey of Student Engagement, 72 percent of faculty used course management systems (The Chronicle of Higher Education, 2010). More universities or colleges are using web-enhanced instruction, and instructors are spending less time on face-to-face contact if they used emails to communicate with students or websites to post course-related information (Warburton, Chen, & Bradburn, 2002).

Self-regulation has been identified as one of the major determinants to completion in community college education; however, fewer studies have empirically examined the role of SRL strategy training in community college student success. Considering the large percent of college faculty using web-based or -enhanced instruction (Warburton, et al., 2002), the relationship between academic self-regulation and educational outcomes in the e-Learning environments, especially at community colleges, has not been extensively examined for the benefit of learners as well as sponsors for college education.

Method

The purpose of this study was to examine, in a community college web-enhanced College Success course, whether a web-based SRL strategy training will positively influence: (1) achievement measured with individual assignment scores and final grade for the course, (2) learner motivation in terms of task value, self-efficacy, goal orientation and self-satisfaction, and (3) learners' self-reported use of strategies. This study was conducted in a fall semester.

Participants

The participants in this study were 21 (8 treatment vs. 13 control) undergraduate students enrolled in 2 sections of the course. The participants were freshmen ($N=18$) and sophomores ($N=3$), whose ages ranged from 17 to 24 ($M=18.9$). Fifteen (71%) of the participants were female and 6 (29%) were male. They were made up of 7 (33%) African-Americans, 13 (62%) Caucasians, and 1 (5%) Hispanic. Five (62.5%) participants in the treatment and seven (53.8%) in the control condition were required to take this College Success course because of deficiency on College Placement Test. Only students who completed all the intervention procedures constituted the participants in this study, and comparison between the pre- and post-intervention results were made on exactly the same set of individuals.

Instructional context

The course, College Success, was designed to develop and reinforce skills necessary for college and career success. It covers topics such as interpersonal relationships, employability skills, financial management, choosing a college major and other career planning topics. The course was designated as web-enhanced, which means materials, such as syllabus and course schedule, were posted to the course's Blackboard website and the instructor and students could use the website for instructional purposes.

Intervention materials

The SRL strategy training included two parts: an online tutorial on SRL Strategies and web-based interactive strategy application practices using online questionnaires.

The web-based tutorial focused on what SRL strategies are, more specifically, the definitions of metacognitive, motivational and cognitive strategies, and examples of the strategies and when and how to use them. Participants were required to complete the tutorial at least once. In addition to knowledge about SRL strategies, the tutorial also provided participants with practice on the knowledge in each chapter. Some multiple choice or case-study exercises were used for participants to become familiar with SRL (See Figure 1 for a tutorial screen capture).

After they practiced the knowledge about SRL, the learners were encouraged to apply the strategies to their actual studying of the course through completing a series of interactive online questionnaires.

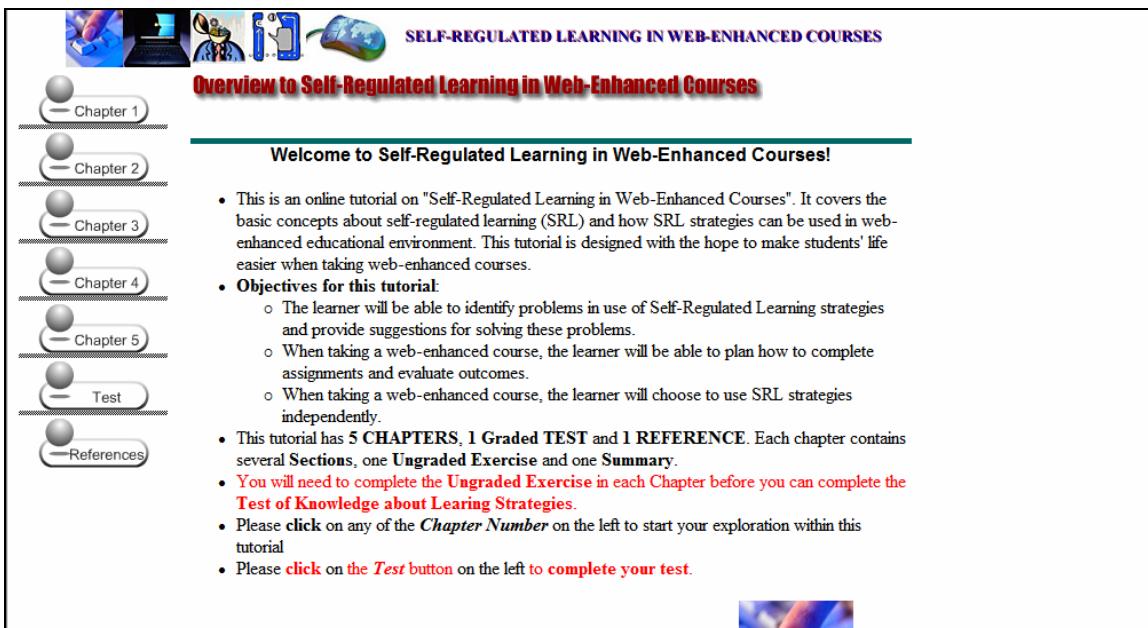


Figure 1. Screen Capture of Web-based Tutorial

Procedure

This study consisted of 4 stages, which lasted for 14 weeks.

In the 2nd week of the semester, an email with the informed consent was sent to students to solicit participation. Interested students began by completing the first set of online questionnaires, within which they provided demographic information, such as year in school, age, gender, GPA, and completed an assessment on their initial motivation indicators and use of SRL strategies. During this stage, the researcher assigned the 2 intact sections of the course to the treatment and control conditions.

One week after the beginning of the 1st stage, students received another email to start their participation in Stage II. Within this stage, treatment participants went through Chapters 1 to 5 of the online SRL tutorial consistent with their instructional content for the course, and they completed all the exercises and a test within the tutorial. Participants in the control condition did not receive any of these treatments. This stage lasted for 4 weeks.

After the 2nd stage, treatment participants received another email to start their participation in Stage III, within which they first completed an online study plan, and then a self-evaluation for a learning period of 4 weeks. Study plan questionnaires appeared at the beginning of each 4-week period for learners to set goals and select strategies for completing tasks. Self-evaluations appeared at the end of each 4-week period for learners to reflect on their progress and effectiveness of strategies. Control participants did not receive any of these treatments. This stage lasted for 8 weeks (2 learning periods).

After Stage III, participants in both conditions received another email with a link to the final questionnaires. In this stage, which lasted for 1 week, learners' motivation indicators and reported use of strategies were measured again. Open-ended questions were also used to collect qualitative data about participants' use of learning strategies.

Data sources and analysis

Data on students' learning achievement were obtained from the course instructor. Data on the other two dependent variables, motivation and reported use of learning strategies, were collected using self-reported on-line questionnaires.

Questionnaires adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich, Smith, Garcia, & McKeachie, 1991) were used to measure the quantitative part of the motivation and strategy use. The original MSLQ included 81 items and was designed to assess motivation and use of learning strategies by college students. The modification of the questionnaire included changing the scale from a 7-point to a 5-point Likert scale, rewriting and eliminating statements for the nature of course and the participants. The Self-Satisfaction Scale (SSS) consisted of 4 researcher-designed items, and was used to measure aspects such as enjoyment from the course and fulfillment of goals. Participants rated on a 5-point Likert-type scale for each item ranging from A (Not at all true of me) to E (Very true of me), with C equaling "Moderately true of me." Cronbach's alpha coefficients for each section of the instruments were 0.93 for Motivation, 0.85 for Self-Satisfaction and 0.91 for SRL Strategies Questionnaire respectively.

During the study, participants were also asked to answer thirteen open-ended questions, which were designed to explore students' motivational beliefs and use of learning strategies qualitatively. These questions were exactly the same at the beginning and end of the study, except for the tense. Present tense was used at the beginning to gather participants' general use of strategies, while past tense was used latterly to ask about students' use of strategies during the study. Some examples for these questions include: "What study strategies do you use that have helped you most in the past? How will your approaches to studying change as the semester progress? Why?"; "How do you know when you understand something really well? What do you do if you don't understand something?"

Participants' responses to these questions were transcribed verbatim and analyzed using the NVIVO 7 software to help explain results from quantitative data. To analyze these data, the researchers followed the guidelines for qualitative content analysis (Chi, 1997), using an inductive constant comparative method (Glaser & Strauss, 1967) because the purpose was to understand the strategies used during a learning process. The researchers read participants' answers to questions and highlighted comment units or references (i.e., word(s), phrase(s) or sentence(s)) that described a type of learning strategy (open-coding) to capture main ideas, themes. Then, a search was performed for patterns within the data on each of the participants, and then across all participants (axial coding) to portray relationships. Finally, learning strategies and motivation were summarized with the patterns found across all participants into a list of 18 categories (See Appendix I) based on the theoretical framework of Pintrich's (1995) general expectancy-value model and Bandura's (2000) social cognitive model of self-regulation. To ensure confidentiality of participants, each participant was assigned a number and a series of numbers were used to indicate responses from each subject; for example, R₀₀₁ stands for a response from the first person of the Control condition, R₁₁₂ means a response from the twelfth person of the Treatment condition.

In this study, quantitative data were analyzed using nonparametric statistical procedures (Wilcoxon-Mann-Whitney Test for between-group comparison and Wilcoxon Signed Ranks Test for within group comparison) due to the small sample size (Siegel & Castellan, 1988). A correlation analysis was conducted on all quantitative measures after possible relationships were noticed from qualitative data analysis. Kendall's tau for non-parametric correlation was used because of a small data set (Field, 2005).

Results and discussion

Learning achievement

A significant difference was found between the treatment and control participants on overall achievement ($U = 28.50$, $p < .05$, $r = .47$), and scores on 3 of the 7 course assignments, such as Test 3($U = 27.00$, $p < .05$, $r = .51$), Career exploration paper ($U = 28.50$, $p < .05$, $r = .48$) and Final exam scores ($U = 28.00$, $p < .05$, $r = .48$). These were tasks completed later in the semester and required more time and effort to prepare. Adding the SRL strategy training seems to help with students' accomplishment of long-term tasks, which involves continuing effort. The descriptive statistics for achievement measures are presented in Table 1.

Table 1. Descriptive statistics for achievement

	Treatment group (N=8)			Control group (N=13)		
Achievement measure	<i>M</i>	<i>SD</i>	<i>Mdn</i>	<i>M</i>	<i>SD</i>	<i>Mdn</i>
Overall Course	93.88	4.55	95.50	88.77	9.04	92.00

	<u>Treatment group</u> (N=8)			<u>Control group</u> (N=13)	
Test 3	91.13	2.36	92.00	85.92	10.00
Paper	87.63	7.74	88.50	58.38	41.01
Final Exam	89.13	4.79	91.00	83.77	8.74

Experimental students might have been using the training materials (esp. online questionnaires) as reminders to work on and complete long-term tasks. The following excerpts from qualitative data might help explain this.

R₁₀₂:

Q: When, during these past 2 weeks, did you start working on the tasks?

A: The day the study plan began, and I usually work about 2 to 3 hours every day.

R₁₀₁:

Q: How did you motivate yourself to complete these tasks?

A: looked at the future with the met goal.

During the study, all of the treatment participants completed each of their course assignments, while 4 of the control participants did not complete 1 to 2 of the long-term assignments (project and paper). This could be the reason why the control group received significantly lower average scores on these assignments and the final course grade. These findings on learners' achievement are in line with results from studies conducted by other researchers (McKeachie et al., 1985; Shafer et al., 2002; Tuckman, 2002, 2003).

Learner motivation

Self-Satisfaction

A significant difference was found between the treatment and control group on self-satisfaction ($U = 27.50, p < .05, r = .39$). Adding the SRL strategies training appears to raise students' self-satisfaction from taking the course. However, no significant difference was found between the treatment and control students in terms of task value, self-efficacy, intrinsic and extrinsic goal orientation.

The positive correlation ($\tau = .50, p < .01$) between self-satisfaction and final cumulative course scores might be an explanation for this result. Since the treatment learners achieved significantly better on the final cumulative score and 3 of the 7 course assignments, it might be reasonable that they would generally feel more satisfied with their learning outcomes from the course. Qualitative data also seem to support a relationship between self-satisfaction and achievement. Within all 29 references related to self-satisfaction, 20 were made by students who received A's for their course grade, 6 were from students who received B's, and 3 were from students who received C's. The following excerpts might help illustrate this.

Q: What goal(s) were you working toward in this course? ... So far, how have you done with reaching your goals?

R107, A student:

A: To learn the material, just studying, **i've done well, completed all to get an A and use skills for other classes**

R102, A student:

A: Becoming a better college student. **Yes. Very well, I am passing my class. 90%**

Task Value & Goal Orientation

Experimental participants reported significantly lower task value ($z = -2.21, p < .05, r = .55$) and extrinsic goal orientation ($z = -2.21, p < .05, r = .55$) at the end than at the beginning of the study (please see Table 2)

Table 2. Wilcoxon Signed Ranks Test for Motivation (treatment)

Motivation measure	Z	Asymp. Sig. (1-tailed)
Task Value after - Task value before	-2.214	.01
Extrinsic G after - extrinsic G before	-2.207	.01

a Based on negative ranks.

b Based on positive ranks.

c Wilcoxon Signed Ranks Test

The quantitative result of significantly lower task value for the treatment condition was out of expectation. However, this result was supported by qualitative findings because there was an increase in the number of references for task value from the beginning ($n = 0$) to the end of the study ($n = 6$). Yet all the remarks in Phase IV were negative. For example, 5 Treatment and 11 Control participants said the course was too easy and there was no need for them to use other resources and 1 Treatment and 5 Control participants mentioned they did not have to deal with any obstacles. This implies that both groups experienced reduction in task value. It was predicted that the treatment learners would have higher task value at the end of the study because of their engagement in SRL; however, it looked like task value was influenced more by other variables, such as whether the course was challenging enough. This following excerpt might help illustrate this.

R013:

Q: Did you use any other resources besides the textbook and material offered online in studying?

A: No, i **didnt even study for this class.**

The quantitative result of significantly lower extrinsic goal orientation for the treatment condition was consistent with the expectation. There might be an effect of the treatment to help learners reduce their emphasis on performance because the web-based tutorial was designed to advocate the importance of intrinsic and both goal orientations. Yet, this quantitative result is opposite to the qualitative findings, which indicated that there was a slight increase in references for the extrinsic goal ($n = 2$ to $n = 3$) from the beginning to the end. There might be several perspectives to look at this inconsistency between the qualitative and quantitative findings.

First, participants tend to select choices for more socially desirable behaviors when they are completing self-report 5-point Likert-type instruments (Ley & Young, 1998). This might have been one reason for the significantly lower extrinsic goal orientation for the treatment learners at the end of the study. Second, it is harder for participants to be dishonest when they answer open-ended questions, yet they might have become less enthusiastic to provide really meaningful answers as the study progresses. With the end of the semester coming closer and final grades being the usual major measure of achievement in courses, it might be reasonable for students to become more extrinsic- or both- goal oriented when they were under extreme pressure for outcome. These following excerpts might help explain this.

R101 (intrinsic → both goals):

Phase I: learning better testing strategies, and prioritizing,

Phase VI: Study Habits, Making good grades and Learning how to balance my time. Try different things and see which is better for me.

Reported use of strategies

Concerning the effects of the strategy training on students' reported use of strategies, even though the treatment group ($M = 37.13, 67.19, 60.25, 164.56$) did report higher use of metacognitive, cognitive and resource management strategies and the total strategies than the control group ($M = 36.85, 61.46, 59.15, 157.46$), the differences did not reach statistical significance.

A positive correlation was found between self-satisfaction and use of cognitive ($\tau = .65, p < .01$), metacognitive ($\tau = .40, p < .05$), resource management ($\tau = .69, p < .01$) and total strategies ($\tau = .67, p < .01$) after the intervention. The intervention, especially the online Study Plans and Self-Evaluation, was intended to encourage treatment participants to engage more in SRL. Treatment learners' immersion in SRL might have brought about higher self-satisfaction, even though the treatment effect might not be strong enough to make their use of strategies significantly

different from those of the control group. This finding is consistent with the result from Zimmerman & Kitsantas' (1999) study on combining a series of kernel sentences into a single nonredundant sentence. In their study, girls who were involved in self-monitoring during the process of combining sentences reported higher degrees of satisfaction than those who did not.

The treatment students also reported significantly higher ($z = -1.98, p < .05, r = .50$) use of rehearsal strategies at the end ($n = 121$) than at the beginning ($n = 109$) of the study and significantly lower use of resource management strategies ($z = -1.96, p < .05, r = .49$) at the end than at the beginning of the study (please see Table 3).

Table 3. Wilcoxon Signed Ranks Test for learning strategy (treatment)

Strategy measure	Z	Asymp. Sig. (1-tailed)
REH_2 - REH_1	-1.997	.02
Resource Mgt after - Resource Mgt before	-1.960	.03

a Based on negative ranks.

b Based on positive ranks.

c Wilcoxon Signed Ranks Test

The quantitative result about significantly lower use of resource management strategies was opposite to the prediction. In addition, the qualitative data also supported this result with a decrease in the number of references to resource management strategies provided by the treatment participants from Phase I to Phase VI. There is a decrease in number of references for overall resource management ($n = 77$ to $n = 66$) and the subcategories of peer learning ($n = 22$ to $n = 17$) and help seeking ($n = 24$ to $n = 13$).

This discrepancy between the findings and hypothesis might be explained from several angles. First, it was found that there was a significantly positive correlation ($\tau = .57, p < .01$) between task value after the intervention and use of resource management strategies. The following excerpts might also confirm this correlation.

Phase VI

R010:

Q: What study strategies did you use that have helped you most to be successful in the course? How did your approaches to studying in this course change as the semester progressed? Why?

A: As the semester passed by I realized that it wasn't really challenging so my study time decreased a lot

R108:

Q: Did you use any other resources besides the textbook and material offered online in studying? Why/Why not?

A: No (other resources), all I needed to know was given to me in class or in the book.

With learners' experiencing significant decrease in their task value, it might be reasonable that they stopped using or at least reduced the frequency of using some of the strategies. The level of course difficulty might not have provided learners enough opportunity to utilize the strategies that they learned from the training and as a result compromised the treatment effect on reported use of strategies. This finding is in line with results from previous research on the positive relationship between valuing (Miller, Behrens, Greene, & Newman, 1993), interest (McWhaw & Abrami, 2001) and the use of SRL strategies.

A second explanation might be that higher frequency may not necessarily mean effective use of strategies. On the contrary, reducing the use of certain strategies might be an effective adjustment according to task difficulty. It might not have been appropriate to hypothesize that the more a student used a strategy, the more successful he or she would be in SRL. Sometimes intentional decrease in strategies may even indicate improvement in strategy use or metacognitive awareness. This might be the case with the treatment learners in this study.

Persistence

In this study, persistence (Stovall, 2000) was assessed in terms of (a) First-term credit hour completion, (b) First-term GPA, (c) Continuing enrollment until the 2nd term, (d) Second-term credit hour completion, and (e) Second-term GPA. The descriptive statistics for persistence measures are presented in Table 4.

Table 4. Descriptive statistics for persistence

Persistence measure	Treatment group (N = 8)			Control group (N = 13)		
	M	SD	Mdn	M	SD	Mdn
First-term credit hour completion (0-15)	11.50	2.78	12.00	11.00	2.08	12.00
First-term GPA (0-4.0)	3.17	.60	3.39	2.81	.66	2.79
Second- term credit hour enrollment (0-15)	11.25	3.41	12.00	12.08	1.50	12.00
Second-term credit hour completion (0-15)	9.75	4.95	10.50	8.46	5.13	9.00
Second-term GPA (0-4.0)	2.75	.53	3.00	1.77	1.27	2.00

Ranges of students' possible scores in each category are given in parentheses.

The treatment learners ($M = 2.75$) achieved significantly higher than the control learners ($M = 1.77$) on 2nd-term GPA ($z = -1.95, p < .05, r = .43$). It was also found that, during the semester for the study, there was no drop-out from the course among the treatment participants, while one control participant withdrew from the class. Furthermore, during the 2nd term, the drop-out rates increased to 29% and 12.5% for the Control and Treatment conditions respectively. However, the treatment condition still had a much lower incompleteness rate. The treatment might have had some positive effects on keeping the treatment participants on task and staying with the course, and it might also have had a long-term effect on GPA and overall persistence.

Treatment learners' better performance on persistence might also be related with students' achievement and self-satisfaction. Significant positive correlations exist between cumulative course score and four of the measures for persistence, which are 1st-term credit earned ($\tau = .49, p < .01$), 1st-term GPA ($\tau = .36, p < .05$), 2nd-term credit earned ($\tau = .50, p < .01$), and 2nd-term GPA ($\tau = .54, p < .01$). Significant positive correlations are also present between satisfaction and three of the persistence measures, which are 1st-term credit earned ($\tau = .41, p < .05$), 2nd-term credit earned ($\tau = .35, p < .05$), and 2nd-term GPA ($\tau = .36, p < .05$).

With the treatment learners achieving significantly better than the control students, they might more likely to feel satisfied with the learning experience and be more persistent when facing difficulty or in the long run. With the final participants in this study mainly consisting of 18 freshmen, this reasoning is in line with the research about public 2-year institution attrition, which indicated that students' academic achievement during the freshman year was negatively related with attrition rate at postsecondary institutions (Bradburn & Carroll, 2002; Horn & Nevill, 2006).

Limitations

This study's external validity was potentially affected by mortality and history threats, which caused the ending uneven small sample size. This study required participants to be involved with the treatment intensely for 14 weeks due to the time requirement for effective learning strategy training (Pintrich, 1995), and only collected self-reported data online, it was very likely for individuals to drop out of the study due to changes in availability or interest.

Within the treatment condition, 8 students completed and 19 left the study. All these 27 participants completed the pretest to measure motivation and learning strategies. The pre-intervention data showed no significant differences between the dropouts and the completers on demographic information (e.g., age, credit hours attempted, etc.); motivation and 10 of the 11 indicators for use of strategies. Thus, it was assumed that the dropouts and the completers were generally similar. However, this might also suggest that the indicators used to identify similarities may not have picked up every significant factor. Although data were analyzed with the recommended nonparametric statistical procedures, the small sample size was still a threat to external validity. Results may be biased and not reliably apply to other populations.

Implications and conclusion

Abundant studies in the field of e-Learning have been conducted on outcomes of instructional media, learner characteristics, learner perceptions and interaction (Simonson, Smaldino, Albright, & Zvacek, 2000), but fewer have

actually examined facilitation on learning strategies at community colleges. This current study can be valuable to the academic community in several respects.

The findings of this study supported the notion that SRL strategy training could assist learners with achievement and self-satisfaction, and it showed a tendency for training to be superior in facilitating use of learning strategies. The e-Learning intervention used by this study can be easily integrated into any Learning Management System as an online orientation for distance education, similar to what Cerezo and her colleagues (2010) did with integrating the TRAL project into Moodle. This can be especially useful for community colleges because a large portion of 2-year public institutions students need remedial education or academic counseling, especially when taking e-Learning courses and it has become a burden for many such institutions (Dembicki, 2006). The intervention from this study can be further adapted for implementation on Mobile devices to provide ubiquitous guidance on Self-regulatory strategies for learning (Jeng, Wu, Huang, Tan & Yang, 2010). Personalized SRL strategy applications can be “pushed” to learners as reminders through their smart phones or tablets. This can allow us to provide embedded scaffolds in hypermedia environments through creative use of the revolutionary advances in new technologies.

The result of this study might challenge the conventional concept of effective strategy use as it concerns adjustment based on task demand. Learners in this study reduced use of resource management strategies, or did not implement any help-seeking strategies after they found out the course was not as challenging as they expected. These deliberate adjustments in strategies might be signs of improvement in students' strategy use or metacognitive awareness. Many traditional studies considered the more frequent use of strategies the better. Future studies might want to investigate the definition of effective use of learning strategies by observing expert and novice learners and reexamining whether resource management strategies are most susceptible to changes in task difficulty. Future research can also investigate if we can use SRL strategies to help students keep themselves motivated, and eventually get more out of courses they perceive as not especially challenging or relevant.

Furthermore, the findings of this study suggested that the training on SRL strategies might be beneficial to learners' persistence. If future research can revalidate the effects of this e-Learning intervention with a larger sample size, more challenging course content, data-mining for more individualized SRL guidance and more effective control for study dropouts, we might be able to find a decent solution for the low completion rate at 2-year higher education institutions, especially for cultivating more 21st century competent e-Learning completers.

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Appendix

I. Definition of Categories

Strategy/Belief	Description	Example
Goal setting	Determining target results of learning or setting of sub-goals	“My goal for this course was to learn how to manage my time and study more.”
Strategic planning	Selection of learning strategies or methods to achieve the desired goals	“My goals were to do better on my quizzes .the plan was to study hard.”
Self-monitoring	Monitoring of attention, comprehension and learning outcomes.	“I asked myself questions while reading.”
Self-evaluation	Comparing feedback information from self-monitoring with certain kind of standard or goal to self-judge if they are making progress.	“i dont think i came to any (obstacles) in this course.”
Task value	Perceptions of a particular course in terms of interest, importance and utility	“i would just read and recite. Nothing (no strategy) changed because there was no need for it to.”
Self-efficacy	Personal beliefs about their capabilities to learn or perform skills for completing the course.	“this class was so easy, i cant think of anything i would have had trouble with”
Mastery/Intrinsic goal orientation	Participating in a task for reasons such as challenge, curiosity, mastery and concentration on learning, comprehending the material and self-improvement.	“in this course i was looking forward to gaining skills that will help me be a better college student”
Performance/Extrinsic goal orientation	Participating in a task for reasons such as performance, evaluation by others, and competition and focuses on grades, approval from others, rewards, or winning.	“I wanted to get an A.”
Both goal orientation	The situation when students have a tendency to focus on both mastery/intrinsic and performance/extrinsic goals	“...to get an A and use skills for other classes”
Self-satisfaction	Feelings about the fulfillment of their learning goals and enjoyment from taking the course.	“I've done pretty well.”
Rehearsal	Selecting and encoding information in a verbatim manner	“read the chapters over and over till I remember them”
Organization	Constructing internal connections among information given in the learning material	“I would read my book and then outline what was important. Then I would go back through the chapter that I read and make an outline of what I underlined.”
Elaboration	Making information meaningful and building connections between information given in the learning material and a learner's prior knowledge	“I made up acronyms for things and little rhythmic notations to help me”
Time management	Scheduling, planning, and managing one's study time.	“All of my classes start around noon, so i would usually utilize my time between 10 am and 12 pm to do all my school work.”
Study environment management	Making study environment organized, quiet, and relatively free of visual and auditory distractions	“I would go to school and study in the library”
Effort Regulation	Controlling effort and attention when facing distractions and uninteresting tasks.	“Really try to ignore them (distractions)”
Peer learning	Collaborating with peers, and using dialogue with peers to help clarify course	“Study Groups and individual study. Because I have made new friends and we

Strategy/Belief	Description	Example
	material and reach insights that may not have been attained when he or she studies alone	can have study groups when major tests are coming up.”
Help-seeking	Securing assistance from others or tools to cope with academic difficulty	“If I didnt understand something I just asked my teacher.”

Development of an Adaptive Learning System with Multiple Perspectives based on Students' Learning Styles and Cognitive Styles

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ABSTRACT

In this study, an adaptive learning system is developed by taking multiple dimensions of personalized features into account. A personalized presentation module is proposed for developing adaptive learning systems based on the field dependent/independent cognitive style model and the eight dimensions of Felder-Silverman's learning style. An experiment has been conducted to evaluate the performance of the proposed approach in a computer science course. Fifty-four participants were randomly assigned to an experimental group which learned with an adaptive learning system developed based on the personalized presentation module, and a control group which learned with the conventional learning system without personalized presentation. The experimental results showed that the experimental group students revealed significantly better learning achievements than the control group students, implying that the proposed approach is able to assist the students in improving their learning performance.

Keywords

Adaptive learning, Personalization, Learning style, Cognitive style

Introduction

The rapid advancement of computer and network technologies has attracted researchers to develop tools and strategies for conducting computer-assisted learning activities (Hwang, Wu, & Chen, 2012; Tsai, 2004). With these new technologies, learning content becomes rich and diverse owing to the use of hypermedia and multimedia presentations. Researchers have indicated that hypermedia systems are suitable for providing personalized learning supports or guidance by identifying the personal characteristics of students and adapting the presentation styles or learning paths accordingly (Tseng, Chu, Hwang, & Tsai, 2008). In the past decade, various personalization techniques have been proposed for developing adaptive hypermedia learning systems, and have demonstrated the benefit of such an approach (Mampadi, Chen, Ghinea, & Chen, 2011; Nielsen, Heffernan, Lin, & Yu, 2010; Wells & McCrory, 2011). For example, Papanikolaou, Grigoriadou, Magoulas and Kornilakis (2002) developed an adaptive learning system by taking students' knowledge levels as the main factor for adapting the learning content; moreover, Tseng, Su, Hwang, Hwang, Tsai and Tsai (2008) developed an adaptive learning system based on an object-oriented framework that composes personalized learning content by considering individuals' knowledge level and the difficulty level of the learning objects.

Although the knowledge level of the students and the difficulty level of the learning content are good factors for adapting presentation layouts and selecting appropriate learning content for individuals, researchers have indicated the importance of taking personal preferences and learning habits into account (Hsu, Hwang, & Chang, 2010; Tseng, Chu, Hwang, & Tsai, 2008). Among those personal characteristics, learning styles which represent the way individuals perceive and process information have been recognized as being an important factor related to the presentation of learning materials (Papanikolaou, Grigoriadou, Magoulas, & Kornilakis, 2002). On the other hand, cognitive styles have been recognized as being an essential characteristic of individuals' cognitive process. In the past decade, researchers have tried to develop adaptive learning systems based on either learning styles or cognitive styles; nevertheless, seldom have both of them been taken into consideration, not to mention the other personalized factors (Hsieh, Jang, Hwang, & Chen, 2011; Hwang, Tsai, Tsai, & Tseng, 2008; Mampadi, Chen, Ghinea, & Chen, 2011).

Researchers have indicated the importance of taking multiple personalization factors into account in order to deliver effective learning systems to individual students (Lee, Cheng, Rai, & Depickere, 2005; Hwang, Yin, Wang, Tseng, & Hwang, 2008). To cope with this problem, in this study, an adaptive learning system is developed by taking students' preferences and characteristics, including learning styles and cognitive styles, into consideration. Moreover, an experiment has been conducted to show the effectiveness of the proposed approach.

Literature review

Learning styles and cognitive styles

Learning styles have been recognized as being an important factor for better understanding the model of learning and the learning dispositions/preferences of students (Filippidis & Tsoukalas, 2009). Keefe (1987) defined an individual's learning style as a consistent way of functioning that reflects the underlying causes of learning behaviors. Keefe (1991) pointed out that learning style is a student characteristic indicating how a student learns and likes to learn. He also stated that learning style could be an instructional strategy informing the cognition, context and content of learning. Reiff (1992) indicated that learning styles are likely to influence how students learn, how instructors teach, and how they interact. Coffield, Moseley, Hall and Ecclestone (2004) further suggested that teachers and course designers pay attention to students' learning styles and design teaching and learning interventions accordingly.

There have been several learning style theories proposed by researchers, such as those proposed by Honey and Mumford (1992), Keefe (1979), Kolb (1984) and Felder and Silverman (1988). Several previous studies have demonstrated the use of learning styles as one of the parameters for providing personalized learning guidance or contents (Graf, Lin, & Kinshuk, 2007; Papanikolaou, Mabbott, Bull, & Grigoriadou, 2006; Tseng, Chu, Hwang, & Tsai, 2008). Among various learning styles, the Felder–Silverman Learning Style Model (FSLSM) developed by Felder and Solomon (1997) have been recognized by many researchers as being a highly suitable model for developing adaptive learning systems (Huang, Lin, & Huang, 2012; Akbulut & Cardk, 2012). Carver, Howard and Lane (1999) indicated that FSLSM could be the most appropriate measurement for developing hypermedia courseware by taking into personal factors into account. Kuljis and Lui (2005) further compared several learning style models, and suggested that FSLSM is the most appropriate model with respect to the application in e-learning systems. Consequently, this study adopted FSLSM as one of the factors for developing the adaptive learning system. On the other hand, cognitive style has been recognized as being a significant factor influencing students' information seeking and processing (Frias-Martinez, Chen, & Liu, 2008). It has also been identified as an important factor impacting the effectiveness of user interfaces and the navigation strategies of learning systems (Mampadi, Chen, Ghinea, & Chen, 2011). Several studies have shown the effectiveness of considering cognitive styles in designing user interfaces for information seeking (Frias-Martinez, Chen, & Liu, 2008) and developing adaptive learning systems for providing personalized learning guidance (Evans, & Waring, 2011; Lo, Chan, & Yeh, 2012). Among various proposed cognitive styles, the field dependent (FD) and field independent (FI) styles proposed by Witkin, Moore, Goodenough and Cox (1977) are the most frequently adopted. Several studies have reported the usefulness of FI/FD cognitive styles in determining the suitability of learning supports or learning system designs (Gerjets, Scheiter, Opfermann, Hesse, & Eysink, 2009; Lin, Hwang, & Kuo, 2009). For example, Weller, Repman and Rooze (1995) indicated that FI/FD cognitive style is very suitable for personalized learning design since it reveals how well a learner is able to restructure information based on the use of salient cues and field arrangement. Ford and Chen (2000) further indicated that the FD/FI cognitive style is highly related to hypermedia navigation and is very suitable for evaluating the usability of websites to students. Therefore, in this study, FI/FD cognitive style is adopted as another factor for developing the adaptive learning system.

Scholars have proposed different aspects to address the relationships between learning styles and cognitive styles. For example, some scholars have indicated that learning styles are applied cognitive styles (Keefe, 1979; Jonassen & Grabowski, 1993; Papanikolaou, Mabbott, Bull, & Grigoriadou, 2006); some have further concluded that learning styles could be viewed as a subset of cognitive styles, and could be classified as activity-centered cognitive styles (Huang, Lin, & Huang, 2011). However, the common definition of cognitive style refers to the individual differences in preferred ways of organizing and processing information and experience (Chen & Macredie, 2002; Triantafillou, Pomportsis, & Demetriadis, 2003), while learning style is defined as a consistent way of functioning that reflects the underlying causes of learning behaviors (Keefe, 1987). Moreover, cognitive styles deal with a cognitive activity (i.e.,

thinking, perceiving, remembering), while learning styles are indicators of how learners perceive, interact with and respond to learning environments, including cognitive, affective and psychological behaviors (Triantafillou, Pomportsis, & Demetriadis, 2003).

To deal with the relationship between cognitive and learning styles, researchers have indicated that cognitive styles could be classified as cognition centered, personality centered, or activity centered; moreover, learning style can be perceived as the activity-centered cognitive style (Sternberg & Grigorenko, 1997). From this aspect, learning styles are viewed as a subset of cognitive styles (Riding & Rayner, 1998; Sternberg & Grigorenko, 1997). Accordingly, this study employs cognitive styles in dealing with the adaption of the learning environment, such as the navigation modes, whereas learning styles are used to deal with the presentation modes of multi-source materials that are composed of figures, videos and texts.

Accordingly, in this study, learning styles are used to provide personalized learning materials and presentation layouts (Liegle & Janicki, 2006), while cognitive styles are used to develop personalized user interfaces and navigation strategies (Chen, Fan, & Maredie, 2004; Chen & Macredie, 2002; Gerjets, Scheiter, Opfermann, Hesse, & Eysink, 2009).

Cognitive load and multimedia learning

To understand, accommodate and align the interaction between learners' cognitive system and the given learning environment, the cognitive load theory (CLT) has become an acknowledged and broadly applied theory for instruction and learning (Van Merriënboer & Sweller, 2005; Schnottz & Kürschner, 2007). Cognitive load theory is a framework of instructional design principles based on the characteristics and relations between the structures that constitute human cognitive architecture, particularly working memory and long-term memory (Wong, Leahy, Marcus, & Sweller, 2012). For a multimedia instructional design, CLT responses the limited working memory for holding visual (such as figures) and verbal (such as text) information as well as the number of operations it can perform on the information (Van Gerven & Pascal, 2003).

Cognitive load is defined as a multidimensional construct representing the load that a particular task imposes on the performer (Paas & van Merriënboer, 1994). It can be assessed by measuring mental load, mental effort (Sweller, van Merriënboer, & Paas 1998; Paas, Tuovinen, Tabbers, & Gerven, 2003). Mental effort is related to the strategies used in the learning activities, whereas mental load refers to the interactions between the learning tasks, subject characteristics and subject materials, which are highly related to the complexity of the learning content that the students need to face (Hwang & Chang, 2011). To respond to the reality that most digital learning materials are developed with multimedia, Mayer (2001) proposed a cognitive theory of multimedia learning (CLML), which assumes that human process pictorial and verbal materials via different sense channels (i.e., sight and hearing). Consequently, cognitive overloading could occur when learners receive redundant information, poorly structured information, or large amount of information in a sense channel.

On the other hand, Paas, Tuovinen, Merriënboer and Darabi (2005) addressed that learners' motivation had a significant relation with cognitive load, especially on mental effort. They suggested that motivation could be identified as a dimension that determines learning success, especially in complex e-learning environments (Paas, Tuovinen, Merriënboer and Darabi, 2005). The relationship between cognitive load and motivation is also stated by Moos (2009).

Adaptive learning systems

An adaptive learning system aims to provide a personalized learning resource for students, especially learning content and user-preferred interfaces for processing their learning (Aroyo et al., 2006). Brusilovsky (2001) has indicated that two adaptation approaches can be used in developing web-based adaptive learning systems, that is, "adaptive presentation" which presents personalized content for individual students, and "adaptive navigation support" which guides individuals to find the learning content by suggesting personalized learning paths. Other researchers have further indicated the importance of providing personalized user interfaces to meet the learning habits of students (Mampadi, Chen, Ghinea, & Chen, 2011).

In the past decade, various adaptive learning systems have been developed based on different parameters that represent the characteristics or preferences of students as well as the attributes of learning content (Wang & Wu, 2011). For example, Karampiperis and Sampson (2005) proposed an adaptive resource selection scheme by generating all of the candidate learning paths that matched the learning objectives and then selecting the most fitting one based on the suitability of the learning resources for individual students. Hwang, Kuo, Yin and Chuang (2010) further developed an adaptive learning system to guide individuals to learn in a real-world environment by generating the personalized learning paths based on the learning status of each student and the relationships between the authentic learning targets. It can be seen that the provision of personalization or adaptation modules, including personalized learning materials, navigation paths or user interfaces, has been recognized as an important issue for developing effective learning systems (Chiou, Tseng, Hwang, & Heller, 2010; van Seters, Ossevoort, Tramper, & Goedhart, 2012).

Several studies have been conducted to develop adaptive learning systems based on learning styles or cognitive styles. For example, Tseng, Chu, Hwang and Tsai (2008) proposed an adaptive learning system for elementary school mathematics courses by considering students' learning styles and the difficulty of the learning content. Mampadi, Chen, Ghinea and Chen (2011) developed a web-based learning environment by providing different user interfaces based on students' cognitive styles. Furthermore, Hsieh, Jang, Hwang and Chen (2011) developed an adaptive mobile learning system that guided individual students to learn in a butterfly ecology garden based on students' learning styles. However, few studies have considered multiple learning criteria, including learning styles, cognitive styles, and knowledge levels, for developing adaptive learning systems.

Research questions

In this study, an adaptive learning system is developed based by taking both cognitive styles and learning styles into account. It is expected that the proposed approach can benefit students in improving their learning achievement, reducing their cognitive load and promoting their learning motivation. Accordingly, the following research questions are investigated:

1. Does the adaptive learning system developed based on both cognitive styles and learning styles benefit students more than the conventional learning style-based system in terms of learning achievements?
2. Can the learning system developed based on both cognitive styles and learning styles decrease students' cognitive load in comparisons with the conventional learning style-based system?
3. Does the learning system developed based on both cognitive styles and learning styles benefit students more than conventional learning style-based system in terms of learning motivations?

Adaptive learning system with multi-dimensional personalization criteria

In this section, an adaptive learning system, AMDPC (Adaptation with Multi-Dimensional Personalization Criteria) is presented. AMDPC consists of four modules: the Learning content-Generating Module (LCGM), the Adaptive Presentation Module (APM), the Adaptive Content Module (ACM) and the Learning Module (LM).

Learning content-generating module

Figure 1 presents the concept of the learning content-generating module, which is used to extract contents from raw materials and generate chunks of information for composing personalized learning materials based on the presentation layout. Each subject unit contains a set of components, such as the ID of the unit, texts, photos, etc. The components of a subject unit are classified into the following six categories:

- *Concept unit*: containing the title, concept ID, abstract and representative icon of the course unit.
- *Text components*: the text content of the course unit.
- *Example component*: the illustrative examples related to the course content.
- *Figure component*: the pictures, photos and figures related to the course unit.
- *Fundamental component*: Fundamental components contain the primary contents of a course, including the title of each learning unit or concept, and the corresponding texts, figures, examples and exercises.

- Supplementary component: Supplementary components contain supplementary materials that are helpful to students in extending the learning scope or realizing the concepts to be learned.

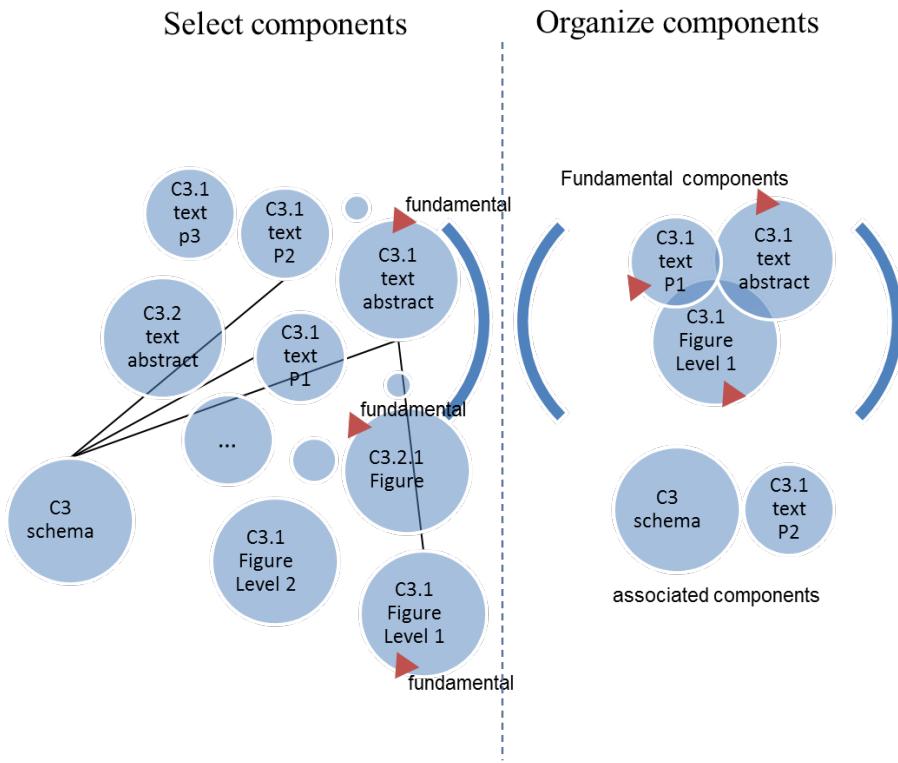


Figure 1. The learning content-generating module

After selecting the appropriate components (learning materials), LCGM organizes the selected components based on individual students' learning styles and cognitive styles. The organized learning content is then presented to individual students based on the presentation layout framework. Figure 2 shows this framework, which consists of the following areas:

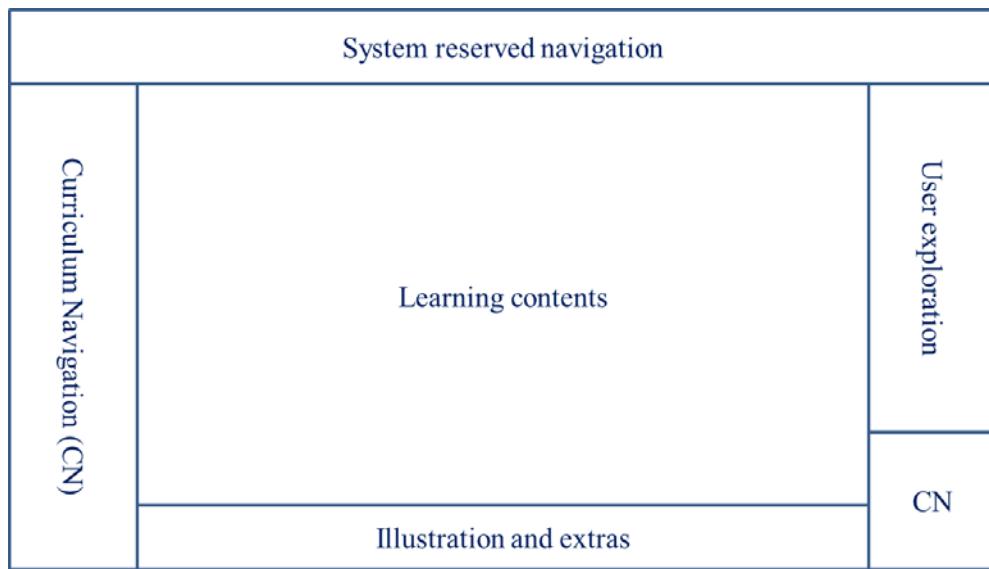


Figure 2. The presentation layout framework of AMDPC

- The system reservation area. This area is reserved for the learning system to display the status or announcements about courses, students or the system.
- The curriculum navigation area. This area contains the information about the relationships between the course units, the outline of individual courses, and the suggested learning sequence of the course units.
- The learning content area. This area is located in the center of the screen for presenting the learning materials organized by LCGM.
- The supplementary material area. This area is used to present supplementary learning materials to individual students based on their personalized learning needs.
- The user exploration area. In this area, three icons linked to three different versions of learning content are presented to enable flexible student control during the learning process.
- The guided navigation area. This area is allocated at the bottom-right corner of the screen. It is used to provide style-matching learning guidance or navigation functions for students with different learning styles or cognitive styles. For example, for the FD students, "next stage" and "previous stage" buttons are provided to guide the students to learn the course materials in an appropriate sequence.

Adaptive presentation module

The adaptive presentation module consists of two parts: The layout strategy based on student cognitive styles and the instructional strategy based on their learning styles.

The layout strategy focuses on adjusting the presentation layout for individual students based on their cognitive styles. In order to measure students' cognitive styles, the Group Embedded Figures Test (GEFT), proposed by Witkin (1971), was employed in this study. According to the score gauge of the GEFT, students are determined as having an FI style if their test score is in the top 50% (in this study, 16); otherwise, if the test score is less than 16, students are categorized as having an FD style of learning. The FD students prefer structured information, promotion and authority navigation; on the other hand, the FI students like to organize information by themselves. From the perspective of the course lesson navigation, the user interface for the FD students is designed to show less information at the same time to avoid distracting them, which is called "Simpler interface" in this study; on the contrary, the interface for the FI students presents more information to help them make a comprehensive survey of the learning content, which is called "more complex interface," as shown in Table 1.

Table 1. User interface design principle for FI/FD students.

Field-Dependent (FD)	Field-Independent (FI)
Simpler interface	More complex interface
Less information presented at the same time	More information presented at the same time
Providing only frequently used functions and links to the information related to the current learning content	Providing links to show the full functions of the system and the schema of the entire learning content

Adaptive content module

The ACM is related to content adjustment for students of different learning styles. The Index of Learning Style questionnaire (ILS), proposed by Felder and Solomon (1997), was embedded in the learning system for measuring the learning styles of the students. There are four dimensions of learning style (LS) in the Felder-Silverman learning style model:

1. Active/Reflective dimension. *Active students* are active, motivated, prefer trial-and-error, and enjoy discussion rather than learning independently. We use the term "learning by doing" to describe how active students learn. *Reflective students* perceive a sense of pleasure when learning by themselves by thinking deeply. The term "learning by thinking" could describe Reflective students.
2. Sensing/Intuitive dimension. *Sensing students* like to learn from facts and dislike surprises; moreover, they are good at memorizing facts and like to solve problems by well-established methods. They are patient with details, good at doing hands-on (laboratory) work. They tend to be practical and careful. They do not like courses that have no apparent connection to the real world. On the contrary, *Intuitive students* like innovative things and

dislike doing the same thing repetitively. They prefer discovering possibilities and relationships and tend to be better at grasping new concepts.

3. Visual/Verbal dimension. *Visual students* remember best what they see, as in pictures, diagrams, flow charts, time lines, films, and demonstrations. *Verbal students* prefer text description and get more out of written and spoken explanations.
4. Sequential/Global dimension. *Sequential students* tend to gain understanding in linear steps, with each step following logically from the previous one, and tend to follow logical stepwise paths when finding solutions. *Global students* tend to solve problems quickly once they have grasped the big picture, and tend to learn in large jumps without seeing connections.

The rating of each dimension ranges from -11 to +11. Based on individual students' ratings in each dimension, the learning system adapts the instructional strategy to meet their needs. The instructional strategies of the proposed system are given in Table 3. The content adjusting principle was designed based on the characteristics of each Felder-Silverman learning style dimension; for example, visual-style learners tend to learn better from visualized materials, such as pictures, diagrams and films, while text-style learners prefer text materials (Felder & Silverman, 1988).

Table 3. Content adjusting principles of ACM

Learning Style	Content adjusting principles	Component selecting rules
Active	<p>Provide examples to further explain the learning content.</p> <p>Provide illustrative examples to link the knowledge to real life or to show the process of solving problems.</p>	Text: fundamental Figure: fundamental Example: fundamental+supplementary
Reflective	<p>Remind students to review what they have learned.</p> <p>Encourage students to think of possible questions or applications.</p> <p>Encourage students to write short summaries or notes based on what they have learned in their own words.</p>	Text: fundamental Figure: fundamental Example: fundamental
Sensing	Provide specific examples of concepts and procedures, and find out how the concepts can be applied to practical applications.	Text: fundamental Figure: fundamental+supplementary Example: fundamental+supplementary
Intuitive	<p>Provide interpretations or theories related to the course content.</p> <p>Remind the students by providing illustrative examples to address some easy-to-confuse concepts.</p>	Text: fundamental+supplementary Figure: fundamental Example: fundamental+supplementary
Visual	Provide the students with more visual materials, such as diagrams, sketches, schematics, photographs, or flow charts.	Text: fundamental Figure: fundamental+supplementary Example: fundamental+supplementary
Text	Provide students with more text materials.	Text: fundamental+supplementary Figure: fundamental Example: fundamental
Sequential	Present the learning materials in a logical order.	Text: fundamental+supplementary Figure: fundamental Example: fundamental Scope: a concept or learning step
Global	Enable students to browse through the entire chapter to get an overview before learning.	Text: fundamental with an abstract Figure: fundamental+supplementary Example: fundamental+supplementary Scope: a chapter

Learning module

The LM provides students with the learning content and user interface generated based on their cognitive styles and learning styles. Figure 3 shows a learning module for an FI student with [ACT/REF: -4], [SEN/INF: 2], [VIS/VRB: -9] and [SEQ/GLO: 4]), while Figure 4 is a learning module for another FI student with [ACT/REF: -8], [SEN/INF: 6], [VIS/VRB: -11] and [SEQ/GLO: 8].

Original scale		
ACT	x	REF
11 9 7 5 3 1 1 3 5 7 9 11 <-- -->		
SEN	x	INF
11 9 7 5 3 1 1 3 5 7 9 11 <-- -->		
VIS	x	VRB
11 9 7 5 3 1 1 3 5 7 9 11 <-- -->		
SEQ	x	GLO
11 9 7 5 3 1 1 3 5 7 9 11 <-- -->		

Figure 3. Illustrative example of a learning module (1)

Intensify scale		
ACT	x	REF
11 9 7 5 3 1 1 3 5 7 9 11 <-- -->		
SEN	x	INF
11 9 7 5 3 1 1 3 5 7 9 11 <-- -->		
VIS	x	VRB
11 9 7 5 3 1 1 3 5 7 9 11 <-- -->		
SEQ	x	GLO
11 9 7 5 3 1 1 3 5 7 9 11 <-- -->		

Figure 4. Illustrative example of a learning module (2)

Figure 5 shows another illustrative example to show the similarities and differences between the learning modules generated for FD students with verbal and visual learning styles. It can be seen that the learning content has been adjusted to meet the students' learning styles. Moreover, the user interface in Figure 5 (for FD students) is much simpler than that in Figures 3 and 4 (for FI students), showing part of the adjustments made for the students with different cognitive styles. The user interface for FI students (Figure 3) included the course schema in the left panel and a navigation button on the top of the screen, while that for the FD students only had the title of current course unit. From literature, most FD students were likely to be affected by contexts. Although the difference between Figure 3 and Figure 5 was not significant, the impact of additional cognitive load could be avoided for FD students via considering those interface details in designing each part of the learning system.

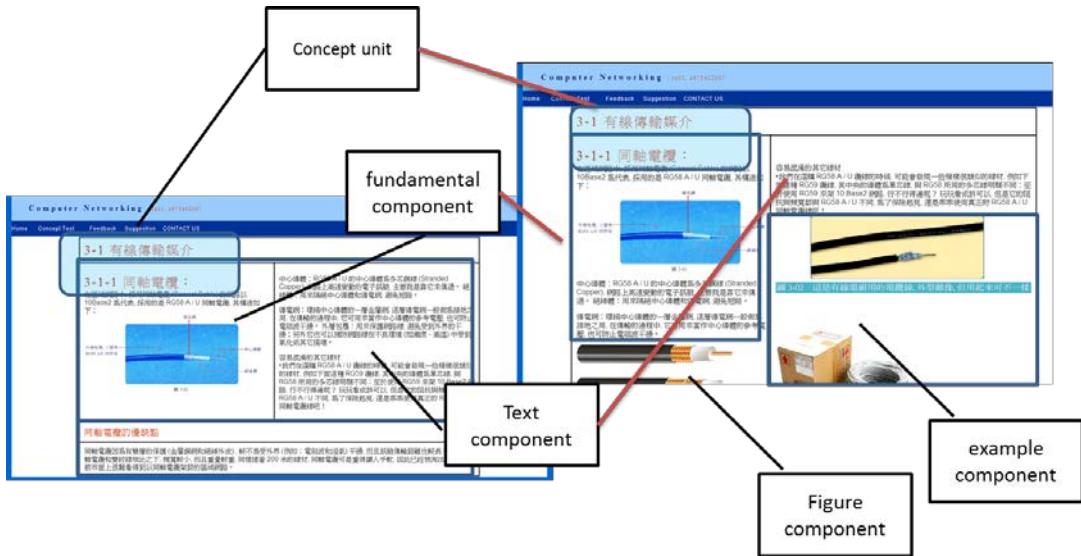


Figure 5. Learning modules for FD students with verbal and visual learning styles

Experiment and evaluation

To evaluate the performance of the proposed approach, an experiment was conducted on the learning activity of the "Computer Networks" course of a college in central Taiwan. In the following, the details of the experiment are stated.

Participants

The participants were fifty-four students, including thirty-two undergraduate students and twenty-two graduate students from a computer science department. The participants were randomly divided into a control group ($n = 27$) and an experimental group ($n = 27$).

Learning activity design

Figure 6 shows the procedure of the experiment. In the first stage (two weeks), the students were instructed in the basic knowledge of computer networks. After receiving this fundamental knowledge, the students were asked to take a pre-test, which aimed to evaluate their basic knowledge before participating in the learning activity.

In the second stage, the students in the experimental group were arranged to learn with the AMDPC system; that is, they were provided with an adaptive interface and learning content by taking both their cognitive styles and learning styles into account. On the other hand, the students in the control group learned with a conventional adaptive e-learning approach; that is, they were provided with only adaptive learning content which took their learning styles into account, as most relevant studies (e.g., Filippidis & Tsoukalas (2009), Hwang, Sung, Hung and Huang (2012), and Tseng, Chu, Hwang and Tsai (2008)) have done. This stage took 120 minutes. After conducting the learning activity, the students took a post-test and answered a post-questionnaire.

Instruments

To evaluate the effectiveness of the proposed approach, a pre-test, a post-test, and the measures of cognitive load and learning motivation were employed in the experiment.

The pre-test aimed to confirm that the two groups of students had the equivalent basic knowledge required for taking this particular subject unit. It was composed of 15 true-or-false items and 15 multiple-choice items with a full score of 100. The post-test consisted of 10 true-or-false items and 23 multiple-choice items with a full score of 100. It focused on evaluating the students' knowledge about network ontology, device and know-how based on the given scenario. Both the pre-test and post-test were designed by the teacher who taught the Computer Networking course to the two groups of students. Moreover, the test items were mainly in the knowledge and understanding levels of the taxonomy of Bloom's educational objectives (1956). The tests were evaluated by two science educators for expert validity.

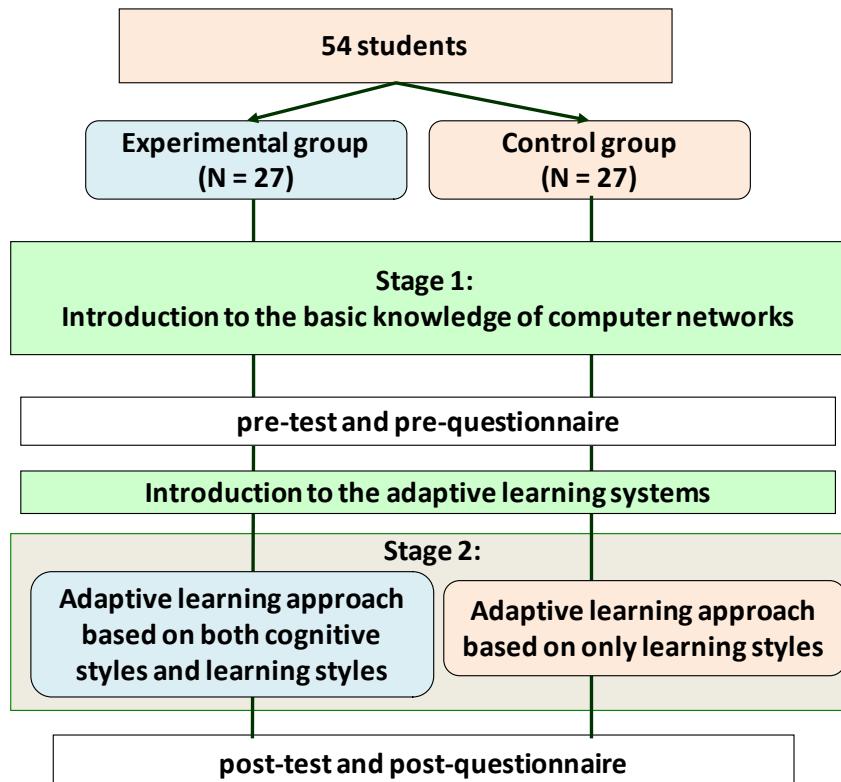


Figure 6. Procedure of the experiment

The cognitive load measure used in this study was proposed by Sweller, van Merriënboer and Paas (1998). It consisted of two dimensions, that is, mental load and mental effort. Each dimension contained two items. The Cronbach's alpha values of the two dimensions were 0.72 and 0.71, respectively.

Furthermore, the Motivated Strategies for Learning Questionnaire (MSLQ) with a five-point Likert rating scheme was used to evaluate the learning motivation of the students. The questionnaire was revised from the measure proposed by Pintrich, Smith, Garcia and McKeachie (1991). It consists of 29 items covering six dimensions, that is, intrinsic goal orientation, extrinsic goal orientation, task value, control beliefs for learning, self-efficacy and test anxiety. The Cronbach's alpha values of the six dimensions are 0.67, 0.73, 0.67, 0.72, 0.73 and 0.74, respectively.

Results

Learning achievement

An independent t-test was used to analyze the pre-test, as shown in Table 4. The result implying that these two groups did not significantly differ prior to the experiment. That is, the two groups of students had statistically equivalent abilities before taking the subject unit.

Table 4. Descriptive data and t-test result of the pre-test scores.

	N	Mean	S.D.	t
Experimental group	27	74.38	10.89	-0.82
Control Group	27	77.34	9.47	

Table 5 shows the ANCOVA result of the post-test using the pre-test as a covariate. It was found that the students in the experimental group had significantly better achievements than those in the control group with $F = 5.35$ and $p < .05$, indicating that learning with the proposed adaptive learning approach significantly benefited the students in comparison with the conventional learning style-based adaptive learning approach.

Table 5. Descriptive data and ANCOVA of the post-test scores

	N	Mean	S.D.	Adjusted Mean	Std.Error.	F value
Experimental group	27	84.85	7.32	84.88	4.76	5.35*
Control group	27	80.33	7.22	80.30	4.76	

* $p < .05$

Cognitive load

Cognitive load refers to the demand on working memory when engaging in learning activities, such as comprehending, problem solving, and reasoning. Table 6 shows the t-test result of the cognitive load ratings of the two groups. There is no significant difference between the two groups in terms of mental effort, while the experimental group showed significantly lower mental load than the control group with $t = 1.46$ and $p < .05$.

Table 6. The t-test of the cognitive load levels of the control group and experimental group. post-test result

		N	Mean	S.D.	t
Mental load	Experimental group	27	4.07	1.07	1.46*
	Control group	27	4.59	1.50	
Mental effort	Experimental group	27	5.56	1.78	-0.84
	Control group	27	5.14	1.77	

* $p < .05$

Learning motivation

An independent t-test was conducted to evaluate the learning motivation pre-questionnaire, and no significant difference was found for the six dimensions, as shown in Table 7.

Table 7. Independent t-test on the pre-questionnaire of the experimental group and the control group students

	Experimental Group (Mean, S.D.)	Control Group (Mean, S.D.)	t
Intrinsic Goal Orientation	4.02/0.50	3.91/0.40	-0.82
Extrinsic Goal Orientation	3.84/0.49	3.77/0.0.54	0.91
Task Value	4.13/0.43	4.01/0.42	-1.08
Control Beliefs for Learning	3.54/0.48	3.52/0.53	0.59
Self-efficacy	3.30/0.59	3.59/0.64	0.59
Test Anxiety	3.14/0.64	2.86/0.64	-1.02

The ANCOVA was then used to analyze the pre-questionnaire ratings of the two groups by using the pre-questionnaire result as a covariate, as shown in Table 8. A significant difference was found between the two groups in terms of the "Control Beliefs" dimension with $F = 5.52$ and $p < .05$. The dimension is related to the students' beliefs that making more effort to learn and practicing more would lead to better results. Therefore, this finding reveals that the proposed learning approach is able to engage the students in the learning process with beliefs of obtaining good learning achievements.

Table 8. ANCOVA results of the learning motivation ratings of the two groups

Variable		N	Mean	S.D.	Adjusted Mean	Std.Error.	F value
Intrinsic Goal Orientation	Experimental group	27	4.12	0.45	4.05	0.20	0.04
	Control group	27	4.08	0.52	4.02	0.28	
Extrinsic Goal Orientation	Experimental group	27	3.84	0.51	3.80	0.37	0.10
	Control group	27	3.88	0.40	3.82	0.30	
Task Value	Experimental group	27	4.29	0.51	4.22	0.26	0.73
	Control group	27	4.16	0.41	4.10	0.16	
Control Beliefs for Learning	Experimental group	27	3.79	0.60	3.74	0.37	5.22*
	Control group	27	3.62	0.74	3.52	0.55	
Self-efficacy	Experimental group	27	3.49	0.72	3.32	0.52	2.22
	Control group	27	3.41	0.70	3.24	0.50	
Test Anxiety	Experimental group	27	3.19	0.57	3.02	0.33	0.40
	Control group	27	3.20	0.66	3.06	0.45	

* $p < .05$

Discussion and conclusions

Adaptive learning has been identified as being an important and challenging issue of computers in education. In the past decades, various methods and systems have been proposed to provide students with a better learning environment by taking personal factors into account. Learning styles have been one of the widely adopted factors in previous studies as a reference for adapting learning content or organizing the content. In most studies, only one or two dimensions of a learning style model are considered while developing the adaptive learning systems. Moreover, in most systems, only a fixed type of user interface is provided. In this paper, we propose an adaptive learning system developed by using both learning styles and cognitive styles to adapt the user interface and learning content for individual students; moreover, the full dimensions of a learning style model have been taken into account. The experimental results showed that the proposed system could improve the learning achievements of the students. Moreover, it was found that the students' mental load was significantly decreased and their belief of learning gains was increased.

As mental load refers to the interactions between the learning tasks, learning content, and the characteristics of the content (e.g., difficulty level), it is highly related to the difficulty level of the content presented to the students and the students' prior knowledge for comprehending the content (Verhoeven, Schnitz, & Paas, 2009). In this study, the learning content provided to both group of students was identical although the presentation style might be adapted based on their learning styles and the interface was adapted based on their cognitive styles. On the other hand, mental effort is related to the learning strategies used in the learning activities (Verhoeven, Schnitz, & Paas, 2009). Therefore, based on the Cognitive Load Theory, it was expected that the two groups had similar mental loads and different mental efforts. However, the experimental result was opposite to the expectation, which challenges some of the main assumptions of the Cognitive Load Theory with regard to learning styles and is worth further studying.

In terms of control beliefs, which refer to learners' beliefs of being able to understand the learning content and have good learning achievement, the generated learning materials were adapted to meet individual students' characters of processing information; that is, the presentation style of the learning content was more suitable to the students' information processing styles. Therefore, it is reasonable that the students in the experimental group showed higher control beliefs than those in the control group.

From the experimental results, it can be seen that the proposed approach is promising. The developed system can be applied to other applications by replacing the learning components with new ones. To develop new adaptive learning applications, teachers or researchers only need to transform the new learning materials into individual types of learning components and store them in the database of the learning system.

On the other hand, there are some limitations of this study. First, the sample size of the experiment was not large; therefore, the findings could not be inferred to general cases. In addition, the present study mainly focused on the use of learning styles and cognitive styles in providing a personalized user interface and learning content, while some other factors, such as the knowledge levels of the students, the difficulty levels of the learning materials and compensation type of adaption, were not considered. Another limitation of this study is that the experimental group received more treatment than the control group owing to the use of different adaptive learning approaches. In the near future, we plan to apply the proposed approach to other applications with larger sample sizes and analyze the size effect as well; in the meantime, we also plan to expand the learning system by taking more parameters into consideration with more precise experiment design to control possible factors that might affect students' learning performance. Furthermore, it is expected that the learning portfolios of students can be analyzed and more constructive suggestions can be given to teachers and researchers accordingly.

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Effective Trust-aware E-learning Recommender System based on Learning Styles and Knowledge Levels

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ABSTRACT

In the age of information explosion, e-learning recommender systems (ELRSs) have emerged as the most essential tool to deliver personalized learning resources to learners. Due to enormous amount of information on the web, learner faces problem in searching right information. ELRSs deal with the problem of information overload effectively and provide recommendations by taking into consideration the learners' preferences such as learning styles, goals, knowledge levels, learning paths etc. In this paper, we propose a weighted hybrid scheme to recommend right learning resources to a learner by incorporating both the learners' learning styles (LSs) and the knowledge levels (KLs). Further, by elicitation of trust values among learners, we develop a scheme such that for a given active learner, the trustworthy learners having greater knowledge and similar learning style patterns as that of the active learner have greater weightage in recommendation strategy. Experimental results are presented to demonstrate the effectiveness of the proposed scheme.

Keywords

E-learning, Recommender systems, Collaborative filtering, Learning styles, Knowledge levels, Trust

Introduction

Due to unprecedented proliferation of information and communication technologies in recent years, e-learning has become more and more popular in academics as well as in commercial environments (Zaiane, 2002). E-learning provides opportunities for learners not only to study courses or to learn professional knowledge without time and space constraints, but also to train themselves at their own pace through the asynchronous and synchronous learning network models (Chao and Chen, 2009). Due to enormous amount of learning resources in e-learning environment, learners face difficulties in searching appropriate resources according to their need (Ghauth & Abdullah, 2010). In this situation, recommender system (RS) seems a proficient solution for dealing with this resource overload in e-learning environment (Khribi et al., 2009).

Recommender systems (RSs) are one of the most promising technologies of web personalization to alleviate the problem of information and product overload. They provide personal, affordable and effective recommendations to users based on their preferences expressed, either explicitly or implicitly (Adomavicius & Tuzhilin, 2005; Al-shamri & Bharadwaj, 2008; Milicevic et al., 2010). E-learning recommender systems (ELRSs) deal with information about learners and their learning activities and recommend items such as articles, web pages, etc. (Nghe et al., 2010). Collaborative filtering provides recommendations to learner based on those learners who have similar preferences. Since CF is able to capture the particular preferences of a user so it has become most widely accepted technique in RSs for recommending web pages, music, books etc (Symeonidis et al., 2008). It has also been successfully employed in ELRSs (Manouselis et al., 2010; Bobadilla et al., 2009; Dwivedi & Bharadwaj, 2011).

RS is strongly context/domain dependent, so it is not feasible that recommendation strategy for one context/domain is transferable to others (Drachsler et al., 2007). The reason why the thriving application of movie or joke recommendation strategies has not had such an efficacy in e-learning because modeling accurate learner profile is a much harder task than in other application domains. Two important open research issues in ELRSs are as follows:

- **Learner's point of view:** Recommended resources should be interesting to learners, according to their needs as well as their characteristics.
- **Designer's point of view:** How to design learning materials considering learners' preferences and how to recommend these resources in a specified sequence so that learners' performance can be enhanced.

We designed our proposed ELRSs based on learner's point of view by taking into consideration learner's characteristics namely learning styles and knowledge levels etc.

In e-learning, learners are characterized on the basis of their learning styles, emotions, knowledge levels and goals etc. (Drachsler et al., 2007). Learning style of a learner can be considered as a valuable factor for enhancing the individual learning that would affect the recommendation task. Learning style (LS) indicates how a learner learns and likes to learn. It can be analyzed or collected from the learning behavior of learner during study (Chang et al., 2009; Garcia et al., 2008). Bobadilla et al. (2009) suggested that learners with greater knowledge should have greater weight in the computation of recommendation than the learners with less knowledge among all neighbors of an active learner in collaborative filtering framework. Therefore knowledge level of learners is an important factor in addition to LSs. Therefore, we are providing a hybrid ELRS which offers resource recommendations by acclimatizing automatically learners' learning styles and knowledge levels that would favor and improve the learning.

The following assumptions that motivated us for the adaptation of learning style and knowledge level in ELRS are:

- Learners with different learning style generate different perspectives on effective strategies for dynamic group interactivity (Kolb, 1976). As a consequence, learners can be grouped on the basis of learning styles to have an impact on recommendation task in our work.
- Researchers believe that learning style is a good predictor of an individual's preferred learning behavior (Bostrom et al., 1990).
- Milicevic et al. (2010) recognize the different patterns of LSs in PROTUS system which provides effective personalized recommendation of learning contents after processing the clusters based on different learning styles and mining frequent patterns for the habits and interest of learners. As a consequence, we generate effective clusters of learners' LSs by utilizing the GA K-means algorithm in our work and develop a collaborative framework (CF-LS) based on these clusters.
- Paechter et al. (2010) suggest that only few variables like exchange of knowledge with peer learners contribute to perceived learning achievements in a course.
- Bobadilla et al. (2009) have also showed that the incorporation of knowledge of other learners provided the better recommendations.

Besides LSs and KLs, we extend our hybrid system (CF-LS-KL) through the incorporation of trustworthiness of learners in recommendation task. The reason behind the incorporation of trustworthiness in recommendation task is that some similar learners may be malicious for the recommendations in collaborative filtering environment and the recommendation provided by them cannot be effective. The work presented in this paper, regarding to above aspects, is an effort towards developing a trust-aware ELRS utilizing both LSs and KLs of learners. The main contributions of this paper are three fold:

- First of all, a collaborative filtering using LSs (CF-LS) is designed utilizing clusters of different learning styles generated through Genetic K-means algorithm.
- Second, a collaborative filtering scheme based on KLs (CF-KL) is developed. Thereafter, a weighted hybrid scheme (CF-LS-KL) is presented to take possible advantages of learner preferences.
- Finally, in order to give weightage to trustworthiness of learners, a trust-aware weighted hybrid scheme (TRCF-LS-KL) is proposed.

The rest of the paper is organized as follows: We first give a brief summary of related work and literature survey on LSs, KLs and clustering technique in Section 2. Section 3 elaborates collaborative filtering framework utilizing LSs and KLs in trust aware e-learning recommendation environment. Section 4 describes the experimental setup, evaluation metrics and results of the evaluation followed by the discussion in Section 5. Finally, Section 6 provides concluding remarks and suggests some future research directions.

Related work and literature survey

In the age of large information space, adaptive hypermedia educational systems try to reduce the size of information space through several techniques and provide effective resources for learners using recommendation techniques. AHA!, the "Adaptive Hypermedia Architecture", has been developed for providing online course recommendations

(De Bra et al., 2003). Generally e-learning recommendation strategies are based on data mining techniques by adapting learner's characteristics and preferences such as learning styles, knowledge levels, goals etc.

Several researchers have shown that the incorporation of LSs, an important factor in e-learning environment, can lead to enhance learning performance of a learner (Graf & Kinshuk, 2007; Milicevic et al., 2010). Al-Hamad et al. (2008) presented a user expert personalized ELRS that integrates learning styles information in e-learning environment to enhance learner efficiency and productivity. Milicevic et al. (2010) proposed PROTUS system that automatically adapts to the interest and knowledge level of learners and recommends the learning contents. They applied clustering technique on learning styles and analyze the habits and interest through frequent sequence patterns by aprori-all algorithm. Bobadilla et al. (2009) also propose that users with greater knowledge have greater weights in recommendation task. They designed new metric in the collaborative filtering framework.

Khiribi et al. (2009) recommends the learning resources that are based on current learner navigational history and exploiting similarities among learner preferences and educational contents. The proposed framework is composed of two module, offline module in which learner and content model are built and another is online module, where recommendation list is provided by recognizing learners' needs, goal. Bitonto et al. (2010) proposed a recommendation strategy that combines two knowledge based techniques which can consider learning goal, cognitive features, learning styles into account in the recommendation process. Lu (2004) proposed a framework of personalized learning RS which aims to provide the learning material according to learners' need. Here, two technologies are developed, one is multi attribute evaluation method to justify a learner need and second one is fuzzy matching method to find suitable learning material to the best match for learners' needs. Gauth and Abdullah (2011) introduce a novel architecture for an ELRS that is based on content-based filtering and good learners' ratings. They also compared the proposed ELRS with exiting ELRSs that use both collaborative filtering and content-based filtering techniques in terms of system accuracy and student's performance. Carchiolo et al. (2010) proposed a model for searching personalized and useful learning path suggested by trusted peers. They exploit the issue of trusted resources. They performed some simulation on real dataset to evaluate the efficiency and effectiveness of proposed model.

In the previous work related to ELRSs, none of the RSs have attempted to use trust in collaborative filtering framework utilizing both learning styles and knowledge levels. Our work in this paper is an attempt towards developing a hybrid trust-aware ELRSs based on both LSs and KLS. The benefits of incorporating trust in proposed scheme are that it will ensure that recommended resources are suggested by trustworthy learners.

Felder Silverman LSs model (FSLSM)

In this work, we adapt the FSLSM model proposed by Felder and Silverman. According to FSLSM, LSs are measured in the following four dimensions in two scales:

Perception

- **Sensing:** sensing learners tend to be patient with details.
- **Intuitive:** intuitive learners prefer principles and theories.

Input

- **Visual:** visual learners prefer to perceive material as pictures, diagrams and flowcharts.
- **Verbal:** verbal learners prefer to perceive materials as text.

Processing

- **Active:** active learners work well in groups.
- **Reflective:** reflective learners prefer to learn alone.

Understanding

- **Sequential:** sequential learners like to learn step wise process.
- **Global:** global learners like to learn in large jumps.

The Felder–Silverman model was chosen among the existing learning style models because it has been successfully used in previous works for individual adaptation of e-learning material (Graf et al., 2010, Milicevic et al., 2010). One of the advantages of this model is that the sliding scales support a classification of student's style more flexible than bipolar models (Alfonseca et al., 2006).

Clustering

Clustering is a widely implemented methodology in various application fields such as image processing, data mining etc (Alfonseca et al., 2006; Milicevic et al., 2010; Kim & Ahn, 2008). The simplest and most popular clustering algorithm is the K-means clustering algorithm. However, K-means has two shortcomings: dependency on the initial seeds or centers and tendency to converge towards local optima. In order to overcome these shortcomings, Krishna & Murty (1999) proposed a Genetic K-means approach that converges to the best known optimum seeds. The main steps involved in GA K-means algorithm are as follows:

GA K-means algorithm (Kim& Ahn, 2008)

1. Firstly, system generates the initial population randomly for finding global optimum initial seeds. Before the search process, chromosome is designed in the form of binary strings.
2. In the second step, system performs the process of K-means clustering. The value of fitness function is updated after the process of K-means algorithm.
3. Finally, GA performs genetic operations such as crossover, mutation and selection on the current population. Update the current population for better initial seeds. After that, Step 2 and 3 are repeated until the stopping conditions are satisfied.

In our work, we have designed a GA K-means scheme for clustering learners based on their learning styles as discussed in the next Section.

Trust-aware CF framework utilizing learning styles and knowledge levels

In this Section, we discuss the hybrid scheme CF-LS-KL based on LSs as well as KLs and also describe the trust enhanced hybrid scheme, TRCF-LS-KL. Firstly we discuss collaborative filtering than we start by presenting two innovative filtering approaches namely; learning styles based collaborative filtering (CF-LS) and collaborative filtering using knowledge levels (CF-KL) which are the major components of our proposed schemes.

Collaborative filtering (CF)

CF systems measure the like mindedness of a pair of users by comparing their inclination for resources which they have evaluated. The process of recommending resources for an active learner l_a comprises of three main steps:

Similarity measure: The Similarity between learners l_x and l_y using the Pearson similarity is computed as.

$$sim(l_x, l_y) = \frac{\sum_{i \in S_{x,y}} (r_{l_x,i} - \bar{r}_{l_x})(r_{l_y,i} - \bar{r}_{l_y})}{\sqrt{\sum_{i \in S_{x,y}} (r_{l_x,i} - \bar{r}_{l_x})^2 \sum_{i \in S_{x,y}} (r_{l_y,i} - \bar{r}_{l_y})^2}}, \quad (1)$$

where $r_{l_x,i}$ is the rating of learner l_x on resource i , $S_{x,y}$ is the set of all resource co-rated by both learners l_x and l_y . \bar{r}_{l_x} is the average rating of learner l_x and \bar{r}_{l_y} is the average rating of learner l_y .

Neighborhood formation: The most popular technique is the k-NN approach which selects the n most similar learners who have also rated the resource to take part in the recommendation process.

Generating recommendations: The most common approach to aggregate ratings as proposed by Resnick et al, 1994, for an resource i for active learner l_a .

$$pr_{l_a,i} = \bar{r}_{l_a} + \frac{\sum_{l=1}^n sim(l_a,l) \cdot (r_{l,i} - \bar{r}_l)}{\sum_{l=1}^n |sim(l_a,l)|}, \quad (2)$$

where $pr_{l_a,i}$ is the predicted rating for learner l_a for resource i , \bar{r}_l is the mean rating for learner l , $sim(l_a,l)$ is the similarity between learners l_a and l .

CF-LS scheme

This approach utilizes the importance of LSs of learners for providing effective recommendations in collaborative filtering framework. For example, if learners X and Y have same LSs then recommendations can be provided to learner X on the basis of experienced resources of Y in e-learning environment. In order to take the importance of LSs in our proposed CF-LS scheme, we grouped learners on the basis of their LSs employing GA K-means algorithm discussed in phase 2 in this section. The following four phases are required to perform the recommendation task in CF-LS scheme as discussed below:

Phase 1. Learner model formation

Generally three types of data can be collected from learners, learning style detection through questionnaire based on index of learning styles (ILS) during registration process, explicit ratings for a subject of available teachers, books, subjects and implicit data from learners' online behavior. As discussed earlier, classification of learning styles of learners is considered according to FSLSM model (Felder & Silverman, 1988) and consequently classified into four dimensions within two scales according to the left handed or right handed scores in the results of questionnaire. So, every dimension is represented by binary value 1 or 0, where 1 bit is used for active, sensitive, visual and sequential dimension (Left handed scores) and 0 is used for reflective, intuitive, verbal and global dimension (Right handed scores). Therefore, four bits are required to represent a learner on the basis of learning styles. Sample data of learning styles of learners is shown in Table1.

Table 1. Sample data for learning styles

Learners	Learning Styles			
	Perception	Input	Processing	Understanding
Sensing:1/Intuitive:0	Visual:1/Verbal:0	Active:1/Reflective:0	Sequential:1/Global:0	
Learner1	0	0	1	1
Learner2	1	1	1	1
Learner3	1	1	1	0

Phase 2. Clustering employing GA K-means

As discussed earlier, K-means does not provide any mechanism for choosing appropriate initial seeds. However, the choice of selecting different initial seeds may generate huge differences in recommendation quality. To handle this situation, we employ GA K-means algorithm for clustering process. The problem of differentiating learners based on LSs is addressed in this phase using GA K-means algorithm as discussed below:

Chromosome representation

Here, we suggest that each chromosome should be a sequence of binary numbers representing k cluster centers with length $4 * k$ bits where the first four bits represent the four dimensions of the first cluster center, the next four bits represent second cluster center and so on. Here, we considered each learner as a cluster center in our chromosome representation. Chromosome representation for three clusters associated with three learners ($k = 3$) is shown in Figure 1.

Learner1				Learner 2				Learner 3			
0	0	1	1	1	1	1	1	1	1	1	0

Figure 1. Representation of chromosome

This figure represents the three cluster centers (0 0 1 1), (1 1 1 1) and (1 1 1 0) corresponding to three learners with learning styles (Intuitive, verbal, Active, Sequential), (Sensing, Visual, Active, Sequential) and (Sensing, Visual, Active, Global) respectively.

Initialization of population

The initial population is selected randomly. It is the collection of chromosomes described as in previous steps.

Genetic operators

Genetic operators drive the search process in GA. Crossover and mutation are the two fundamental genetic operators.

Crossover: It allows each individual has a chance to interchange gene information from two parent chromosomes. Two-point crossover generates two random positions and interchanges the genes between the two positions from the parent chromosomes, as Figure 2 depicts.

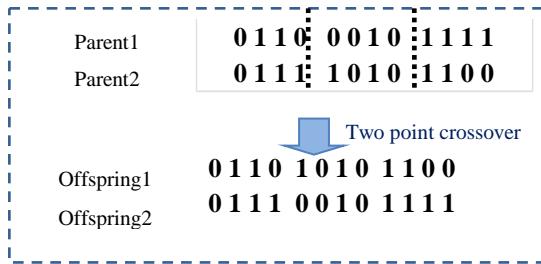


Figure 2. Two point crossover

Mutation: It randomly alters one or more genes of a selected chromosome. Figure 3 illustrates mutations operation that alters three randomly chosen genes.

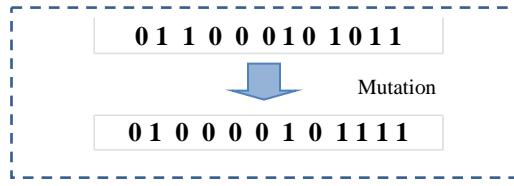


Figure 3. Mutation

Fitness function

Fitness function is a factor which drives the GA process towards convergence to the optimal solution. Here fitness function is evaluated to find out the compactness of clusters. We computed the fitness of chromosome to find the optimal initial seed for K-means algorithm using the following fitness function.

$$F = \sum_{i=1}^k \sum_{p \in C_i} |p - m_i|^2, \quad (3)$$

where p is the point in space representing given learner, m_i is the mean of cluster C_i and k is the number of clusters.

A pseudo-code for GA K-Means algorithm is depicted in Figure 4.

GENETIC K-means Algorithm

Input: Database=D, Number of clusters=k, maximum number of generations= MAX_GEN
Output: Optimal cluster centers C^*

Step 1: Initialization

```

 $g \leftarrow 0;$ 
 $P_g \leftarrow$ Initial random population of size, N;

```

Step 2:

```

for  $g = 1$ : MAX_GEN
    for each  $C_i^g \in P_g$  /*  $C_i^g$  is the  $i^{th}$  chromosome of population  $P_g$  */
         $C_i^* =$ K-means ( $C_i$ );
         $F(C_i) = \sum_{j=1}^k \sum_{p \in C_j} |p - m_j|^2$ ; /* Computing fitness of chromosome*/
    end
    if Stopping criteria is not satisfied
         $P_g \leftarrow GenerateNewPopulation(P_{g-1})$ ; /* By applying Crossover and Mutation*/
    else
        Stop;
        Return ( $C^*$ );
    end
end

```

Figure 4. Pseudo code of GA K-means

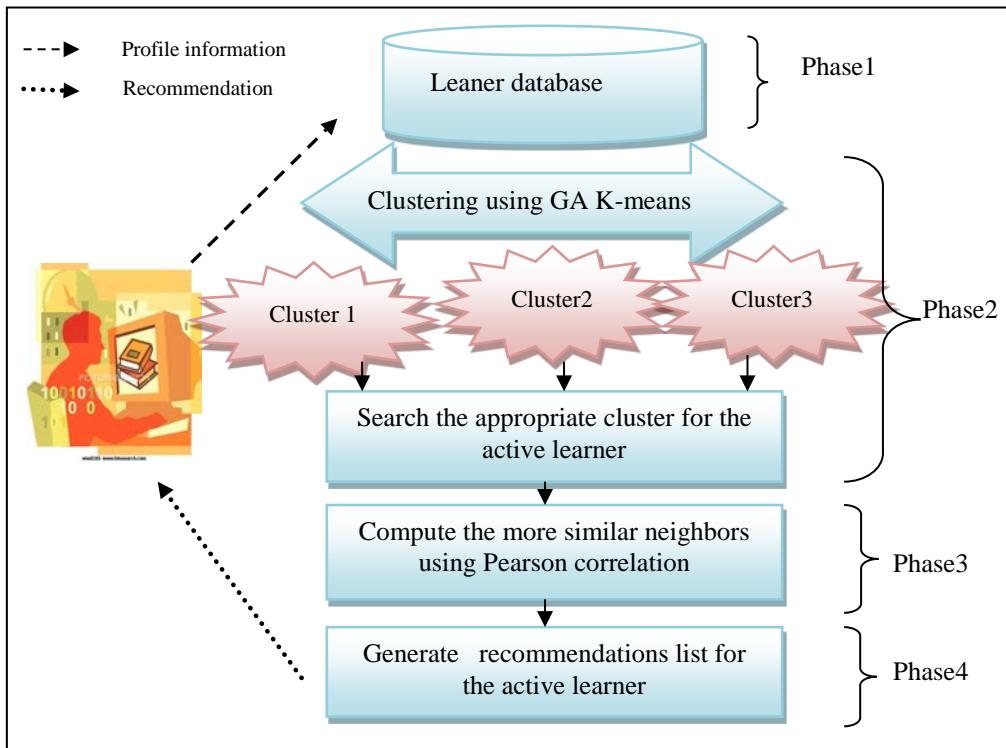


Figure 5. CF-LS architecture

Phase3. Neighborhood set generation

Once the process of clustering using GA K-means has been completed, the system matches the active learner to the available clusters and generates a set of top- n neighbors for him. We used the most popular Pearson similarity function (Eq.1) for generating more similar neighbors.

Phase4. Making predictions

CF-LS system assigns predicted rating to all the resources experienced by the neighborhood set and unseen by the active learner. The predicted rating can be computed for an active learner l_a to an unseen resource i using Eq. (2). A pictorial representation of the CF-LS scheme is given in Figure 5.

CF-KL scheme

Knowledge level of a learner is an important factor for recommending the valuable resources in collaborative e-learning environment and Bobadilla et al. (2009) designed a new metric which capture the importance of knowledgeable learners in recommendation task. In our work, a two level filtering methodology is presented by incorporating knowledge level in recommendation task. Firstly, the set of neighbors is generated using Pearson similarity and thereafter the knowledge levels are used to refine the set of recommenders who are more knowledgeable than the active learner. The recommendation task using CF-KL would require the following three phases.

Phase 1. Learner model formation

Along with the learner model for CF-LS scheme, knowledge level for each learner is also included for the formation of learner model in CF-KL scheme. Importance of knowledge level in recommendations for each learner is computed through the Eq. (4) (Bobadilla et al., 2009).

$$f(x) = \begin{cases} K_x - K_y, & K_x > K_y \\ 0, & K_x \leq K_y \end{cases} \quad (4)$$

where K_x is the knowledge of learner l_x and K_y is the knowledge of learner l_y .

Phase 2. Neighborhood set generation

In this phase, a proposed two level filtering scheme is used to generate more effective neighborhood set. At the first level, top- n neighbors are selected using Pearson similarity Eq. (1). Thereafter, knowledge level is used as a means for filtering neighbors prior to recommendation. So that only the neighbors, who are more knowledgeable than the active learner participate in recommendation process.

Phase 3. Making predictions

CF-KL system assigns predicted ratings to all the resources experienced by learners in the neighborhood set and unseen by the active learner. The predicted rating can be computed for an active learner l_a to an unseen resource i using Eq. (2). CF-KL architecture is represented in Figure 6.

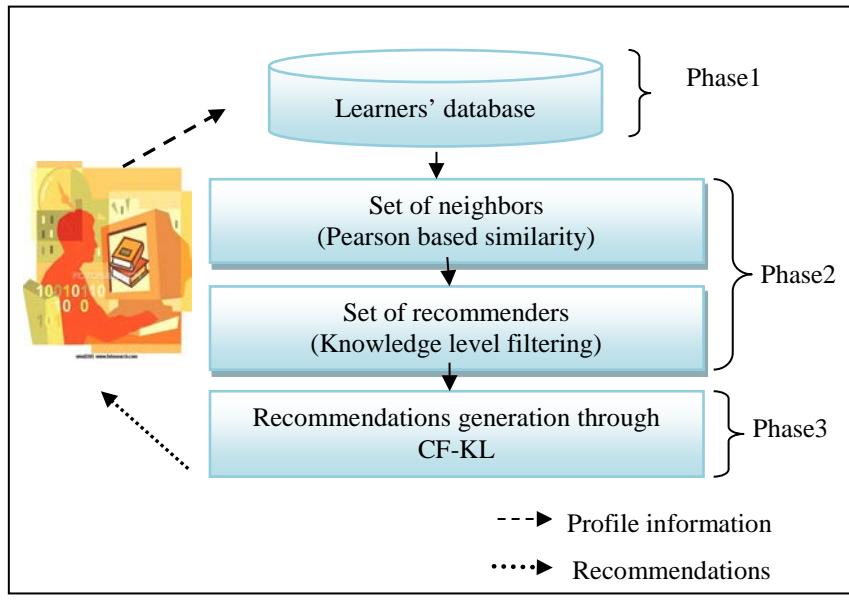


Figure 6. CF-KL Architecture

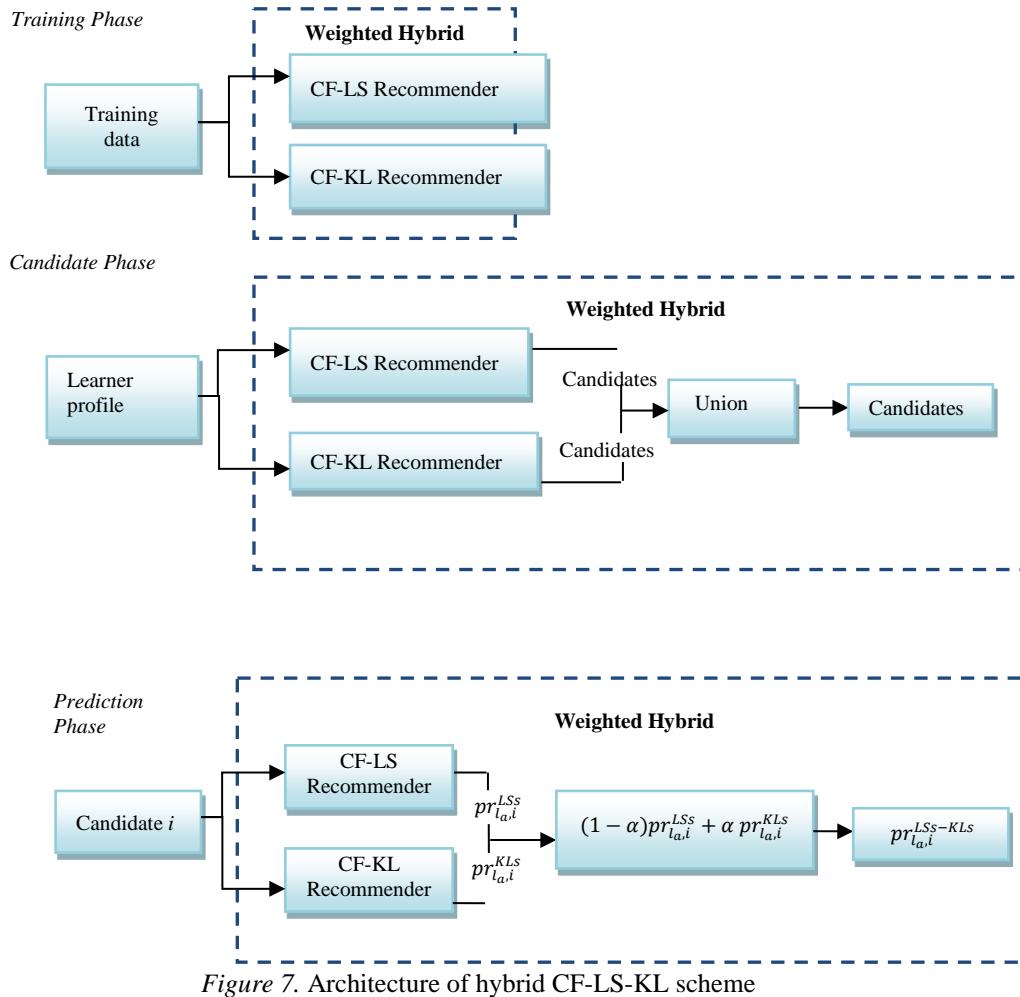


Figure 7. Architecture of hybrid CF-LS-KL scheme

CF-LS-KL scheme

The proposed ELRS has two components: Prediction based on CF-LS scheme and prediction generated through CF-KL scheme. Output of these two components is hybridized using linear weighting scheme shown in Figure 7.

For evolving the more knowledgeable recommenders who have similar LSs pattern, we combined both preferences LSs and KLs together as hybrid CF-LS-KL scheme using appropriate α value. The main steps involved in CF-LS-KL scheme are as follows:

Step1: Predict the rating of resource i to active learner l_a , $pr_{l_a,i}^{LSS}$, using CF-LS scheme.

Step2: Predict the rating of resource i to active learner l_a , $pr_{l_a,i}^{KLS}$, using CF-KL scheme.

Step3: Merge the ratings predicted by both CF-LS and CF-KL schemes to compute rating predicted by, $pr_{l_a,i}^{LSS-KLS}$, of CF-LS-KL scheme:

$$pr_{l_a,i}^{LSS-KLS} = (1 - \alpha)pr_{l_a,i}^{LSS} + \alpha pr_{l_a,i}^{KLS}, \quad (5)$$

As in Eq. (5), we employed parameter α to balance the prediction based on CF-LS scheme and prediction based on CFKL Scheme. Here α can be set empirically in the range of [0, 1] for capturing various possibilities of hybridization. For example

$\alpha = 0$: prediction completely based on CF-LS scheme

$\alpha = 0.2$: more weightage given to CF-LS scheme.

$\alpha = 0.5$: equal weightage given to both CF-LS and CF-KL scheme.

$\alpha = 0.8$: more weightage given to CF-KL scheme.

$\alpha = 1$: prediction completely based on CF-KL scheme

TRCF-LS-KL scheme

This scheme is an extended version of proposed hybrid scheme CF-LS-KL scheme by utilizing the trustworthiness of learners in recommendation process. The motivation behind it from real life situation where people would like to take suggestions from those on which they trust highly, whether suggestions related to careers, subjects, books or other items. In order to find out most similar as well as trustworthy neighbors, we design the following new similarity metric $TrustSim(l_x, l_y)$ for any two learner l_x and l_y :

$$TrustSim(l_x, l_y) = Trust(l_x, l_y) * Sim(l_x, l_y), \quad (6)$$

where term $Trust(l_x, l_y)$ represents the importance of trustworthy learners that is computed by the following formula (Lathia et al., 2008):

$$Trust(l_x, l_y) = 1 - \frac{\sum_{i=1}^n |r_{l_x,i} - r_{l_y,i}|}{r_{max,n}}, \quad (7)$$

and $Sim(l_x, l_y)$ refers to the similarity between learners according to Pearson formula (Eq.1).

Trust between two learners l_x and l_y can be computed using the following formula (Eq.7)

where n is the number of common resources between l_x and l_y , r_{max} is the maximum rating, $r_{l_x,i}$ is the rating of learner l_x on resource i and $r_{l_y,i}$ is the rating of learner l_y on resource i .

It is to be noted that the Eq.6 involving product of Trust and Sim ensures that $TrustSim$ is using only when both trust and similarity are high.

For the proposed TRCF-LS-KL scheme, we have incorporated the metric $TrustSim(l_x, l_y)$, that obtained the top n neighbors of active learner who are trustworthy as well as more similar, into CF-LS-KL scheme instead of $Sim(l_x, l_y)$.

An illustrative Example

We now present an example that demonstrates the effectiveness of proposed metric in recommendation task. Table 2 is an example of rating matrix in which five learners have reported ratings on seven resources. Some entries are empty because learners do not rate every resource. Here, system would make the prediction for resource R7 for active learner, (Bob).

Table 1. Example of Learner ratings matrix

Learners	Resources						
	R1	R2	R3	R4	R5	R6	R7
Bob	5	2		5	3		4 ?
Alice		2	4		4		3
Jacob			5		5		3
Liu	3		3	5		1	1
John	4	2	4		4	2	4

Traditional similarity based CF

Similarity (Eq.1) between Active learner Bob with other learners are:

$$\text{sim}(\text{Bob}, \text{Alice}) = 0.5855, \text{sim}(\text{Bob}, \text{Jacob}) = 0.2425, \text{sim}(\text{Bob}, \text{Liu}) = 1, \text{ and}$$

$$\text{sim}(\text{Bob}, \text{John}) = 0.9864$$

Here neighbor Liu has the highest similarity. Employing CF through Pearson similarity (Eq.1 & 2), the predicted rating and MAE for resource R7 for the active learner are 2.75 and 1.25 respectively.

Proposed TrustSim based CF

- First we compute trust between Bob and remaining learners using Eq.(7)

Computation of trust between Bob and Alice:

For n=2 and $r_{max}=5$.

$$\text{Trust}(\text{Bob}, \text{Alice}) = 1 - \frac{|2-2|+|3-4|}{5*2} = 0.9$$

Similarly, we can compute Trust (Bob, Jacob) = .8, Trust (Bob, Liu) = .6 and Trust (Bob, John) = 0.9

- Similarity computation is again based on Eq. (1).

- TrustSim using Eq.(6) between Bob with other learners are:

$$\text{TrustSim}(\text{Bob}, \text{Alice}) = \text{Trust}(\text{Bob}, \text{Alice}) * \text{sim}(\text{Bob}, \text{Alice}) = 0.9 * 0.5855 = 0.5269$$

Similarly, TrustSim (Bob, Jacob) = 0.1940, TrustSim (Bob, Liu) = 0.6, and TrustSim (Bob, John) = 0.8878

Here, neighbor with the highest TrustSim value is John. Because TrustSim is able to identify neighbors who have high values for similarity as well as trust in comparison to Jacob who has high trust value(0.8) but less similarity(0.2425) and Liu who has low trust value(0.6) but high similarity(1.0) .

The predicted rating and MAE for resource R7 for the active learner Bob, utilizing proposed metric (Eq. 6) are 3.75 and 0.25 respectively.

Hence MAE results show that similar learners who are also trustworthy are better recommenders.

All the schemes proposed in this work are listed in Table 3.

Table 2. Representation of all proposed schemes

Schemes	e-learning recommender system
Traditional CF-PR	Traditional collaborative filtering approach based on Pearson correlation
CF-KL	Proposed two level filtering approach utilizing knowledge levels in collaborative filtering framework
CF-LS	Proposed learning styles based collaborative filtering approach
CF-LS-KL	Proposed hybrid approach based on both the learning styles and knowledge levels
TRCF-LS-KL	Proposed trust-aware hybrid approach incorporating trust in CF-LS-KL

Experiments and results

In order to evaluate the performance of proposed hybrid schemes, utilizing LSs and KLs in trust-aware ELRSs, we are conducting two experiments in the proposed collaborative filtering framework are as follows:

1. Evaluation of system's performance based on proposed scheme using MAE and Coverage measures
2. Effect of number of varying neighborhood size on system's performance

Experimental setup

Since there is no well known dataset publically accessible for research (Bobadilla et al., 2009) in the domain of ELRSs, we mapped well known datasets MovieLens and Jester from the RSs domain to ELRSs domain (here after referred as EL dataset) for our experimentation. MovieLens dataset consists of 100,000 ratings provided by 943 learners on 1682 movies. The rating scale follows the 1-bad, 2-average, 3-good, 4-very good and 5-excellent. Each user has rated at least 20 movies in this dataset. Jester dataset provides 4.1 million ratings by 73421 users on 100 jokes. The ratings are continuous and lie in range -10 to 10. MovieLens (ML) and Jester are different from each other, since the sparsity level of MovieLens is quite high whereas the jester dataset is dense. We mapped movies of ML dataset and jokes of jester dataset as teachers, books and subjects and the ratings to movies and jokes are considered as ratings provided by learners to teachers, books and subjects. Because of the requirement of learning styles and test scores in our proposed work, we assigned learning styles as well as test scores for each learner randomly. LSs are generated randomly using ILS questionnaire. For establishing correlation between LSs of learners and their ratings patterns, we generate LSs patterns for similar learners on the basis of the questionnaire and select pattern with high correlation.

To compare proposed schemes more thoroughly, we conducted the experiments under several configurations. We randomly selected subsets of 150-550 with increment of 100 learners called EL150, EL250, EL350, EL450 and EL550 from both of the datasets respectively. This is to illustrate the effectiveness of the proposed scheme under varying number of participating learners. Each of these sub datasets was randomly split into 60% training and 40% test data (Anand & Bharadwaj, 2011). The ratings of the items in the test set are treated as items unseen by the active learner while the ratings in the training set are used for neighborhood construction and for prediction of ratings. For each dataset, experiments were run 20 times to eliminate the effect of any bias in the data.

Performance evaluation

In order to test the performance of our schemes, we measure system's accuracy using two evaluation metrics, namely the mean absolute error (MAE) and the total coverage of system. The MAE measures the deviation of predictions generated by the RS from the true ratings specified by the learner. On the other hand, coverage measures the percentage of resource for which a RS can provide predictions

The MAE for the active learner l_a (Breese et al., 1998) is as follows:

$$MAE(l_a) = \frac{1}{|S_i|} \sum_{k=1}^{|S_i|} |pr_{i,k} - r_{i,k}| , \quad (8)$$

where i is the resource and S_i is the cardinality of the test ratings set of learner l_a ratings.

The total MAE over all the active learners N_A can be computed as:

$$MAE = \frac{1}{N_A} \sum_{a=1}^{N_A} MAE(l_a) \quad (9)$$

Coverage: It is measured as number of resources for which RS can generate prediction over the total number of unseen resources.

$$Coverage = \frac{\sum_{i=1}^{N_A} p_i}{\sum_{i=1}^{N_A} S_i} \quad (10)$$

here, p_i is the total number of predicted resources for active learner l_a . Low coverage value indicates that RS will not able to suggest the learner with many of resource he has not rated.

Experiment 1

In order to reveal the performance of system based on proposed schemes, we conduct experiments using datasets EL150, EL250, EL350, EL450 and EL550 mapped from MovieLens and Jester. By fixing the neighborhood size, we compare MAE and coverage. Using an appropriate value of α , we measured the effect of CF-PR, CF-KL, CF-LS, CF-LS-KL and TRCF-LS-KL.

Analysis of the results

Tables 4 and 5 show that TRCF-LS-KL outperforms CF-LS-KL, CF-LS, CF-KL and CF-PR for all the different configurations generated from MovieLens and Jester datasets respectively. The total MAE for TRCF-LS-KL is always smaller than CF-LS-KL, CF-LS, CF-KL and CF-PR schemes. Tables 6 and 7 show that TRCF-LS-KL outperforms CF-LS-KL, CF-LS, CF-KL and CF-PR generated from MovieLens and Jester datasets respectively. The coverage for TRCF-LS-KL is always greater than CF-LS-KL, CF-LS, CF-KL and CF-PR schemes.

Table 4. Comparison of MAE among CF-PR, CF-KL, CF-LS, CF-LS-KL and TRCF-LS-KL on EL datasets mapped from MovieLens dataset

Datasets	CF-PR (MAE)	CF-KL (MAE)	CF-LS (MAE)	CF-LS-KL (MAE)	TRCF-LS-KL (MAE)
EL150	.8775	.8603	.8561	.8412	.8018
EL250	.9082	.8808	.8625	.8513	.8432
EL350	.9402	.9205	.8982	.8843	.8644
EL450	.9312	.9180	.8851	.8700	.8503
EL550	.9475	.9089	.9004	.8991	.8745

Table 5. Comparison of MAE among CF-PR, CF-KL, CF-LS, CF-LS-KL and TRCF-LS-KL on EL datasets mapped from Jester dataset

Datasets	CF-PR (MAE)	CF-KL (MAE)	CF-LS (MAE)	CF-LS-KL (MAE)	TRCF-LS-KL (MAE)
EL150	4.1509	3.7551	3.6743	3.6600	3.2214
EL250	4.3241	3.8132	3.7675	3.6645	3.4326
EL350	4.7062	3.9982	3.9648	3.8871	3.6652
EL450	3.8171	3.6167	3.5671	3.5000	3.4211
EL550	4.4507	3.9867	3.7111	3.6772	3.5286

Table 6. Comparison of coverage among CF-PR, CF-KL, CF-LS, CF-LS-KL and TRCF-LS-KL on EL datasets mapped from MovieLens dataset

Datasets	CF-PR (Coverage%)	CF-KL (Coverage%)	CF-LS (Coverage%)	CF-LS-KL (Coverage%)	TRCF-LS-KL (Coverage%)
EL150	76.6848	79.7543	86.3468	88.3214	88.9987
EL250	70.5201	76.3456	82.2864	82.6548	82.6777
EL350	69.9815	70.3457	78.6143	80.1112	80.2345
EL450	63.3694	69.6634	75.6911	75.7436	76.1234
EL550	60.1599	64.3426	72.5489	72.9986	73.0067

Table 7. Comparison of coverage among CF-PR, CF-KL, CF-LS, CF-LS-KL and TRCF-LS-KL on EL datasets mapped from Jester dataset

Datasets	CF-PR (Coverage%)	CF-KL (Coverage%)	CF-LS (Coverage%)	CF-LS-KL (Coverage%)	TRCF-LS-KL (Coverage%)
EL150	96.7788	96.8622	97.9583	97.9622	98.9756

EL250	81.0811	87.6543	98.8225	98.9002	98.9407
EL350	85.7143	86.4532	87.5104	87.5421	89.7634
EL450	96.8322	97.4522	98.8707	98.8814	98.9123
EL550	94.7368	96.5342	98.7517	98.8345	98.8424

Experiment 2

In order to evaluate the effect of neighborhood size on performance of CF-PR, CF-KL, CF-LS, CF-LS-KL and TRCF-LS-KL, we conducted an experiment where we varied the number of nearest neighbors that were used and computed MAE for each scheme. We showed only the results for configuration EL250 and EL450 mapped from MovieLens and Jester datasets respectively. Results are shown in Figure 8(a) and Figure 8(b). We can observe that the size of neighborhood does affect the performance. All schemes improved the accuracy of prediction as neighborhoods size increases from 5 to 30 with increment 5.

Analysis of the results

Figure 8 (a) and Figure 8 (b) show that CF-KL performs better than CF-LS when the size of neighborhood lies in between 5 to 10. TRCF-LS-KL scheme is always better than other schemes. When the neighborhood size increases, MAE of all schemes decreases.

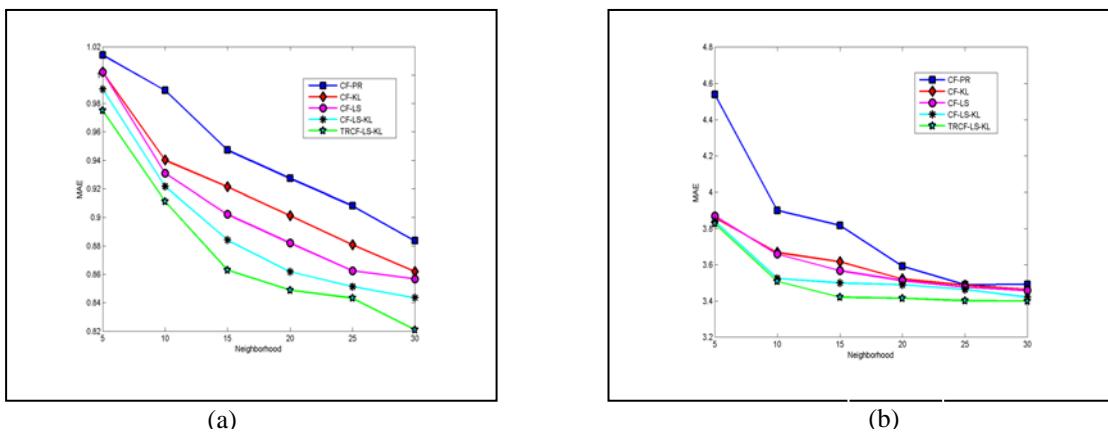


Figure 8. Sensitivity of neighborhood size on (a) EL250 mapped from MovieLens dataset (b) EL450 Mapped from Jester dataset

Discussion

The experimental results have clearly demonstrated that our proposed schemes namely, CF-KL, CF-LS, CF-LS-KL and TRCF-LS-KL have produced high predictive accuracy and better coverage on two different datasets (MovieLens and Jester) as compared to traditional collaborative filtering CF-PR. For TRCF-LS-KL, the mean MAE of all sample datasets of MovieLens decreases approximately by 8.5 % and the mean coverage increases by 18%. The improvement in accuracy via MAE and coverage is seen significantly for Jester dataset also. This improvement is possible because of the adaptation of trustworthy as well as similar learners in terms of their LSs and KLS in our proposed schemes. The proposed ELRS (TRCF-LS-KL) would be quite effective for providing resource recommendations to learners registered in online courses through e-learning systems.

Conclusion

E-learning recommender systems (ELRSs) need to consider specific demands and preferences of learners. Our proposed ELRS clearly demonstrates that trustworthy as well as similar learners generate effective resource

recommendations considering their learning styles (LSs) and knowledge levels (KLs). Experimental results reveal that the incorporation of trust in ELRS based on LSs and KLs has significantly outperformed other traditional schemes in terms of accuracy and coverage.

Even though the results reveal that the proposed scheme, TRCF-LS-KL has produced better accuracy and coverage, further studies are planned to extend the TRCF-LS-KL in the following two different directions:

Firstly, LS vector is fixed in our proposed system during learning process. It would be more promising by adapting the dynamic behavior of LSs and incorporating emotional states of learners such as sad, anger etc for further enhancing recommendation quality of our proposed system.

Further, our proposed system is error prone to the cold start and the sparsity problems. In future, we are planning to develop a hybrid ELRS for alleviating these problems by combining our system with content based filtering and incorporating trust propagation schemes into our system. The results presented in this study are still preliminary due to the lack of publically available datasets; it would be interesting to establish the effectiveness of our proposed system on future datasets with different data characteristics.

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An Expert System-based Context-Aware Ubiquitous Learning Approach for Conducting Science Learning Activities

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ABSTRACT

Context-aware ubiquitous learning has been recognized as being a promising approach that enables students to interact with real-world learning targets with supports from the digital world. Several researchers have indicated the importance of providing learning guidance or hints to individual students during the context-aware ubiquitous learning process. In this study, an expert system-based guidance approach is proposed for conducting effective context-aware ubiquitous learning activities based on the domain knowledge provided by experienced teachers. To evaluate the effectiveness of the proposed approach, an experiment on a learning activity in a senior high school Geosciences course has been conducted. The experimental results show that, with this new approach, the students' learning achievements have been significantly improved in terms of several cognitive processes in Bloom's taxonomy of educational objectives, such as "analyzing" and "evaluating." Consequently, it is concluded that the context-aware ubiquitous learning system with the interactive guiding approach has benefited the students in enhancing their higher order thinking competencies.

Keywords

Ubiquitous learning, Expert systems, Mobile technology, Science courses, RFID

Background and objectives

Educators have indicated the importance of learning from observing or interacting with real-world learning targets (Arnseth, 2008; Rogers et al., 2005). In the traditional approach, a teacher usually needs to guide dozens of students to learn in the field or in science laboratories to interact with those learning targets (Hwang & Chang, 2011; Lin, Hsieh, & Chuang, 2009; Wu, Hwang, Su, & Huang, 2012). Researchers have indicated that such a learning approach has several problems. One is the lack of personalized learning guidance and feedback, since a teacher usually needs to face dozens of students; therefore, some students might fail to keep up with the teaching progress (Shih, Chuang, & Hwang, 2010). Another problem is the lack of an effective tool to help the students organize their findings during the observing and detecting process; consequently, the students might memorize some features of individual learning targets, but without being able to compare and differentiate them (Hwang, Chu, Lin, & Tsai, 2011).

The advancements of mobile and wireless communication technologies seem to provide an opportunity to cope with these problems (Looi et al., 2009; Peng et al., 2009). More and more studies that use mobile and wireless communication technologies to conduct real-world learning activities have been reported in recent years. For example, Wong, Chin, Tan and Liu (2010) developed a mobile learning environment to conduct Chinese idiom learning activities; Hwang and Chang (2011) employed mobile and wireless communication technologies to support in-field learning activities of a social science course. Some researchers have further employed sensing technologies, such as RFID (Radio Frequency Identification) and QR (Quick Response) codes, to detect the location of students during the learning process (Chen, Chang, & Wang, 2008; Hwang, Kuo, Yin, & Chuang, 2010; Ogata & Yano, 2004). With the help of sensing technologies, students can easily access supplementary materials on the server without inputting web addresses or requests; instead, they only need to read the tags on the learning targets with the sensing devices (Chen et al., 2009; Hwang, Wu, & Ke, 2011; Hwang, Wu, Zhuang, & Huang, 2013; Lin, 2007). Hwang, Tsai and Yang (2008) have named such a learning approach that employs mobile, wireless communication and sensing technologies to provide learning supports in real-world environments *context-aware ubiquitous learning*, which is called *u-learning* in the following discussions for short.

In the meantime, researchers have pointed out the necessity of providing effective learning strategies or tools to assist students in interpreting and organizing what they have learned from such authentic learning environments with complex and rich resources (Chu, Hwang, & Tsai, 2010; Hwang, Shi, & Chu, 2011; Chiou, Tseng, Hwang, & Heller, 2010; Hwang, Wu, & Kuo, 2013). Jonassen, Carr, and Yueh (1998, p. 1) have formally defined such tools as “Mindtools,” which they describe as “Computer applications that, when used by learners to represent what they know, necessarily engage them in critical thinking about the content they are studying.”

Among the existing approaches to developing Mindtools, expert systems have been recognized as being an effective tool for providing personalized guidance or suggestions based on domain knowledge elicited from experts or experienced teachers (Cragun & Steudel, 1987; Edwards, McDonald, & Young, 2009; Jankowicz, 2004). Researchers have indicated that, with the help of expert systems, students are able to reorganize their knowledge for identifying the similarities and differences between learning targets (Ford, Petry, Adams-Webber, & Chang, 1991; Hwang, Chu, Lin, & Tsai, 2011; Jonassen, Carr, & Yueh, 1998). Among various objectives of science education, fostering identification and differentiating competences of students has been recognized as being an important and challenging aim (National Research Council, 2000). Such a “differentiating” ability has been categorized by Anderson, Krathwohl, Airasian, Cruickshank, Mayer, Pintrich et al. (2001) as being an “analyze” competence, which includes the cognitive processes of “focusing,” “selecting,” “discriminating” and “distinguishing.”

Therefore, in this study, an expert system is developed for supporting context-aware ubiquitous learning activities based on a grid-based knowledge acquisition approach. Moreover, an experiment is conducted on a Geosciences learning activity to evaluate the performance of the proposed approach. The objective of this study is to investigate whether the expert system is helpful to the students in improving their u-learning performance and enhancing their higher order thinking competences via providing learning guidance and hints in the fields.

Development of an expert system for context-aware ubiquitous learning

An expert system is a computer program developed to simulate the reasoning and decision-making process of domain experts based on the knowledge elicited from the experts (Chu, Hwang, & Tsai, 2010). Various successful applications of expert systems have shown the effectiveness of this approach, such as medical diagnosis, web service, and education (Chu & Hwang, 2008; Leitich et al., 2001; Liebowitz, 1997; Yang, Zhang, & Chen, 2008).

The aim of this study is to develop an expert system to support context-aware ubiquitous learning activities that engage students in developing and organizing knowledge for differentiating a set of learning targets in the real world, which has been recognized as being a higher order thinking ability by researchers (Anderson et al., 2001; Cartwright, 2002). During the learning process, the students are guided by the expert system, which employs guiding strategies and domain knowledge provided by experienced teachers in providing learning suggestions, to observe the learning targets and to collect data for identifying and differentiating the targets.

Figure 1 shows the structure of the expert system, which consists of an inference engine, a knowledge base and a web-based interface. The inference engine and web interface were implemented using Microsoft Visual Studio 2008 and Windows Mobile 6 Professional SDK. The knowledge base was developed with Microsoft SQL Server 2005. Moreover, a C# program was developed to access the RFID tag information from the reader on the Personal Digital Assistant (PDA) that served as the mobile learning device in this study.

The knowledge base of the expert system is represented by a tabular “repertory grid,” which is a matrix with columns representing elements and rows representing constructs (Kelly, 1955). An element can be a decision to be made, an object to be classified or a concept to be learned. A construct is a characteristic or a feature for describing or classifying the elements. It consists of a trait (e.g. hard), and the opposite of that trait (e.g., soft) for identifying the elements (e.g., a set of target rocks). Moreover, the value ranging from 1 to k, where k is an odd integer, assigned to an element-construct pair, represents the relationship between the element and the construct. For most applications of the repertory grid, a rating mechanism with k = 5 is usually used to represent the relationships (Chu & Hwang, 2008; Chu, Hwang, & Tseng, 2010). In such a 5-scale rating mechanism, “1” represents “highly inclined to the trait,” “2” represents “more or less inclined to the trait,” “3” represents “no inclination” or “no relevance,” “4” represents “more or less inclined to the opposite” and “5” represents “highly inclined to the opposite” (Chu & Hwang, 2008).

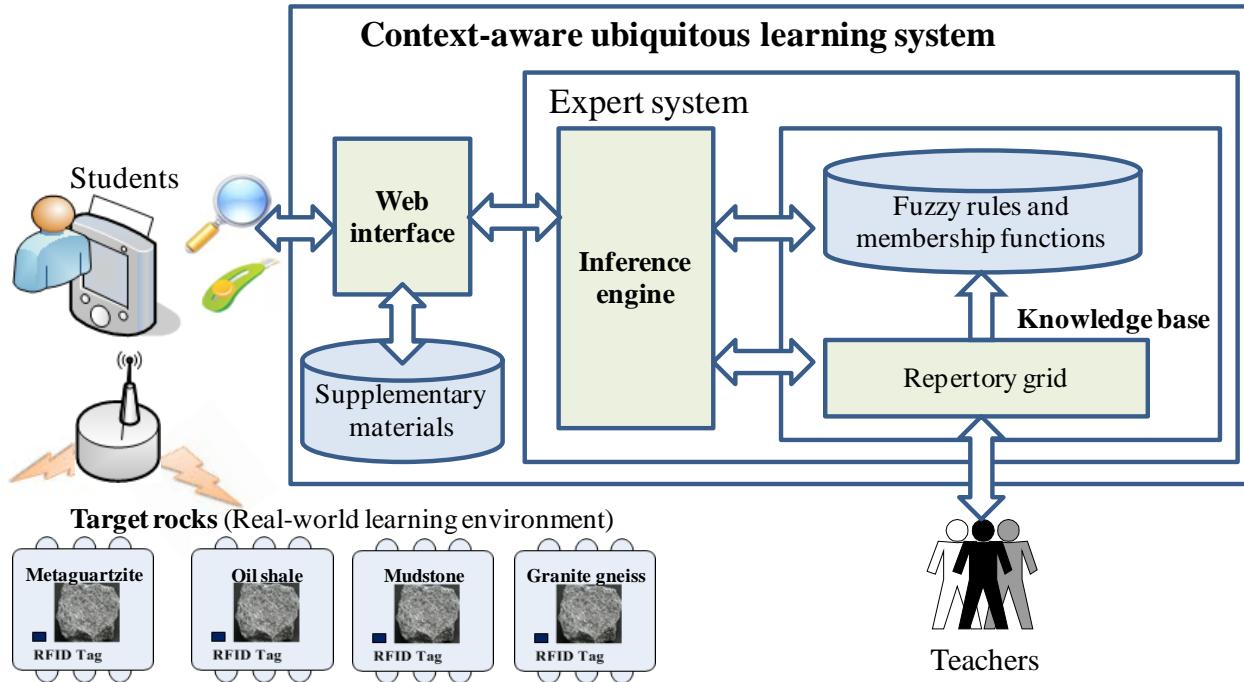


Figure 1. Structure of the expert system-based context-aware ubiquitous learning environment

Before a learning activity, domain experts (i.e., experienced teachers) are asked to provide the knowledge for identifying the learning targets by employing the repertory grid approach. The elicited knowledge is then used for guiding the students to construct their own repertory grids and to clarify some misconceptions during the learning process. Table 1 shows an illustrative example of a partial repertory grid developed by the teachers, which contains the knowledge for distinguishing a set of rocks that are often used to identify geological age for learning about the Earth's history and processes.

Table 1. Illustrative example of a repertory grid with $k = 5$

	Granite gneiss	Oil shale	Mudstone	Gabbro	Serpentinite	
Highly Crystallized	1	5	5	1	1	Not crystallized
Highly hard	1	3	5	2	1	Not hard
Highly glossy	2	5	5	4	5	Not glossy
Highly Laminated	5	1	2	5	5	Not laminated

In addition to the original repertory grid provided by the domain experts, the content of the grid is transferred to a set of fuzzy rules based on the procedure proposed by Tseng and Wu (2007), that is, a rule is generated from each column of the repertory grid by using High, More or less high, Average, More or less low and Low to represent the rating values 1, 2, 3, 4 and 5, respectively. For example, from the first column of Table 1, the following rule is generated:

R₀₁: IF the Crystallized degree is High
 AND the hardness degree is High
 AND the glossy degree is More or less high
 AND the Laminated degree is Low
 THEN the target rock is likely to be Granite gneiss.

The membership functions for Low, Average and High are defined as follows:

$$LOW(x; \alpha, \beta, \gamma) = \begin{cases} 1 & \text{for } x \leq \alpha \\ 1 - 2\left(\frac{x-\alpha}{\gamma-\alpha}\right)^2 & \text{for } \alpha \leq x \leq \beta \\ 2\left(\frac{x-\gamma}{\gamma-\alpha}\right)^2 & \text{for } \beta \leq x \leq \gamma \\ 0 & \text{for } x \geq \gamma \end{cases}$$

$$AVERAGE(x; \alpha, \beta, \gamma) = \begin{cases} 0 & \text{for } x \leq \alpha \\ 2\left(\frac{x-\alpha}{\beta-\alpha}\right)^2 & \text{for } \alpha \leq x \leq \frac{(\alpha+\beta)}{2} \\ 1 - 2\left(\frac{x-\beta}{\beta-\alpha}\right)^2 & \text{for } \frac{(\alpha+\beta)}{2} \leq x \leq \beta \\ 1 - 2\left(\frac{x-\beta}{\gamma-\beta}\right)^2 & \text{for } \beta \leq x \leq \frac{(\beta+\gamma)}{2} \\ 2\left(\frac{x-\gamma}{\gamma-\beta}\right)^2 & \text{for } \frac{(\beta+\gamma)}{2} \leq x \leq \gamma \\ 0 & \text{for } x \geq \gamma \end{cases}$$

$$HIGH(x; \alpha, \beta, \gamma) = \begin{cases} 0 & \text{for } x \leq \alpha \\ 2\left(\frac{x-\alpha}{\gamma-\alpha}\right)^2 & \text{for } \alpha \leq x \leq \beta \\ 1 - 2\left(\frac{x-\gamma}{\gamma-\alpha}\right)^2 & \text{for } \beta \leq x \leq \gamma \\ 1 & \text{for } x \geq \gamma \end{cases}$$

In these membership functions, the parameters α , β and γ are determined by the domain experts based on the characteristics of the target elements. For example, assume that the values of hardness degree range from 0 to 1.0, α , β and γ could be 0, 0.5, 1.0, respectively.

Based on the knowledge provided by the domain experts (i.e., teachers), the context-aware ubiquitous learning system is able to evaluate whether the students can correctly identify the target rocks by comparing their answers with those of the expert system.

Figure 2 shows how the learning system guides the students to complete their learning tasks. In each learning stage, the student is asked to walk toward the specified learning target and sense the tag on the target with the RFID reader on the mobile device. Once the learning system has confirmed the location of the student, it starts to state the learning tasks and guide the student to observe the target based on the knowledge provided by the teacher. If the student fails to correctly collect a datum for describing some features (e.g., the distance between the student's input value and the corresponding value in the objective grid is greater than $\theta = (k-1)/2$; that is, they are in different poles of the grid), the learning system will guide the student to observe a comparative target to better understand that feature. Following that, the learning system will ask the student to go back to the current target to collect the datum again.

Consider the illustrative example given in Table 1; assuming that Mudstone is the current target, it should be “not crystallized” (with a rating value of 5); however, the value given by the student is 2, which represents “crystallized.” For the 5-scale rating mechanism, $\theta = (5 - 1)/2 = 2$. In this case, the distance between the input value and the corresponding value in the objective grid is $5 - 2 = 3$, which is greater than $\theta = 2$. In this case, the learning system judges that the student has difficulty in identifying the feature “crystallized,” and hence guides the student to observe a comparative rock that is “crystallized” to clarify the misconception. After making the comparison, the student is asked to input the value again. Once the student has correctly identified the feature, the learning system guides him/her to identify the next feature of that rock. The learning activity is completed when all of the features of each target rock have been correctly identified.

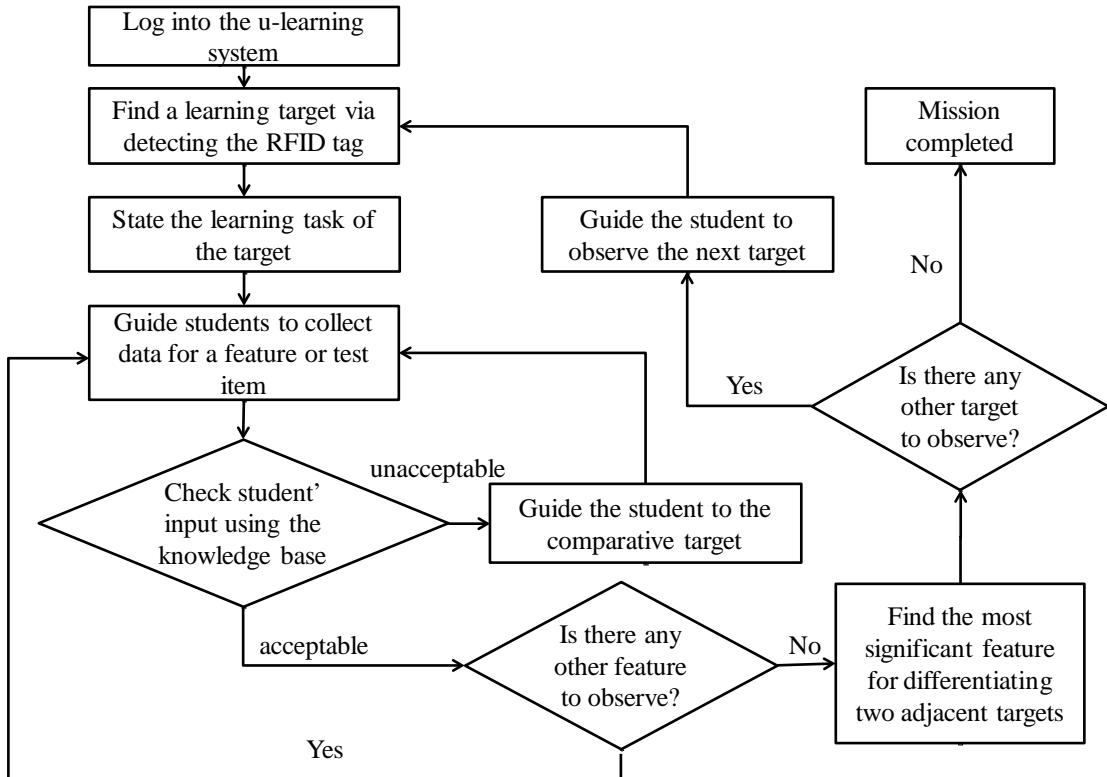


Figure 2. The learning guidance procedure

In addition to helping the students collect data based on observations, the learning system also guides them to collect data from the learning targets. For example, Figure 3 shows how the context-aware ubiquitous learning system guides a student to test the hardness of the target rock in a Geosciences learning activity. The student is asked to use the knife to scratch the rock, and then use the magnifying glass to observe the surface of the rock.

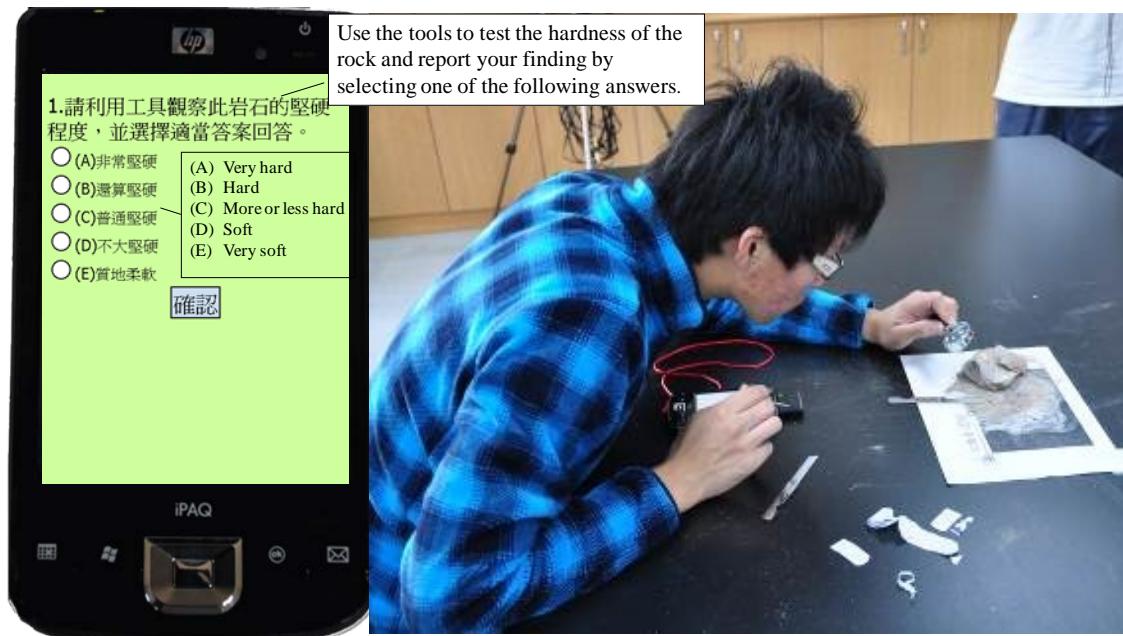


Figure 3. Example of guiding the student to test the hardness of a rock

Furthermore, the learning system will guide the student to observe and record every feature of the target, and then those of the next target. During the learning activity, the students are arranged to observe the targets and collect data in a “most similar-first” sequence; that is, any two adjacent targets that the students observe have the most similar features. Consequently, the learning system will ask the students to compare the features of two adjacent targets once the observation and data collection tasks for the two targets are completed. For example, Figure 4 shows the context-aware ubiquitous learning system interface for guiding the students to find the most significant feature that can be used to differentiate two rocks, that is, Mudstone and Oil shale.

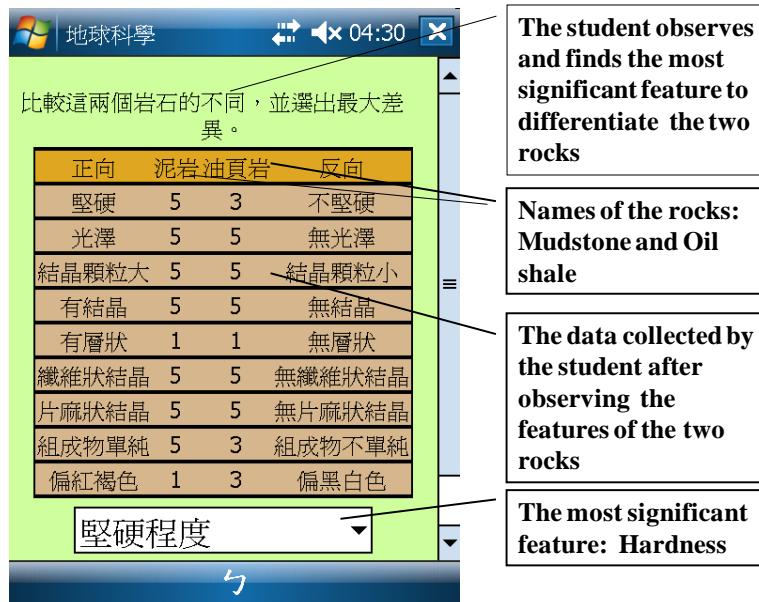


Figure 4. Example of comparing the features of two rocks

After the students have completed the observations and data collection for all of the learning targets, the learning system depicts the collected data to the students, with which the students can make an overall review of the learning targets; moreover, they can have an integrated view of the similarities and differences between the targets. Following that, an in-field assessment is conducted to evaluate whether the students have the competence to identify the target rocks based on what they have observed and learned during the learning activity. The learning system guides individual students to each learning target and asks them to identify it. The answers given by the students are evaluated by the expert system. For those incorrect answers, feedback is given by showing the “correct” and “incorrect” elements with the ratings of each construct to help the students make reflections.

Experiment design

Based on the proposed approach, an experiment was conducted on a senior high school Geosciences course. The objective of this learning activity was to train the students to identify and differentiate the features of a set of target rocks (i.e., Metaguartzite, Oil shale, Mudstone, Granite gneiss, Granite, Diorite, Serpentinite, Gabbro and Conglomerate), which has been recognized as an important and fundamental topic for understanding the Earth’s history and processes (Kortz & Murray, 2009). It should be noted that the learning activity was part of the existing curriculum of the sample school; that is, the learning activity conducted in this study reflected the teaching reality of that school.

The real-world learning environment is a science laboratory, in which each target rock is labeled with an RFID tag, and each student is equipped with a set of tools, including a mobile device with an RFID reader, a knife and a magnifying glass. The learning system first presents the learning task via the mobile device and then checks the location of individual students via the RFID reader. Once the student is near the target rock, the learning system starts to guide the students to observe the rock based on the features pre-defined by the teacher. The student can use the knife to scratch the surface of the rock to test its hardness, observe the color, shape and size of the rock, and

touch the rock to feel its surface granular structure. Moreover, the student can also use the magnifying glass to more closely observe the crystallized, glossiness and laminated degrees of the rock.

During the learning process of identifying rocks, the students need to collect various data concerning the rocks (e.g., color, shape, texture, transparency and hardness) via observing the surface and detecting the physical properties of the rocks (Ramasundaram, Grunwald, Mangeot, Comerford, & Bliss, 2005). Like other science courses, the aim of the subject unit is to engage students in “focusing” on important features of the learning targets (i.e., the rocks) and “selecting” proper features for “discriminating” and “distinguishing” the targets via conducting contextualized inquiry-based learning activities (Bloom, 1994; Feletti, 1993; Levy, Aiyegbayo, & Little, 2009; Li & Lim, 2008).

Participants

The participants of this experiment were 58 tenth grade students from two classes of a senior high school in Tainan County, Taiwan. One class with 30 students, including 20 males and 10 females, was assigned to be the experimental group. The other class with 28 students, including 20 males and 8 females, was the control group. All of the students were taught by the same teacher who had more than 5 years experience teaching the Geosciences course.

Experiment procedure

As shown in Figure 5, the students in the experimental group were guided to learn with the Geosciences context-aware ubiquitous learning system with the proposed repertory grid-oriented guiding mechanism. Both groups of students were equipped with a knife and a magnifying glass during the learning activity.

During the learning activity, the Geosciences context-aware ubiquitous learning system guided the students in the experimental group to observe and compare the target rocks. Moreover, they were asked to collect data related to the current target rock via observations, touching or even using the knife to test the hardness of the rock. Furthermore, the learning system would invoke the expert system to evaluate whether the students were able to correctly identify the target rocks and gave them hints or guides them to make further observations if their answers were incorrect.

On the other hand, the students in the control group learned with the conventional context-aware u-learning approach, in which the learning system presented the same learning tasks to the students, guided them to observe the target rocks, and provided the same supplementary materials to them for completing the learning missions. In each learning stage, the students were also asked to collect data of the current target rock for completing the learning sheet via observations, touching or using the knife to test the hardness of the rock.

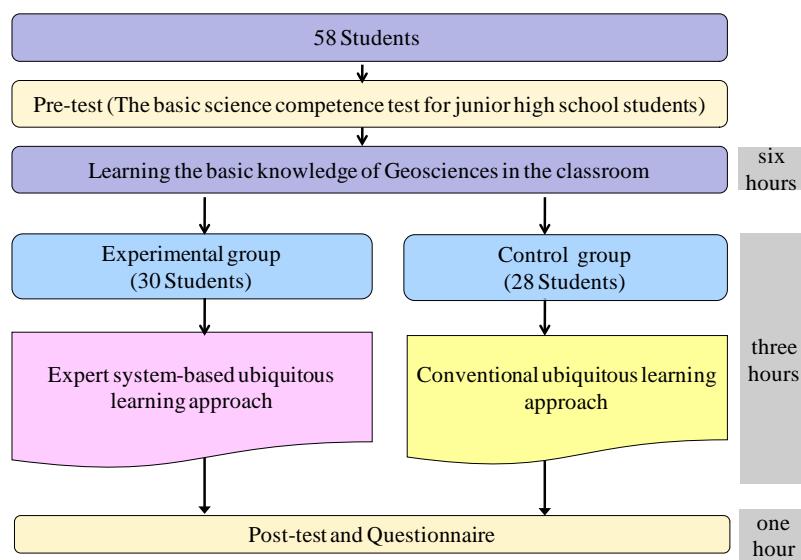


Figure 5. Experiment procedure

Measuring tools

The pre-test aimed to evaluate the basic Geosciences knowledge of the students before participating in the learning activity. It consisted of 40 multiple choice items with a perfect score of 80. The post-test aimed to test the students' competences for identifying and differentiating the target rocks. It consisted of 24 multiple choice items with one point per item, including 5 items for the "Remember" category, 4 items for the "Understanding" category, 3 items for the "Apply" category, 7 items for the "Analysis" category, and 5 items for the "Evaluate" category, based on the revised Bloom's taxonomy of educational objectives (Anderson & Krathwohl, 2001). All of the test items were developed by two teachers who had more than 5 years experience teaching the course, and were verified by a researcher who had more than 20 years experience in developing test items.

The learning attitude and technology acceptance questionnaire originated from the questionnaire developed by Chu, Hwang, Tsai, and Tseng (2010). It consisted of 19 items with a six-point Likert rating scheme, including 6 items for "Learning attitude toward Natural science," 5 items for "Perceived usefulness" and 7 items for "Perceived ease of use." The Cronbach's alpha values of the questionnaire and the three dimensions were 0.94, 0.9, 0.95 and 0.94, respectively.

Experimental results and discussion

In this study, a context-aware u-learning environment for Geosciences courses was developed by providing an interactive guiding mechanism to help students recognize and differentiate the target rocks in the real world. In this section, the experimental results are presented and discussed in terms of the dimensions of learning achievement, Bloom's taxonomy of educational objectives, perceived ease of use and perceived usefulness of using the context-aware ubiquitous learning system, as well as learning attitudes toward the Geosciences course.

Learning achievements

Before participating in the learning activity, the students took a pre-test, which aimed to evaluate their prior knowledge for learning the subject unit. The means (SDs) of the experimental group and the control group were 77.56 (1.94) and 76.71 (2.19), respectively. The t-test result of the pre-test scores of the two groups showed no significant difference ($t = 1.57, p > .05$), implying that the two groups of students had equivalent prior knowledge before participating in the learning activity.

To evaluate the performance of the context-aware ubiquitous learning system, ANCOVA was used to exclude the difference between the prior knowledge of the two groups by using the pre-test scores as the covariate and the post-test scores as the dependent variable. Table 2 summarizes the ANCOVA results, in which the adjusted mean values of the post-test scores were 17.94 for the experimental group, and 13.67 for the control group; moreover, a significant difference was found between the two groups with $F = 47.12$ and $p < .05$, implying that the context-aware ubiquitous learning system had significantly positive effects on the learning achievements of the students for the Geosciences course.

Table 2. Descriptive data and ANCOVA results of the post-test scores

		N	Mean	S.D.	Adjusted Mean	Std.Error.	F
Post-test	control group	28	13.54	2.46	13.67	0.44	47.12*
	experimental group	30	18.07	2.36	17.94	0.43	

* $p < .05$

Bloom's taxonomy of educational objectives

In the Geosciences learning activity, the tasks were arranged to foster the students' various competences concerning the cognitive processes of Bloom's Taxonomy of educational objectives, including "Remember" (e.g., recognizing or identifying the rocks), "Understand" (e.g., illustrating and classifying the rocks), "Apply" (e.g., addressing the usage of the rocks), "Analyze" (e.g., differentiating or distinguishing the rocks) and "Evaluate" (e.g., detecting and testing

the features of the rocks) (Anderson et al., 2001; Bloom et al., 1956). Without effective guidance, such a learning scenario might be too complex for the students, in particular, for those higher order cognitive processes, such as “Analyze” and “Evaluate” (Hwang, Chu, Lin, & Tsai, 2011). Therefore, it is worth investigating the effects of the context-aware ubiquitous learning approach on the cognitive processes of Bloom's Taxonomy of educational objectives.

Table 3 shows the ANCOVA results for the two groups' post-test scores of the test items related to the individual cognitive dimensions. It is found that the F values of the “Remember,” “Apply,” “Analyze” and “Evaluate” dimensions are 6.10, 6.10, 6.14 and 44.21, respectively, with $p < .05$. Moreover, the average scores of the experimental group (i.e., 3.63, 2.73, 5.27 and 2.70) are higher than those of the control group (i.e., 2.79, 2.21, 3.18 and 1.82), implying that the learning achievements of the experimental group are significantly better than those of the control group in these four dimensions. Consequently, it is concluded that the context-aware ubiquitous learning approach with the interactive guidance mechanism can benefit the students in enhancing their learning performance, including those higher order thinking competences such as “Analyze” ($F = 44.21$ and $p < .05$) and “Evaluate” ($F = 7.15$ and $p < .05$).

Table 3. ANCOVA results for the post-test scores of the individual cognitive dimensions

		N	Mean	S.D.	Adjusted Mean	Std. Error.	F	d
Remember (5 points)	control group	28	2.79	1.33	2.80	0.24	6.10*	0.64
	experimental group	30	3.63	1.30	3.61	0.24		
Understand (4 points)	control group	28	3.54	0.69	3.54	3.30	1.36	0.31
	experimental group	30	3.73	0.52	3.71	3.50		
Apply (3 points)	control group	28	2.21	0.88	2.26	0.13	6.14*	0.74
	experimental group	30	2.73	0.45	2.70	0.12		
Analyze (7 points)	control group	28	3.18	1.25	3.19	0.22	44.21*	1.81
	experimental group	30	5.27	1.05	5.25	0.21		
Evaluate (5 points)	control group	28	1.82	1.02	1.88	0.21	7.15*	0.79
	experimental group	30	2.70	1.18	2.65	0.20		

* $p < .05$

Perceived ease of use and usefulness of the context-aware ubiquitous learning system

To better understand the students' perceptions of the use of the context-aware ubiquitous learning system, this study also collected the students' feedback in terms of “perceived usefulness” and “perceived ease of use,” as shown in Table 4. It is found that most students gave positive feedback concerning the two dimensions of the context-aware ubiquitous learning system. The average ratings for “perceived usefulness” are 4.59 and 4.42 for the experimental group and the control group, respectively; moreover, their average ratings for “perceived ease of use” are 4.38 and 4.51, implying that the context-aware ubiquitous learning system has been well accepted by the students. However, in comparison with the ratings given by the control group, it should be noted that the students in the experimental group gave higher ratings to “perceived usefulness,” while giving lower ratings to “perceived ease of use.”

By applying the t-test to the ratings given by the two groups, significant differences were found between the ratings for the items “I do not need to put in lots of effort during the context-aware ubiquitous learning activity” and “It is not difficult to use the context-aware ubiquitous learning system,” indicating that, in comparison with the control group, the students in the experimental group put in more effort during the learning activity and felt that using the context-aware ubiquitous learning system was not very easy. Moreover, the experimental group also gave lower average ratings for the items “It is very easy to work with the interface of the context-aware ubiquitous learning system” and “Generally speaking, the context-aware ubiquitous learning system is easy to use” than those given by the control group. It can be seen that, on average, the use of the mobile devices is not difficult for the students, but the design of the user interface can be improved, in particular, for the context-aware ubiquitous learning system with the interactive guiding approach.

In terms of perceived usefulness, the items “The context-aware ubiquitous learning system is helpful to me in learning new knowledge” and “Using a PDA to learn and observe the learning targets in the real world is helpful to

me” received the highest average rating from the experimental group, implying that most students in the experimental group identified the usefulness of the context-aware ubiquitous learning approach for guiding them to learn in the real world. It should be noted that, for the item “The context-aware ubiquitous learning system provides a more convenient learning environment,” the experimental group gave a lower average rating (4.43) than that of the control group (4.54). This result is consistent with those findings concerning “perceived ease of use.”

Table 4. Questionnaire results about perceived ease of use and usefulness of the context-aware ubiquitous learning system

Dimension	Questionnaire item	Group	mean	S.D.	t
Perceived Usefulness	The context-aware ubiquitous learning system provides a convenient learning environment.	Control	4.54	0.96	0.29
		Experiment	4.43	1.61	
	The context-aware ubiquitous learning system is helpful to me in learning new knowledge.	Control	4.50	0.75	-0.84
		Experiment	4.73	1.28	
	The use of sensing technology has smoothed the context-aware ubiquitous learning process.	Control	4.04	1.00	-0.81
		Experiment	4.30	1.44	
Perceived Ease of Use	Using a PDA to learn and observe the learning targets in the real world is helpful to me.	Control	4.71	0.85	-0.78
		Experiment	4.93	1.23	
	I feel that I can learn better with this context-aware ubiquitous learning approach.	Control	4.32	1.02	-0.07
		Experiment	4.53	1.28	
	It is not difficult to use the context-aware ubiquitous learning system.	Control	5.32	0.67	2.47*
		Experiment	4.73	1.08	
	I do not need to put in lots of effort during the context-aware ubiquitous learning activity.	Control	4.61	0.99	3.42*
		Experiment	3.53	1.36	
	The context-aware ubiquitous learning content is easy to understand.	Control	4.32	0.99	-0.05
		Experiment	4.33	1.03	
	I learned how to use the context-aware ubiquitous learning system quickly.	Control	5.00	0.72	-0.48
		Experiment	5.10	0.84	
	During the learning activity, operating the PDA is not difficult for me.	Control	5.04	0.79	-0.29
		Experiment	5.10	0.88	
	It is very easy to work with the interface of the context-aware ubiquitous learning system.	Control	3.71	1.12	-1.04
		Experiment	3.37	1.40	
	Generally speaking, the context-aware ubiquitous learning system is easy to use.	Control	4.97	0.92	1.22
		Experiment	4.63	1.13	

Learning attitudes toward Geosciences

Table 5 shows the students’ feedback concerning their learning attitudes toward Geosciences. It is found that the students in the experimental group showed better learning attitudes than those in the control group; in particular, for the items “I would like to learn more about the rocks in the real world environment” and “I would like to observe the real-world targets of Geosciences,” which showed significant differences between the average ratings given by the two groups. Consequently, it can be seen that the provision of an interactive guiding mechanism in the real-world environment is important for improving the learning attitude of students.

Table 5. Questionnaire results about learning attitudes toward Geosciences

Questionnaire item	Group	Mean	S.D.	t
I like to learn to identify and differentiate the rocks after participating in this learning activity.	Control	4.46	0.96	-0.64
	Experiment	4.67	1.40	
I would like to learn more about the rocks in the real world environment.	Control	4.54	0.96	-2.47*
	Experiment	5.17	0.99	
It is important to learn to differentiate the rocks.	Control	4.32	0.98	-1.32
	Experiment	4.70	1.18	
I would like to observe more real-world targets of Geosciences.	Control	4.82	0.86	-3.38*
	Experiment	5.57	0.82	
I will actively search for more information and learn about	Control	4.50	0.92	-1.26

Geosciences. It is important for everyone to take the Geosciences course.	Experiment	4.87	1.25	
	Control	4.11	0.92	
	Experiment	4.47	1.25	-1.24

Conclusions

In this study, an expert system was developed to support context-aware ubiquitous learning activities for science courses. An experiment was conducted in a Geosciences course to help students recognize and differentiate the target rocks in a laboratory. The experimental results showed that the students' learning achievements were significantly improved in terms of several cognitive processes in Bloom's taxonomy of educational objectives with the assistance of this real-world learning guidance approach. Moreover, it is found that the experimental group students had significantly better learning achievement than the control group students in the "Remember," "Apply," "Analyze" and "Evaluate" dimensions, while no significant difference was found between the two groups in the "Understand" dimension.

As the grid-based interactive guiding mechanism can be seen as a Mindtool that assists students to collect and organize what they have observed and learned in the real world, such findings conform to what has been reported in previous studies, namely that computerized Mindtools are able to engage students in higher order thinking, such as "Analyze" and "Evaluate" (Chu, Hwang, & Tsai, 2010; Jonassen, 2000). In particular, the students' learning performance related to the "Analyze" category reveals a rather large effect size, showing that the use of Mindtools in such a context-aware u-learning environment is helpful to the students in improving their analysis performance (Cohen, 1988, 1992). Furthermore, researchers have found that representing knowledge in grids makes it easy to examine and interpret the structure and logic of the knowledge as well as to recognize the differences between the targets (Cragun & Steudel, 1987; Hwang, Chu, Lin, & Tsai, 2011); therefore, the findings of this study concerning those four dimensions are reasonable. In terms of the "Understand" dimension, the difference between the two groups is not significant since both groups of students have been situated to learn in the real-world environment with access to digital supplementary materials. Researchers have pointed out that such an authentic learning approach is helpful to students in understanding the concepts to be learned (Arnseth, 2008; Hwang, Yang, Tsai, & Yang, 2009; Resnick, 1987); that is, the students' performance concerning the "Understand" dimension could mainly be affected by the real-world environment in which they have been situated.

Although the performance of the learning system is desirable, it should be noted that the PDAs used in this study cannot represent modern mobile technology. In fact, modern mobile technology is no more a byproduct of desktop technology as was the case with PDAs that mimicked desktop and laptop behavior. New mobile devices, such as iPads and Android Pads, not only deviate from the established PC world, but also tend to integrate and interconnect with users in such a manner that cannot be reached by simple PDAs. Therefore, it is worth adapting the proposed approach of this study to modern mobile technology. Furthermore, there are several extended issues of this study to be investigated. First, the real-world learning behaviors of the students have not been fully recorded and analyzed; therefore, it is worth investigating the real-world learning patterns of the students and the relationships between the learning patterns and the learning achievements. Second, it is worth applying this approach to other subject units to evaluate its effectiveness in depth. Third, for those learning subjects that are not concerned with differentiating knowledge, it is worth developing new learning guidance mechanisms or Mindtools to help students improve their learning effectiveness. Third, one limitation of this study is that PDAs are not as popular and powerful (in terms of user interface, screen resolution, memory size and CPU performance) as those modern mobile platforms, such as iOS or Android; therefore, it remains a challenging issue to implement such an approach on the modern mobile devices (e.g., smartphones and tablet personal computers) with new sensing technologies, such as the QR (Quick Response) code, in the future.

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Digital Performance Learning: Utilizing a Course Weblog for Mediating Communication

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ABSTRACT

Two sections of university-level technical writing courses were given an authentic task to write an article for publication for an outside stakeholder. A quasi-experimental study was conducted to determine the differences in learning outcomes between students using traditional writing methods and those using social media to generate articles. One section was randomly assigned to follow the traditional writing process using computer-mediated writing and small group peer workshops of paper drafts, while the other section published its work-in-progress on a course blog and engaged in web-mediated online collaboration to determine if there are meaningful differences between computer-mediated and web-mediated writing as measured by learning outcomes in terms of publication rates and grades. The results of this study demonstrate that utilizing an online social network in the form of a course blog positively impacted learning outcomes; however, a close examination of the published peer review feedback on the course blog indicated a moderately negative relationship between the quality of the feedback received and acceptance scores. Thus, the value of the web-mediated workshop was not based on the outcome of the workshop, but rather on having providing feedback, which generated a higher level of engagement and more time spent on task as compared to the paper draft workshop section.

Keywords

Course blog, Web-mediated writing, Authentic task, Collaboration

Introduction

There's an old folk saying that goes something like this: *No man knows the truth about himself, only his neighbors do*. Having students publish their work on blogs is one way for them to find out the truth about their writing from their peers. Online publishing provides a motivating factor for students to improve performance as quickly and efficiently as possible, increasing their level of engagement and enhancing attention to collaboration, self-regulation, and performance. This study will compare the process and outcome of writing published on blogs to computer-generated paper drafts to determine if a web 2.0 social learning space in the form of a course blog affects learning outcomes.

Much ado has been made of the introduction of digital publishing and social networks into the writing classroom; in fact, a number of exploratory studies indicate that blogs enhance a sense of community, improve writing, increase self-reflection, and build professionalism (Lee, 2010; Frye, Trathen & Koppenhaver, 2010; Camp & Bolstad, 2011; Chretien, Goldman & Faselis, 2008; Fessakis, Tatsis, & Dimitracopoulou, 2008; Quible, 2005; Byington, 2011; Miyazoe, & Anderson, 2010; Gallagher, 2010). No experimental studies have established the effectiveness of writing instruction, which employs web-mediated writing tools and publishing. Thus, this research study was designed as a quasi-experimental study involving two nonrandomized sections of university-level technical writing classes that were given a project to write an article for publication. One group worked in a traditional classroom with paper drafts while the other worked in a computer lab and generated their work on a course blog, allowing for a direct comparison of learning outcomes and a challenge: paper versus digital media, which group would publish the most articles and generate higher grades?

Scientists and engineers, who are responsible for the bulk of technical writing, are often prepared to write academically for scholarly publications; however, many scientists and engineers end up working for public and private companies and find themselves in need of skills that will help them communicate with audiences that lack specialized training. A project to write an article for the Pennsylvania Center for the Book was ideal to train this

group of junior- and senior-level university students to write for the general public. In order to publish an article, each student had to meet standards of excellence as set forth by the editor in terms of meeting goals of engagement, readability, diligent research, and an effective visual argument.

Literature overview

Building on social constructivist theory, Slavin (1996) argued that collaborative learning ties motivational factors directly to levels of social cohesion and its impact on cognitive processes. Writing instruction combines the cognitive process of knowledge construction when creating content, scaffolding, through the generation of multiple drafts, and social interaction in the form of peer review. One way to further enhance social interaction is through the introduction of a social learning space and technologies that expand the boundaries of the traditional writing classroom to a larger, more visible online community, which ultimately enhances social cohesion and peer interactions through a web-mediated writing environment.

Furthermore, Lave and Wenger's (1991) social theory of learning argues that social participation is at the center of the learning process. In this sense, community, according to Lave and Wenger (1991), is the social configuration defined by action, which occurs through discourse. They identify this learning environment where individuals are joined by relationships that share common practices and activities as "Communities of Practice" or (CoP), or individuals joined by relationships that share common practices and activities. CoP have been integrated into the learning theory of situated cognition, which claims that all human thought or knowledge is situated or adapted to the environment. Proponents of this theory believe that learning takes place during participation in a CoP (Driscoll, 2005).

Accordingly, blogs are an interactive communication technology (ICT), which allow for the formation of CoP. With this social network platform, blog users with no technical expertise can post content, and readers can make comments. According to Minocha (2009), "Social software enables communication and networking between groups where the members are made aware of what other groups are doing and where each member of the group benefits" (p. 382).

Bower, Hedberg, and Kuswara (2010) argued that technology is "the mediator for collaboration and representation" (p. 181). They noted that the most effective use of blogs has been through the creation of a course blog, which allows students to collaborate in order to formulate expertise in a shared field of knowledge. Their theory of learning design argues that blogs are best used in situations where concepts and issues are being explained and when the immediacy of feedback is required (p. 190). Thus, learning design is a function of the content of the subject being taught and the context to which a writing response is generated, which, in turn, determines the "best practice" technology to incorporate into the design (Bower et al. 2010). Writing involves increasing interactivity with tools and their social usage, according to Shaffer and Clinton (2006); they argue that digital worlds make learning easier by creating meaningful experiences, which accomplish meaningful ends. Our study utilized a course blog to act as a mediator of activity.

Social media writing and the role of audience

Essentially blogs, or online journals, are rapidly being adopted for instructional purposes to amplify the importance of audience in the writing situation since blogs expand audience in terms of numbers and types of readers (Woo & Wang, 2009; Magnifico, 2010; Warschauer & Grimes, 2007; Lin & Chien, 2009). For example, Magnifico (2010) explored how social media environments affect the cognitive process of writing and the role of audience. A traditional writing perspective contends that writers imagine the audience is interested in the subject matter; thus, the focus is cognitive rather than social; that is, the focus is on the subject matter itself and not the audience (Magnifico, 2010). The writer's role is to act as an individual expert on the subject matter, making new connections to the audience's prior knowledge (Magnifico, 2010). With online publishing, the focus shifts to the audience, making the social, rather than the cognitive, the driving force underlying the rhetorical situation, thereby, increasing student engagement.

Blogs as learning communities

A number of studies support the development of blogs to promote learning and community at the university level (Lee, 2010; Frye, Trathen, & Koppenhaver, 2010; Camp & Bolstad, 2011; Chretien, Goldman & Faselis, 2008; Fessakis, Tatsis & Dimitracopoulou, 2008; Quible, 2005; Byington, 2011; Miyazoe & Anderson, 2010; Gallagher, 2010). For example, Hung and Yuen (2010) in an exploratory study found that blogs promoted community and raised feelings of social connectedness. In their study, Camp and Bolstad (2011) addressed the need for learning communities as an attrition tool for retaining first-year university students; however, the results of their qualitative research study were mixed. While blogs improved writing, very few students believed that the exercise had any value in terms of their future career (Camp & Bolstad, 2011). However, the bulk of the studies examining the effectiveness of weblogs have been exploratory. For this reason, this study was designed as a quasi-experimental study to test, empirically, the differences in learning outcomes between traditional and web-mediated writing processes.

Blogs develop professionalism

A number of studies have been conducted that demonstrate blogs can be used effectively to develop professionalism (Hodgson & Wong, 2011; Chretien, Goldman & Faselis, 2008; Lapp, Shea & Wolsey, 2011; Chong, 2010). For example, Buechler (2010) in a one-shot case study found that blogs could be used effectively to teach collaboration, demonstrate professional communication proficiency, and ingrain a sense of responsibility for publicly expressed opinions. Manion and Selfe (2012), through the retrospective analysis of three case studies of university students, identified the “appropriate assessment ecology” for designing digital media projects: the work should derive from students’ interests, students should be responsible for the final product, and stakeholders outside of the classroom should take part in the assessment. The Manion and Selfe (2012) study identified the idea ecology for testing blogs. Our study set out to measure this ecology’s effectiveness. Students selected topics for articles based on their research interests and were responsible for producing the content for an outside editor.

Evaluating peer review

A number of studies have established the effectiveness of the peer review process (Wilkinson & Fung, 2002; Reese-Durham, 2005; Lundstrom & Baker, 2009). Armstrong & Paulson (2008) identified peer review as being the most popular tool used in composition classes to improve student writing; however, in spite of its common use, no standardized formula for conducting peer review sessions is practiced. Peer review sessions can generate a wide range of activities from editing and critiquing, to evaluating the quality of writing. Despite the prevalence of the peer editing according to Zundert, Sluijsmans, and van Merriënboer (2010), gaps in the literature make it difficult to describe exactly what constitutes effective peer review.

Resistance to blogs

A number of studies have assessed the risks, benefits, and perceptions of using blogs in the writing classroom and have made a strong case that blogging is less effective than what the proponents of blogging suggest (Divitini, Haugalokken & Morken, 2005; Halic, Lee, Paulus & Spence, 2010; Lin & Chien, 2009; and Lin, Lin, & Hsu, 2011). For example, Lin, Lin, and Hsu (2011) examined claims that blogs were labor-intensive and that evidence attributed to their benefits was unconvincing. In a quasi-experimental study, Lin et al. (2011) found that both the control and experimental blog group demonstrated improvement and that given the labor and time implementing the blogs required, they concluded that perhaps, after all, blogs were not the most effective intervention tool. In addition, Woo & Reeves (2007) found that blogs only promote critical thinking when a suitable topic is chosen with available strong information sourcing, and without this support, information literacy training is a necessary component to improving the effectiveness of online writing in terms of its ability to generate critical thinking. Perhaps, using blogs to collaboratively construct knowledge is not effective means to this end, although in terms of peer interaction and self-reflection, blogs are relatively useful (Woo & Reeves, 2007). Sharma (2010), in two unique case studies, found that blogs promote reflective thinking only when structured guidelines are present; however, they served as an effective tool to archive information and thinking. In this sense, Sharma’s pre-experimental results suggest that blogs may not be effectively engaging learning tools without a structured environment. Furthermore, Kim (2008) found

that using shared blogs and one-size fits all customized course blogs in the university setting are no more effective than current computer-mediated communication applications. Thus, the only quasi-experimental studies that have been conducted to test the effectiveness of blogs have demonstrated weblogs to be less effective than traditional writing classrooms.

This study proposes to demonstrate empirically that a social learning space in the form of a course blog might improve writing effectively. Building on research that indicates social media writing enhances the role of audience (Magnifico, 2010; Warschauer & Grimes, 2007; Lin & Chien, 2009; Deng & Yuen, 2011; Clark, 2010), this study was designed to demonstrate that a social learning space combined with an authentic writing project and outside stakeholders will improve learning outcomes beyond what is experienced in a traditional writing classroom.

The purpose of this study is to measure and evaluate the effectiveness a course blog, which uses web-mediated writing practices combined with digital publishing, as compared to the practices of a traditional writing class, which uses paper drafts. Measurements will include a comparison of acceptance scores of articles rated by an outside editor, grades, and an evaluation of the basic components of technical writing including the following variables: the use of images, outside sources, and measures of error rates. In addition, the study will include an examination of the published feedback forums on the course blog to determine feedback relationships to learning outcomes. Specifically, the type and quality of peer review feedback, as published on the course blog, will be measured to determine its relationship to levels of acceptance for publication. The following research questions will be addressed:

- How does the publishing of writing on blogs as compared to the traditional computer assisted writing on paper affect learning outcomes in terms of levels of acceptance rates for publication?
- How does the publishing of writing on blogs as compared to the traditional computer assisted writing on paper affect learning outcomes in terms of grades?
- Does the type and quality of peer draft comments as published on a course blog relate to or predict the level of acceptance of the final article?

Method

This study was designed as a two-part study, with the first part including a nonrandomized control group in the form of a traditional writing classroom, and an experimental group that received a treatment in the form of a course blog for publishing web-mediated work-in-progress, feedback, and final drafts. The second part of the study involved a close examination of the peer feedback published on the course blog and did not include a control group working on paper.

The following null hypotheses will be tested:

- There will be no statistically significant measurable difference between learning outcomes of participants who used the blogs and those who were in the traditional classroom as measured by rates of acceptance.
- There will be no statistically significant measurable difference between learning outcomes of participants who used the blogs and those who were in the traditional classroom as measured by grades.
- The quality and types of peer review comments will demonstrate no relationship to acceptance of the final article.

A number of exploratory studies support the development of blogs to promote learning and community (Lee, 2010; Frye, Trathen, & Koppenhaver, 2010; Camp & Bolstad, 2011; Chretien, Goldman & Faselis, 2008; Fessakis, Tatsis & Dimitracopoulou, 2008; Quible, 2005; Byington, 2011; Miyazoe & Anderson, 2010; Gallagher, 2010); thus, it is likely that the null hypothesis will be rejected in all four cases.

The research took place in two separate Penn State University campus classrooms. Participants were enrolled in two sections of technical writing. Both sections were taught by the same instructor and met back-to-back in the late afternoon. The classes met twice weekly for one hour and 15 minutes. The project grade was divided into three parts: an annotated bibliography, a proposal letter, and an article.

Participants

Participants were enrolled in two sections of technical writing taught through the English Department at Penn State. The course is designed for students enrolled in the applied sciences and scientific fields and is tailored to help students prepare to write professionally rather than for scholarly purposes. Each technical writing section consists of approximately 24 students, and in the case of this study, each section consisted of predominantly male students between the ages of 19 and 22 who were majoring in engineering fields. The students were chosen from a convenience sample of two nonrandomized sections of technical writing students. Each section was randomly assigned as a control group or an experimental group. Students were informed that they were participating in a classroom study to determine the effectiveness of utilizing a course blog. Since the students formed a non-vulnerable population and the study involved normal classroom activities, the Office for Research Protections at Penn State granted an exemption for the study and subsequent publication of data.

Data collection

The data collection included the following items: the course blog peer review feedback, recorded grades, and an editorial evaluation instrument. Grades were determined based on a series of grading rubrics designed specifically to address the learning objectives of each phase of the project. In addition, tabulation of numbers of outside sources, images, and errors for each article occurred during each phase of the writing project.

An outside stakeholder, or editor, was given a rubric for scoring each article. Each article was evaluated on a simple Likert scale that measured the amount of revision the student would have to complete in order to make the article of sufficient quality to be publishable. Two additional construct variables were added to the scoring sheet to provide internal validity: ease of reading and quality of article. The editor expressed his discomfort using blogging technology and his preference for paper submissions.

A model for coding and measuring the peer review comments was designed based on models developed by Sluijsmans et al. (2002), Prins et al. (2006) and Gielen et al. (2010). An analysis of the draft workshop will categorize and compare the value of the feedback based on the following criteria:

- Judgment or evaluative statements (1 pt)
- Comments pertaining to writing style and grammar and mechanics (2 pts)
- Constructive suggestions pertaining to content and organization (3 pts)

Published draft feedback was coded and scores were recorded for each category and for the overall total score for each draft and draft workshop. Learning outcomes were evaluated and scored by the instructor, the main researcher in this study, who measured grades according to a pre-designed rubric, and by an external editor who scored and selected articles for publication.

Procedures

Both the control group and treatment group were given the opportunity to write a course project for publication, an article, written expressly for the Pennsylvania Center for the Book, an award-winning website sponsored by the United States Library of Congress. The treatment group utilized a course weblog, which functioned as an online writing mediator for the publishing and collaboration of work-in-progress as online digital files; whereas, the control group followed traditional computer-assisted writing processes, submitting all work on paper.

The participants were asked to write an article in three stages:

- I. Annotated bibliography
- II. Research proposal
- III. Article

The treatment group's utilization of a course blog and the resulting online digital publishing of work-in-progress and completion and the web-mediated peer review is the main difference in behaviors between the control group and treatment group. Participants submitted annotated bibliographies, project proposals, and the final draft of their articles to the editor of the PA Center for the Book for approval and to the instructor for grading purposes. Prior to

each submission, with the exception of the annotated bibliography, a draft workshop took place, which involved generating feedback from student peers, the instructor, and the editor at each stage of the project. Peer review among the students, as well as review, comments, and corrections by the editor were also handled through the means respective to the class section, one taking place online as web-mediated peer review in the form of comments added to the draft pages, and the other taking place through writing printed on paper and through group work. The control group had no access to the course weblog.

The treatment group published its work-in-progress on a course blog developed for the project. Online collaboration in the form of electronic feedback took place by writing feedback in comment boxes at the bottom of each draft. Both groups received instructor intervention during the draft workshop: the treatment group in the form of projecting work-in-progress on screen during the online collaboration sessions to answer questions and model web-mediated response generation, and the control group in the form of individualized instructor intervention during the draft workshop. The control group wrote computer-assisted papers and brought hard copies to class for small group draft workshops. The editor also received paper copies and provided feedback via notes on the hard copies and discussion during the draft workshop. The editor was present during the online and paper draft workshops to provide additional verbal feedback.

Results and discussion

Part 1: Comparing web-mediated to computer-mediated writing

The null hypothesis that there are no statistically significant differences between learning outcomes of participants who used the blogs and those who were in the traditional classroom as measured by the acceptance score of the final articles of the project was rejected. The results indicate that the 25 participants in the treatment group ($M = 2.28$, $SD = 1.137$) and the 24 participants in the control group ($M = 2.94$, $SD = 1.149$) demonstrated a significant difference in performance; a Mann Whitney U test revealed that the mean ranks of the paper and blogs groups were 20.73 and 29.10, respectively; $U = 197.50$, $Z = -2.167$, $p < 0.05$; as expected, the participants in the blog treatment received higher acceptance scores than the participants in the traditional classroom. One participant was lost in the control group halfway through the project and missing values were replaced with the mean average for each missing category. Table 1 demonstrates the mean differences in acceptance scores between the two groups.

Table 1. Average Group Mean Acceptance Scores

	Group	N	Mean	Std. Deviation	Std. Error Mean
Acceptance scores	Paper	24	2.9442	1.14893	.23452
	Blogs	25	2.2800	1.13725	.22745

Acceptance scores were strongly correlated with the editor's ranking of the quality of an article, $r(49) = .837$, $p < .001$ and moderately with the editor's ranking of the ease of reading an article, $r(49) = .425$, $p < .01$. The high level of shared variance suggests that both scores, acceptance and quality, are evaluating the same item, confirming the internal validity of the results.

The social aspect of blogging initiates a level of engagement that is not experienced in the traditional writing classroom, in the sense, that writers must produce work within the framework of a community (Magnifico, 2010). Furthermore, the editor shared at the end of the course that his relationship with the blogging or treatment section was stronger. The editor was able to reach the students effortlessly through blogging communication or social media and, thus, was able to connect socially more effectively. Having a stronger relationship with the outside editor most likely instigated higher levels of motivation for the blogging group and probably led the bloggers to revise their work more fully. The paper or control group received editorial feedback through the physical exchange and transmission of notes on paper, thus, dulling the impact of the exchange.

As expected, the null hypothesis that there will be no statistically significant difference between the learning outcomes as measured by the grades of participants who experienced the course blog treatment and those who were in the traditional classroom was rejected. The results of a Welch's t-test indicated that there was a significant difference between group means for the proposal draft grade, $t(44.593 = 6.134$, $p < .05$, and for the final article grade, $t(38.566) = 6.482$, $p < .05$; the participants in the blog treatment, ($M = 95.04$, $SD = 5.76$ proposal grade) ($M =$

96.76, $SD = 4.88$ final article grade), received higher scores than the participants in the traditional classroom, ($M = 89.71$, $SD = 8.21$ proposal draft grade) ($M = 92.04$, $SD = 7.72$ final article grade). Table 2 demonstrates differences in mean grade scores between the paper and blog groups.

Table 2. Average Group Mean Grading Scores

	Group	N	Mean	Std. Deviation	Std. Error Mean
Proposal grade	Paper	24	89.7083	8.20646	1.67514
	Blogs	25	95.0400	6.76067	.35213
Final article grade	Paper	24	92.0417	7.72055	1.57595
	Blogs	25	96.7600	4.87579	.97516

Even though the hypothesis was rejected, the asymptomatic distribution of grades might indicate that grades are not a valid discriminatory measurement of learning outcomes.

Images

A statistically significant difference in the mean average of the number of images in the final article, $t(54) = 5.43$, $p < .001$ was found, with blog articles ($M = 5.40$, $SD = 1.53$) reporting more images than paper drafts ($M = 3.50$, $SD = 1.25$). No statistical differences were found between groups for the mean average of the number of images included in the proposal draft for paper ($M = 1.21$, $SD = .98$) and blogs ($M = 1.84$, $SD = 1.31$), $t(47) = -1.904$, $p = \text{n.s.}$. The results indicate that differences between the two groups were not significant until after the draft workshops, suggesting that time might be an independent variable, in terms of producing an interaction effect with web-mediated elements combined with successive drafts. In other words, the ability of the bloggers to compare their work to their peers' work may have created a competitive atmosphere and set higher standards for revision.

Sources

There were also statistically significant differences found between groups for the number of outside sources in the final article, $t(54) = 5.43$, $p < .001$, with blog articles ($M = 7.80$, $SD = 28.89$) reporting more sources than paper drafts ($M = 6.29$, $SD = 1.65$). Table 3 shows the means and standard deviations of the number of outside sources for the paper and blog groups.

Table 3. Average Mean Scores Differences in Number of Outside Sources

	Group	N	Mean	Std. Deviation	Std. Error Mean
Number of outside sources proposal	Paper	24	5.2917	.75060	.15322
	Blogs	25	6.1200	2.00666	.40133
Number of outside sources final article	Paper	24	6.2917	1.65448	.33772
	Blogs	25	7.8000	2.88675	.57735

The results indicate that the first measure, the proposal measure, demonstrated no group effect. Perhaps time was also a factor; repetitive exposure to community feedback from published draft workshops might instigate higher levels of motivation, thereby, producing a group effect in the final article. The results also suggest that there is a floor effect for the paper group, a meeting of the minimal standards or requirements for the project (five sources). The paper group included a mean average of five outside sources with an extremely narrow standard deviation (s.d. of .75). While the blog group produced a relatively small gain in the number of outside sources, the standard deviation was much larger than the paper group's standard deviation (s.d. of 2.00) indicating that there was not as strong a floor effect for the blog group. In other words, the majority of the participants in the control group met no more than the minimal standards of the assignment; whereas the treatment or blogging group had a greater variation in terms of working beyond the minimum.

Errors

No statistical differences were found between groups for the mean average of the number of errors found in the proposal draft for paper ($M = 3.38$, $SD = 3.00$) and blogs ($M = .236$, $SD = 2.19$), $t(47) = 1.354$, $p = \text{n.s.}$; and between the mean average number of errors in the final article for paper ($M = 1.29$, $SD = 1.78$) and blogs ($M = .800$, $SD = 1.35$), $t(47) = 1.095$, $p = \text{n.s.}$

Writing articles for publication for the Pennsylvania Center for the Book provided an authentic task. Woo and Reeves (2007) argued that meaningful interaction occurs in web-based learning environments when authentic tasks are provided to learners. This argument has been supported by subsequent research (Pearson, 2010). Introducing an outside stakeholder creates an incentive to produce higher quality professional work (Manion & Selfe, 2012). Thus, this study, which included an outside stakeholder in the form of an editor who selected the best articles for publication, provided an ideal “assessment ecology” for utilizing a course blog. The course design played to the strengths of an online social learning space; the results of the study, in terms of publication rates and grades, supports developing CoP through blogging technologies.

Part 2: Examining web-mediated draft workshops

The sample size for this part of the study consisted of the 24 participants of the treatment or blog group that participated in a draft workshop. The control group’s draft workshops were blended workshops, which included both unrecorded oral comments and written comments. Their results differed significantly in nature and quantity, making a statistical comparison invalid. Thus, only the draft workshop feedback comments published to the course blog were coded and given weighted scores based on the following categories and values: judgment comments, such as good or nice work evaluating the quality of the work without providing specifics or reasons (1 pt.), stylistic comments involving word choice and sentence structure (2 pts.), and constructive comments asking for more information or suggestions regarding organization of the parts or sections of articles (3 pts.). One rater, the instructor, evaluated the feedback.

The null hypothesis stating that the quality and types of published peer review comments on the course blog would show no relationship to acceptance scores was partially rejected. The results demonstrate a moderately negative relationship between the independent variable, acceptance scores and the total weighted points of the proposal draft, $r(20) = -.463$, $p < .05$; and the overall weight of points scored from both draft workshops was nearly significant with an $r(24) = -.400$, $p < .053$. Correlational testing of the specific types of peer review comments (judgment, stylistic and constructive) demonstrated no significant relationship to acceptance scores.

Furthermore, the total weighted scoring of the proposal draft workshop significantly predicted the final article acceptance scores, $b = -.463$, $t(20) 2.144$, $p < .05$; however, this relationship is negative, the higher the quality of the feedback received during the proposal workshop indicated a reduced chance of having the final article accepted for publication.

Drafts, which received a higher percentage of quality feedback, might have garnered such feedback due to a weakness in the overall quality of the draft reviewed; in essence, weaker drafts receive more constructive feedback. The lower acceptance scores of drafts receiving the highest scores in terms of the quality of feedback might indicate that the writer was unable to translate feedback into an adequate revision process, suggesting that collaboration not only has an insignificant effect on learning outcomes, but a negative impact.

The results indicate that receiving quality feedback won’t ensure positive learning outcomes. An explanation for this result might be found in the literature. For example, Lundstrom and Baker (2009) divided students into two groups—the givers of feedback and the receivers of feedback—and found that the givers made larger gains improving their writer than the receivers. This indicates that the generation of feedback is more valuable than the actual feedback itself; however, in a true experimental study, analyzing an online peer-reviewing situation, Trautmann (2009) found that students who received critiques outperformed students who generated the critiques or who solely critiqued their own work and not that of their peers. Trautmann concluded that web-mediated peer review led to improved revision and high levels of engagement. This result of the study should be examined further in a future study.

Limitations

The results of the study cannot be generalized to any population other than the participants of the current study due to it consisting of a convenience sample of participants and the relatively small sample size. Furthermore, the inconsistencies in the results between the paper and web-mediated draft workshop prevented any direct comparisons of the feedback. However, it might be argued that the two processes differ significantly in nature and outcome. The paper draft workshop is a blend of oral and written feedback; whereas, the web-mediated draft workshop provides feedback solely in the form of published comments.

Suggestions for further study

A more effective research design, which allows for the direct comparison of the nature and amount of feedback generated during a paper and web-mediated draft workshop, would provide greater insight and possibly explain the benefits of incorporating a socio-cognitive learning situation or CoP in the form of a course blog. Furthermore, a longitudinal repeated measures research design, which includes a pre-test and post-test, would produce a more reliable and valid measure of learning outcomes.

Conclusion

Social media enhanced the learning environment by providing a level of engagement that is not found in the traditional classroom. Students who published their work on a course blog published a significantly higher number of articles and received higher grades. An examination of the published peer workshop draft comments and their relationship to learning outcomes produced mixed results with students receiving the most feedback having the lowest grades and publication rates. Perhaps, providing feedback has a greater impact on learning outcomes than receiving feedback.

In the overall context of this study, web-mediated writing proved to be useful in terms of generating more effective learning outcomes. During in-class activities, such as draft workshops, more time was spent on task. When more time is spent on task, learners master skills more quickly and effectively. Furthermore, having an outside stakeholder enhanced the social aspect of blogging and the authenticity of the CoP framework, creating an apprenticeship learning environment. The editor was able to communicate more effectively through the weblog and thus produced deeper relationships or bonds and trust. Students understood how to effectively respond to the editor's directions and needs and were able to outperform the control group. In addition to the editor's presence, the course blog provided the instructor with a higher degree of oversight. The instructor was able to monitor the work of the students more effectively due to having access to the student's work in real time. Finally, peer influence became more significant as peers were able to view the work of the class holistically and could then rank and score each of their respective positions in the class, thus eliminating the tendency to simply meet the floor or minimal requirements of an assignment. Instead students were inspired to contribute beyond the minimum in order to show well on the course blog.

For the blogging group, the classroom boundary expanded dramatically. The work of the course became genuine in the sense that online publication augmented the importance of audience (Manion and Selfe, 2012). The awareness of audience shifted focus to the writing process and social engagement and mirrored the predominant writing process on social media sites like Tumblr and Facebook. Writing was then viewed through an imagined or real perception of an audience's reactions rather than the narrow lens of the author's world. Students ultimately found genuine readers outside of the classroom who were self motivated to read their work.

Overall, the study revealed that a CoP that takes place in the form of a course blog can impact learning outcomes significantly. Hodgkinson-Williams et al. (2008) argue that higher education institutions have "operated on the assumption that learning is an individual process best encouraged by explicit teaching that is, on the whole, separated from social engagement with those outside the university community" (p. 435). Introducing a CoP, Hodgkinson-Williams et al. (2008) contend, will demonstrate that "learning doesn't happen in a void" (p. 435). This study

further the case for incorporating blogging technologies to establish an effective and engaging CoP, making it possible for learners to practice knowing.

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A Near-Reality Approach to Improve the e-Learning Open Courseware

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ABSTRACT

The open courseware proposed by MIT with single streaming video has been widely accepted by most of the universities as their supplementary learning contents. In this streaming video, a digital video camera is used to capture the speaker's gesture and his/her PowerPoint presentation at the same time. However, the blurry content of PowerPoint slice in this recorded video isn't rich enough for students' further learning. This motivates us to find a novel approach to integrate the details of teacher's gesture and presentation with digital video camera and screen catcher, respectively. Due to the integration technologies of multimedia applied in this paper, this proposed method can significantly improve the quality of streaming video especially the content of PowerPoint and moving data on PC screen. In addition, the variety of scenes occurred inside a classroom can be easily directed and then recorded for future learning. A utilized experimental design was applied to check the degree of clarity and validate the learning effectiveness. The results showed that the proposed method was much better than the conventional method that with only one single digital video camera.

Keywords

E-Learning, Open courseware, Situated learning, Recorded video, MOOCs

Introduction

The media/video sharing data recorded with streaming format have been widely accepted by most of the people, including the information in YouTube and the open courseware proposed by MIT (Abelson & Long, 2008; Carson & Forward, 2010; Lerman & Potts, 2006; Tovar, 2010). Currently, a lot of universities develop the program of open courseware as part of their distant learning activities including University of Tokyo OCW, Tufts Open Courseware, Utah State University Open Courseware, National Chiao Tung University OCW, etc (Carson & Forward, 2010; MIT OCW; University of Tokyo OCW; Tufts OpenCourseWare; Utah State University OpenCourseWare; National Chiao Tung University of Taiwan OCW). Teaching and learning are no longer restricted to classroom learning (Marold, Larsen, & Moreno, 2000; McAllister & McAllister, 1996; Papanikolaou, Mabbott, Bull, & Grigoriadou, 2006; Zhang & Nunamakter, 2003). As we know, most of the contents from open coursewares are recorded in classroom and then translated into web site for online self-learning purpose. Even students can read the same data from the classroom recorded by themselves, they actually cannot endure the poor quality media if the recording procedure inside the classroom is not well-controlled. Up to now, a number of studies have demonstrated how e-Learning technology influences today's education (Davies & Graff, 2005; Naeve, Lytras, Nejdl, Blacheff, & Hardin, 2006). Wentling et al. suggested that "e-Learning is the acquisition and use of knowledge distributed and facilitated primarily by electronic means" (Wentling, Waight, Gallaher, La Fleur, Wang, & Kanfer, 2000, p. 5). Hence, in this paper, the advantage of e-Learning technology will be taken to improve the recording quantity and quality of open courseware such that students can read everywhere and anytime with enough amount of high quality streaming data.

Inside a classroom or studio room, several streaming data from computer screen, digital camera, and document camera are recorded to preserve the details. The best way to keep all data together is to apply the integration technology to fuse those streaming data into a single streaming media (Boer, Koomers, & Brock, 2011; Liu, Chen, Wang, & Zhang, 2010; Reisslein, Seeling, & Reisslein, 2005). Two technical issues have to be considered. One is to decide what kinds of catching devices including digital camera, document camera, and VGA grabber are used. Another is the integration software to fuse those caught streaming data into the single streaming. The VGA grabber is a hardware device which can catch the screen of another computer with fine quality. The software system receives raw signals from grabber and then to process, analyze, integrate, and compress images (Diaz, Pelayo, Ortigosa, & Mota, 2006; Will, 2001). As shown in Figure 1, the VGA grabber is embedded in a PC which can catch teacher's gesture and notebook screen. This technique has been widely used to catch the computer screen with dynamic

content, for instance, the moving particle run on teacher's notebook and shown in front of students in the physics lecture can be recorded by this skill (Diaz, Ros, Carrillo, & Prieto, 2007; Kim, Lee, Jeon, & Song, 2010).

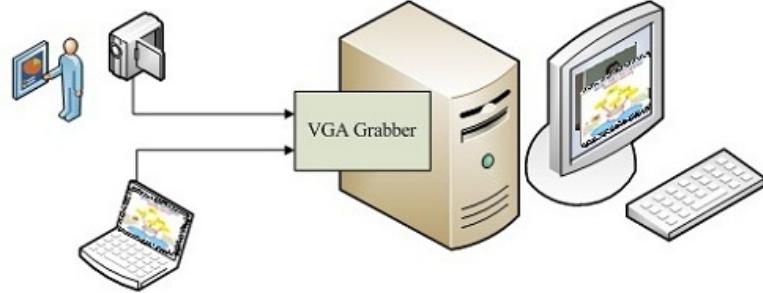


Figure 1. The catching flow with VGA grabber

As we know, most of the contents of open courseware just provide students with more opportunities to review the lecture after they go back home for self-learning. Currently, a lot of universities try to improve the quality of open courseware to be suitable for regular distant lectures. Hence, how to record teaching lectures and retouch those recorded materials to be high quality materials such that students can have better learning outcomes is a critical issue (Leijen, Lam, Wildschut, Simons, & Admiraal, 2009; Ochoa & Duval, 2009; Wilson & Harris, 2003).

In contrast to advertisement program which just consists of short messages or illustrations, the teaching program needs to present the detailed knowledge with more verbal illustration. In order to provide a suitable learning content instead of just a short message, a stable and easy solution operated inside the classroom by teachers, teaching assistant-assistants or students has to be considered such that a variety of situations occurred among teachers and students during a long period lecture can be directed and recorded. Huang, Lubin and Ge (2011) found that the students in the situated learning environment could demonstrate more sophisticated problem-solving skills, exhibit metacognitive awareness, produce coherent artifacts, and show high levels of motivation.

The digital video cameras are usually used to capture speaker's gesture and his/her PowerPoint content projected on screen simultaneously. However, these recorded videos can only preserve teacher's gesture in details instead of his/her PowerPoint content which is always with blurry quality.

In Figure 2, the content of video includes both teacher's gesture and the content of PowerPoint. The text and figure inside the PowerPoint slice is not clear enough to let students concentrate on their study. In this paper, one of the contributions is to solve above questions and requirements. Thus, a near reality approach is proposed to preserve the recording style of situated learning including teacher's gesture, body language, interaction, and the content of PowerPoint. Then, the design overhead is lower than in other systems which are usually used in professional studio room or micro-teaching classroom and the users can integrate the system by themselves with primitive devices (Casakin, 2011; Eddings, Stephenson, & Harvey, 2009; Ginns, Norton, & Gupta, 2005; Wahba, 1999).

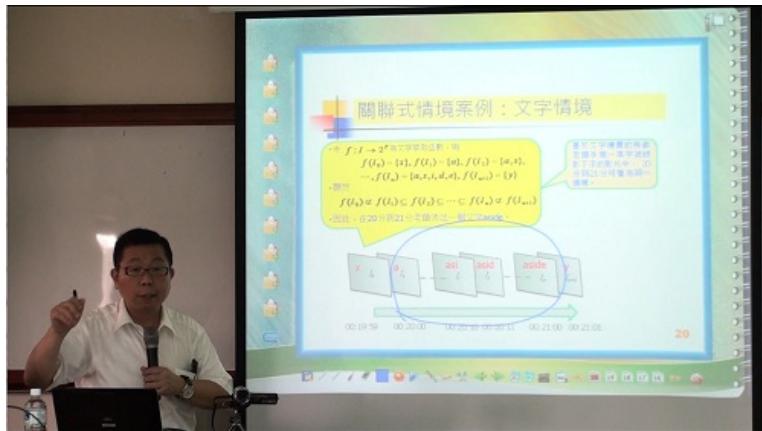


Figure 2. Speaker's Gesture and the content of PowerPoint

In this paper, an integration technology is proposed to integrate the streaming from VGA grabbers and digital cameras such that the near reality from classroom can be easily obtained by using our self-design recording instrument. We believe that the quality of the recorded video with quality guarantee of near reality can give online readers more real situation like inside classroom.

Situated learning

Anthropologists Schon, Suchman, Lave and Wenger collated and analyzed the people in the learning process (Lave, 1988; Lave & Wenger, 1991; Schön, 1987; Suchman, 1987). Schön (1987) proposed two concepts about learning, the knowledge in action and reflection in action, after he studied the learning about professional model. Suchman (1987) issued a situational action argument after he observed people in learning how to operate a copy machine. He emphasized that if the people learned knowledge without combining with the operating situation of this real copy machine, he just played a game of abstract symbols without physical impact. Learners must construct their concepts and rules of knowledge through practical experience and through practical action to understand its true meaning. Lave and Wenger (1991) found that people who engaged in the butcher, midwives, tailors, and helmsman did not receive a complete education or formal training, but they learned their techniques from observing their masters or from their own inventions in daily activities and practices under the real working situation. They could use their skills and knowledge intuitively to solve problems around the real resources. Furthermore, when they faced the complex professional issues, their performance was still satisfactory. Also, Brown, Collins and Duguid (1989) and other cognitive psychologists used the anthropological perspective to define “situational learning” as people continue to interact with the actual situation during a long period of time and then they can use effective strategies to solve the problem in a specific situation. Therefore, learning and practice under the real situation has its effect on the construction of knowledge. In this paper, the real recording in classroom which can give students more vivid situation for future study to construct their deep knowledge is emphasized.

McLellan (1996) considered that situated learning should include eight factors: stories, reflection, cognitive apprenticeship, collaboration, coaching, multiple practices, articulation of learning skills and technology. Therefore, these factors can derive eight recording actions to record the corresponding situation into video during the lecture hour.

- Story Action: The digital devices can take the teacher's presentation with his/her body language as a story about the lecture content.
- Reflection: The students' reflection with respect to teacher's story can also be recorded to let other students who read this recorded data on line understand why their peers ask this kind of questions.
- Cognitive apprenticeship: A sequence of interactions between teacher and students can also be recorded to let other students who read this recorded data on line understand how the teacher leads their peers to correct their wrong concepts and skills.
- Collaboration: When a group of students is working on an experiment, this situation can be recorded to let other students who read this recorded data on line fell how cooperative tasks can be achieved by a group.
- Coaching: This kind of videos can refer to the teaching activity about teacher's coaching procedure which has detailed steps to show how a teacher coaches a pupil to learn some concepts and skills.
- Multiple practices: The integration technology can be applied to fuse the videos from each practice into a situation of multiple practices such that students can easily read several practice experiences with a single streaming data.
- Articulation of learning skills: The recorded video can preserve the details of each learning skill. Students can repeatedly read this video to find out the micro skills from each step.
- Articulation of technology: The recorded video can preserve the details of technology. Students can repeatedly read this video to find out the inside concepts about the interesting technology.

Inside the classroom, the teacher can lead students with his/her eye contact, body language, and other teaching strategies. This kind of real activities can form a vivid situation for students' learning. Hence, the best way to preserve the learning situation is to record the whole scenes inside the classroom.

Near reality approach

A near reality (NR) approach that can record video effectively to achieve the recording style of situated learning including speaker's gesture, body language, interaction with students, and presentation with PowerPoint file is developed (Yu, Hwang, Liao, & Su, 2011). In this section, the near reality approach will be introduced in details.

Scenario

Near reality approach is grounded on the situated learning and the results of He, Grudin and Gupta (2000), Baecker (2003), and Zhang, Rui, Crwaford and He (2008). These design principles are described as follows:

- The system is friendly: Teacher can act or behave normally during his/her talk or lecture. That is, no restrictions are imposed on him or her. The only device which the teacher needs to wear is a wireless clip-on microphone.
- The system has no pre- or post-production: Teacher does not need to give his/her slides/transparencies in advance for pre-processing. After the presentation, no post-production such as slide integration is needed. The lecture is immediately available for on-demand viewing.
- The system captures synchronized high resolution visual aids: Such synchronization is done on-the-fly during the lecture. Both the live and the on-demand viewers can watch them synchronously with the audio/video stream of the lecture.
- The system allows the remote clients to view the lecture at their own pace: Students can view the lecture at home or in any place.

In order to realize above requirements, a specific system including hardware and software is designed to let the teaching assistant easily handle it. The design of this system will be specified in the following subsection. Due to the recording procedure operated by the teaching assistant instead of by the teacher, this kind of recording is called as other-record skill. On the contrary, the recording procedure operated by the teacher is called as self-record skill, that is, the teacher needs to teach and record simultaneously during the lecture.

While the other-record procedure is in progressing, the teachers can concentrate on their teaching without worrying about the recording business. An example of teaching situation translated to an integrated form with the proposed method is shown in Figure 3.

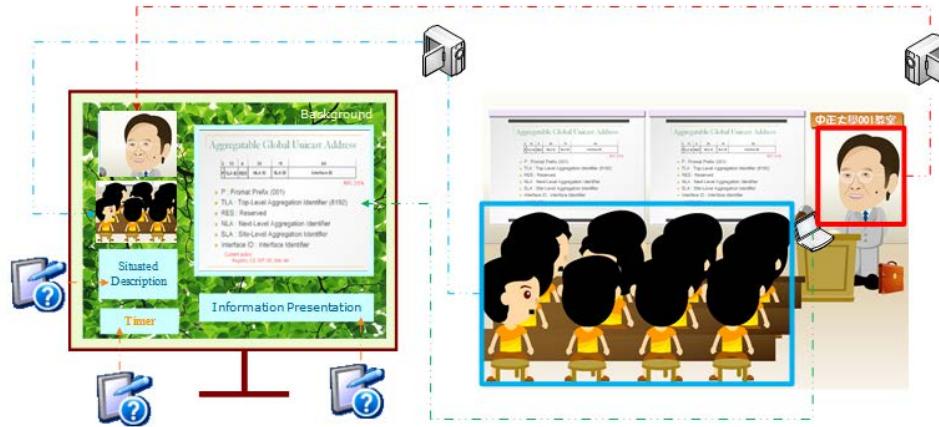


Figure 3. A translated scenario from classroom situation to an integrated form

First, the teaching assistant creates a display board based on NR system. On this display screen, there are two DV cards, one VGA grabber card, two text cards, and one timer card. Second, the teaching assistant operates all the devices including two DV cameras and one VGA grabber with a control software installed in NR system. Hence, the teacher's image, students' image, and the teacher's notebook screen can be captured by these three cards, respectively. Finally, the teaching assistant applies another VGA grabber to capture the integrated screen corresponding to the content of display board. Then, the vivid video including almost all the teaching situations

inside the classroom can be obtained. In addition, this recorded video can be uploaded immediately to the media server for students' instant or further learning.

Method

The function of NR system is to integrate multiple signals mainly obtained from the devices of DV cameras and VGA grabbers. Moreover, in order to collect the details inside a classroom, some extra components have to be concerned. All the devices used to design NR system are listed as follows:

- VGA grabbers: There are two VGA grabbers, one for capturing the signals from VGA mixer and another for capturing the integrated signal from the display board.
- Audio mixer: It can mix different sounds from five microphones used by different users into a signal.
- VGA mixer: This device can translate digital videos from digital camera into VGA signals and then mix above signals with usual VGA signals into regular VGA signals.
- VGA/Audio matrix with RS232 controller: There is a 2x3 VGA/Audio matrix which can provide 2^3 possible output combinations. The control configuration can be selected from the software installed inside the PC to realize the possible project situation.

The structure of NR system is shown in Figure 4 and it includes three components, the signal inputs, the process engine, and the signal outputs. The recording procedure with this system can be described as follows:

Step 1: The NR system captures the audio and video signals from microphones, notebook, and digital cameras.

Step 2: The video signals from DVs and notebook are translated to the VGA mixer, and then the mixer integrates the signals to create an integrated video signal.

Step 3: The machine for other-recording skill can receive an integrated video signal from VGA grabber which captures the signal from VGA mixer and a mixed audio signal from audio mixer. Then, this machine is continuous to process those signals with some assigned learning situations given by teachers or teaching assistants. Finally, the integrated content is obtained and ready to be delivered to VGA/Audio matrix for further processing.

Step 4: Based on the switching function of VGA/Audio matrix, signals from other-recording PC which creates the integrated content and from VGA grabber can be delivered to two projectors and the audio signal can be delivered to the loudspeaker. In order to record the high quality of integrated content, another VGA grabber is applied to capture the feedback signal instead of recording desktop content directly.

Step 5: The machine for other-record skill finally receives the integrated content from VGA grabber to create the video of situated learning where the machine only processes the recording task without worrying about the signal retrieval which is already shared by VGA grabber.

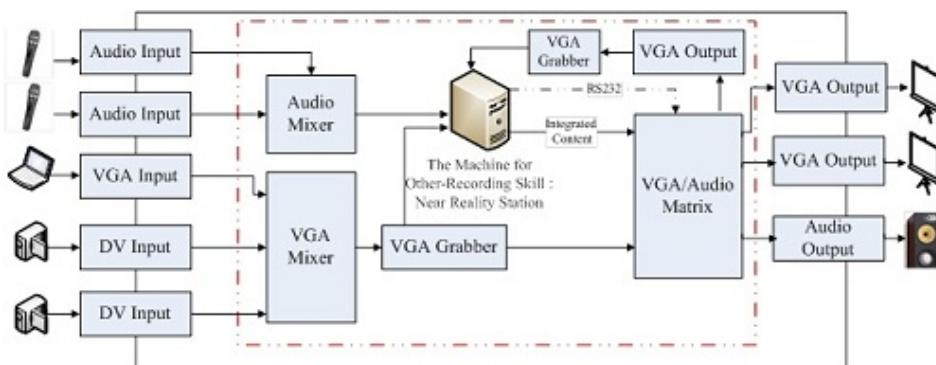


Figure 4: The architecture of near reality system

Implementation

The control panels of NR system are shown in Figure 5. There are five modules corresponding to those panels and the function of each module will be specified as follows.

In Figure 5, the panels can be divided into three parts. The left-hand side of the panels is used to control the audio-related devices as audio input port. The right-hand side of the panels is used to control the video-related devices such as the control ports of DV camera, and VGA grabbers. Moreover, the middle side is a 12-key control panel which can control DVI, VGA, and audio as parts of the system inputs and outputs. Also, the 12-key control panel can control the configurations of picture-in-picture, picture-aside-picture to display on a screen.



Figure 5. The control panel of NR system

The content of this display screen is just the integrated content shown in Figure 6. First, the teaching assistant can select an appropriate picture as the background of this display screen. Second, the teaching assistant can select some available blocks offered by the NR system to direct a suitable learning situation for their students. Those blocks consist of images, pictures, text, scrolling text, marquees, etc.

In this paper, three scenarios are applied to direct the situations occurring inside classroom. The details about these situations are specified as follows.

1. Presentation situation

This situation consists of teacher's body language and the content of PowerPoint. In addition, a text description is added into this situation to specify the lecture topic and teacher's name as shown in Figure 6. Readers can feel the teacher's charm and atmosphere during the presentation, just like teachers in front of them.



Figure 6. Presentation situation

2. Interaction situation between teacher and students

This situation consists of the content of PowerPoint, teacher's and students' body language. According to the active around the teacher and students in the video, readers can feel their interaction like talking with teachers inside classroom as shown in Figure 7.



Figure 7. Interaction situation between teacher and students

3. Interaction situation among students

This situation consists of the content of PowerPoint and students' body language as shown in Figure 8. According to the interaction among students in the video, readers can feel their participation like they really join in the classroom.



Figure 8. Interaction situation among students

We can find that key components in above three situations are the content of PowerPoint, teachers' and students' body language. Therefore, we can select the combination of key components to form a variety of situations. This combination can be shown in Figure 9.

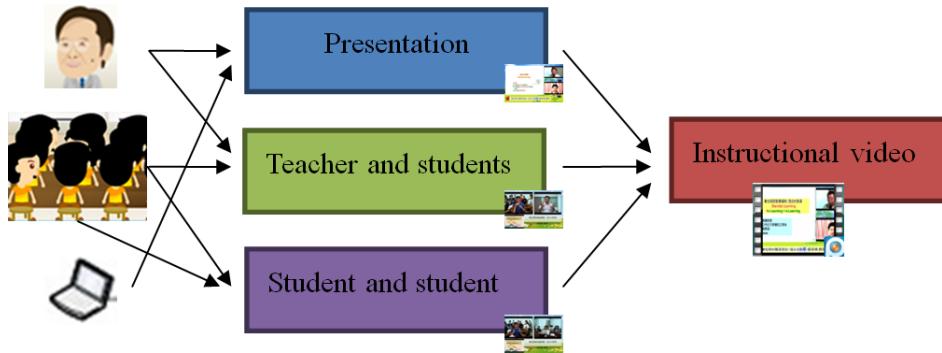
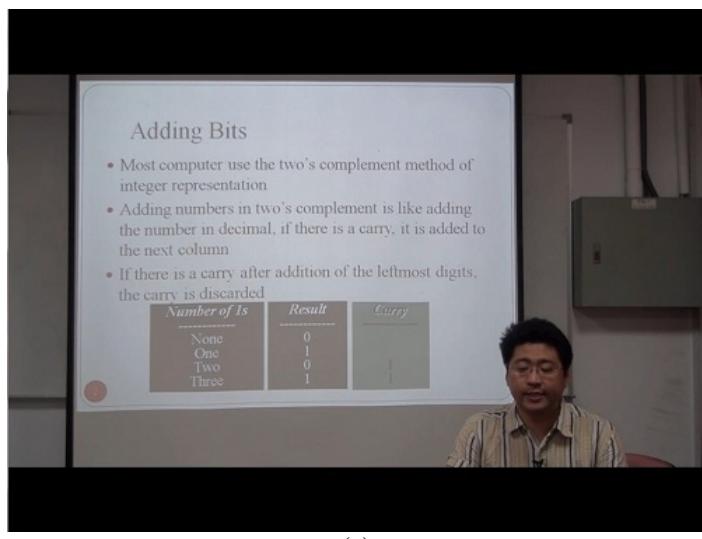


Figure 9. The instructional video recorded with a variety of situations

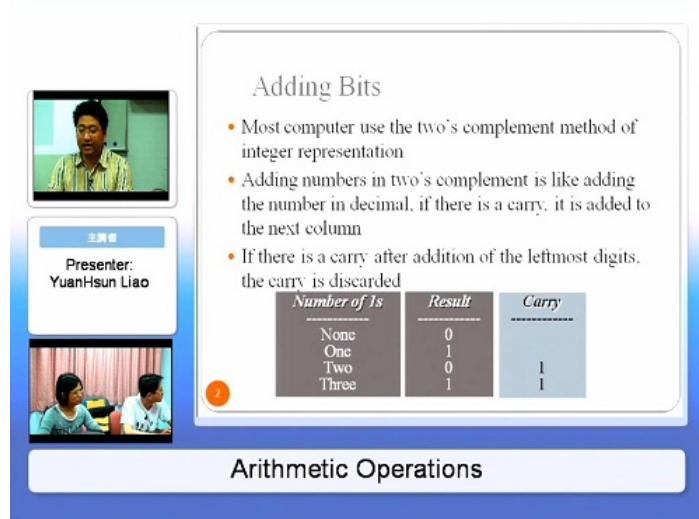
Teaching strategies often utilized in situated learning environments include the stories, reflection, anchored instruction, cognitive apprenticeship, modeling, collaboration, competition, coaching, scaffolding and judging, multiple practice, exploration, articulation, science and technology (McLellan, 1986; Brown, et. al. 1989). In near real video, the all of the teaching strategies and interaction situation including teacher's presentation, interaction situation between teacher and students, and interaction situation among students were recorded by the near reality approach. The content of near real video can enrich self-learning situation for readers who do not participate in the actual process of learning to feel their interaction like talking with teachers inside classroom and students who participate in class to practice and reflect learning content.

The degree of clarity

A series of lectures of Computer Science in authors' university were recorded with two methods, conventional method with only one digital camera and the proposed method with NR system, simultaneously. Those recorded videos were uploaded into a media server for further usage as shown in Figure 10. Those videos can be used in the regular lecture with teacher-led (c-Learning) or self-learning (e-Learning) approach. Also, they can be used by students for supplementary learning out of classroom. As we know, most of the videos taken by a single digital camera are blurry especially in content of texts. Consequently, it is hard to let teachers and students use them in teaching and learning. Therefore, in this paper, the degrees of clarity about conventional and the proposed methods are studied. Definitely, the higher degree of clarity is good for reading. In order to check the degree of clarity, the skill of optical character recognition (OCR) is applied. Note that the higher recognition rate is assumed to be the higher degree of clarity.



(a)



(b)

Figure 10. (a) Video recorded by conventional method, (b) Video recorded by the proposed method

Objectively, two sets of experimental samples were got from the videos recorded by conventional and the proposed methods by an automatic detection algorithm, respectively. The Sobel mask which is a filter is applied in this algorithm to detect the contents of different pages inside the recorded videos (Yu, Liao, Su, & Tsai, 2010). Then, all the pages in the PowerPoint file presented by the teacher can be extracted out. That is, two series of images from videos recorded by conventional and the proposed methods can be obtained, respectively. Without loss of generality, the series of images obtained from the conventional method can let be $slice_{11}, slice_{12}, \dots, slice_{1N}$, and let the series of images obtained from the proposed method be $slice_{21}, slice_{22}, \dots, slice_{2N}$, where N is the number of pages in the PowerPoint file presented by the teacher. The definition can be specified as follows.

the degree of clarity of the $slice_i$

$$\begin{aligned}
 &= c(slice_i) \\
 &= \text{the recognition rate of } slice_i \text{ about the words on this image} \\
 &= \frac{\text{the number of correct words extracted from } slice_i}{\text{the number of words on the } i\text{th page of the PPT file}} \times 100\%
 \end{aligned} \tag{1}$$

If $\sum_{i=1}^N c(slice_{1i}) < \sum_{i=1}^N c(slice_{2i})$ or more strictly require $c(slice_{11}) < c(slice_{21}), c(slice_{12}) < c(slice_{22}), \dots, c(slice_{1N}) < c(slice_{2N})$ occurs, then the proposed method is better than the conventional method with respect to the comparison of clarity.

The experimental procedure is shown in Figure 11. In order to speed up the experiment, the function of OCR available in Adobe Acrobat writer to extract the texts from each slice is applied.

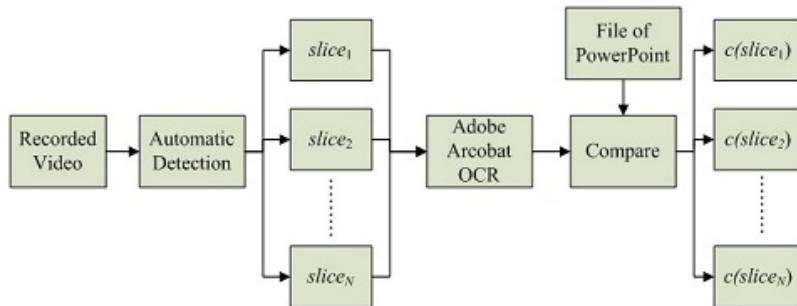


Figure 11. The flow of OCR experimental

The experimental samples are obtained from five lectures of Computer Science, Lecture 1 Arithmetic Operations, Lecture 2 Logical Operations, Lecture 3 Integer Representation, Lecture 4 Representing Data, and Lecture 5 Excess System. In Lecture 1, there are 15 pages, that is, $N=15$. In Table 1, the detail experimental result about Lecture 1 is listed. The results of other 4 Lectures are briefly shown in Figures 13 to 16 with graphic style.

Table 1. The experimental result about Lecture 1

Lecture 1	No. of words	The proposed method		Conventional method	
		No. of correct words	Recognition rate	No. of correct words	Recognition rate
slice 1	20	20	100.0%	15	75%
slice 2	230	206	89.6%	81	35%
slice 3	142	122	85.9%	45	32%
slice 4	151	144	95.4%	35	23%
slice 5	154	147	95.5%	34	22%
slice 6	154	146	94.8%	42	27%
slice 7	189	175	92.6%	30	16%
slice 8	197	154	78.2%	43	22%
slice 9	87	87	100.0%	39	45%
slice 10	35	35	100.0%	28	80%
slice 11	131	119	90.8%	30	23%
slice 12	128	120	93.8%	59	46%
slice 13	172	165	95.9%	30	17%
slice 14	372	317	85.2%	103	28%
slice 15	292	279	95.5%	59	20%
Average			92.9%		34.1%

From Figure 12, the proposed method is definitely much better than the conventional method. The same experimental results also can be found in Figures 13 to 16. In Table 2 and Figure 17, the average recognition rates of Lectures 1 through 5 are listed. Lecture 1 has the lowest rate among five Lectures due to the small size of characters on each page in contrast to other four Lectures. Therefore, to simplify the content with enlarging the character size on each page is an important factor to improve the recognition rate. In experimental results, the conventional method has the recognition rate less than 35% in difference characters size (Table 2). Significantly, our proposed method has the recognition rate more than 84% in large or small characters size. And, it can enhance recognition rate to 95% more if the characters size is large enough. But, the conventional method is only about 2% increasing in regardless of the characters size. Therefore, these effects cannot be reached by conventional method.

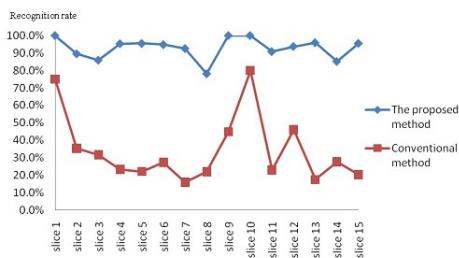


Figure 12. Recognition rate of OCR about Lecture 1

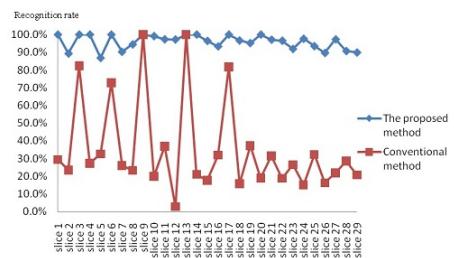


Figure 13. Recognition rate of OCR about Lecture 2

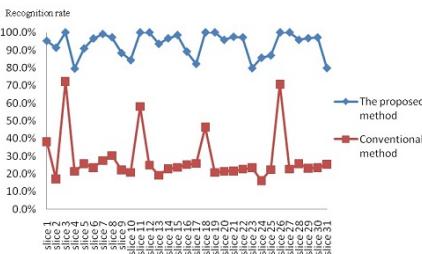


Figure 14: Recognition rate of OCR about Lecture 3

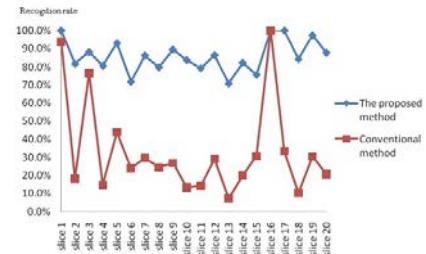


Figure 15: Recognition rate of OCR about Lecture 4

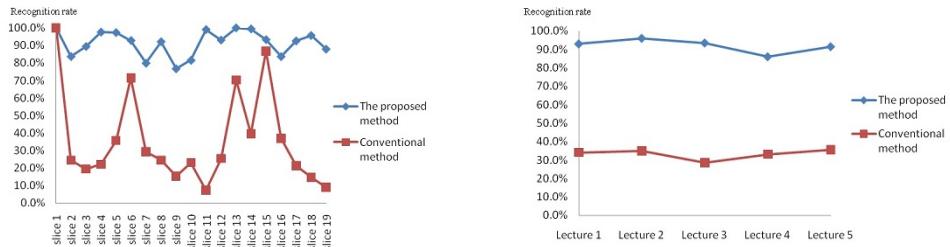


Figure 16: Recognition rate of OCR about Lecture 5 Figure 17: Average recognition rate of OCR about Lectures 1 through 5

Table 2. Average recognition rates of Lectures 1 through 5

	Average recognition rate of Lecture 1	Average recognition rate of Lecture 2	Average recognition rate of Lecture 3	Average recognition rate of Lecture 4	Average recognition rate of Lecture 5
The proposed method	92.9%	95.9%	93.4%	86.0%	91.4%
Conventional method	34.1%	34.9%	28.6%	33.1%	35.6%

In addition, the environment factors including the light inside the classroom will highly affect the quality of conventional method due to the conventional method taking the content on each page directly from displayed screen. The proposed method catches the content of each page from VGA grabber. Therefore, it can neglect the light factor.

Learning effectiveness analysis

Research design

This study designed to find the significant effects of learning computer knowledge in the situation video. The learners taking the Computer Science course were invited to participate in this experiment. The learning effectiveness of participants was collected after learning with the particular subjects of Computer Science. The research design of this study was described as follows in details.

Participants

Participants were sixty-four students in authors' university for this study. Based on their ability distribution obtained from a pre-test which was the ability test given at the beginning of this lecture, both thirty-two groups were decided as control and experimental groups, respectively. The independent-samples t-test was involved to compute the values of the means on the learning scores to examine the differences in pre-test and post-test between the experiment and control groups.

Instructional Materials

The experimental and control groups watched the video courses recorded by the proposed and conventional methods, respectively. In order to make an accurate evaluation, both groups all watched a series of 12-week samples. There was a sample shown in Figure 10. After 12 weeks, all students had to take a learning achievement test. Students were required to watch two units each week which is equal to two 40-min regular lectures of Introduction to Computer Science in each week. Of course, during these 12 weeks, some home works and quizzes were given to them.

Instruments

The instruments in this study were used to address the learning achievement. Zhang finds that interaction video enhances the learner's understanding and improves learning effectiveness (Zhang, Zhou, Briggs, & Jr, 2006). In this

research, we designed an experiment to understand the improvement of students' knowledge and skills on the subject of computer logic unit and its arithmetic computing. Mainly, we analyzed their test scores to understand whether their knowledge and skills were significantly improved or not. We designed a pre-test before experience of our study. The test of computer basic conceptions was divided into 20 multi-choice items. Depending on the test scores, we can understand participants' level of prior knowledge. By randomly assigning participants, we divided the participants into two groups, the experimental and the control groups. There are 30 multi-choice items and 5 question items in the post-test.

Procedures

One teacher and 64 students in one class contributed to trial of the system. The class agreed to teach with the recording videos of NR system and convention to support teaching of their lecture in the Winter 2011 semester. The reading materials were uploaded to the learning management system (LMS) for students. Students were able to watch the audio-video materials produced. The procedure of the experiment, as shown in Figure 18, is described as follows.

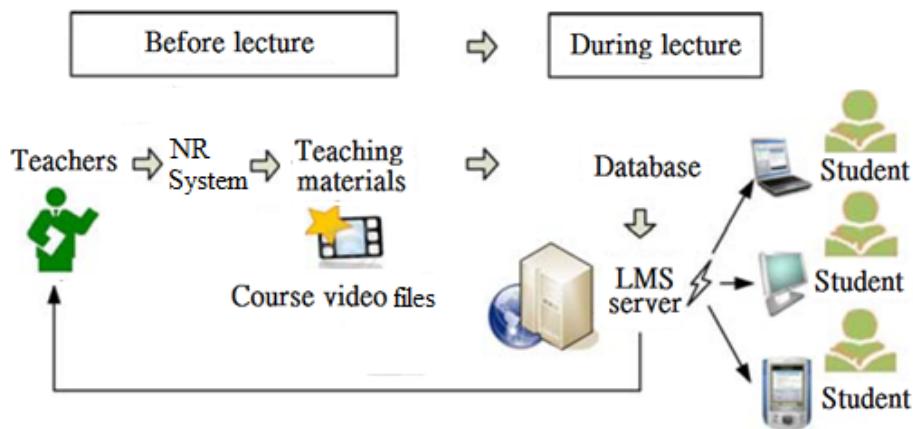


Figure 18. The procedure of experiment

1. Before lecture: Teachers prepare and produce the instructional videos into the teaching materials by using recording system. In the preparation of teaching materials, teachers can record teaching situation into instructional videos according to the difficulty of teaching activity. Finally teachers upload the materials to the LMS.
2. During lecture: Students need to login the LMS system to watch the online materials. They can learn one concept from interaction situation of instructional video. Teachers can always amend teaching materials and understand the situation of students watch the materials.
3. After class: Students were tested for the learning result.

Data analysis

Research data were collected through the test of the Computer Ability Achievement Test. The experimental group watched the video courses recorded by the proposed methods, while the control group watched the video courses recorded by the conventional methods. Independent-samples t-test was involved to compute the values of the means on the learning scores to examine for differences in pre-test and post-test between the experiment group and control group. Here, the significant level was set at $p = 0.05$. As boys and girls were shown differences in performing learning ability, the reason could be the video information to acquire knowledge. (Karadeniz, 2011; Piccardi, Risetti, Nori, Tanzilli, Bernardi, & Guariglia, 2011) Therefore, we were testing the learning differences of student's gender and scores level in learning environment. The two-way ANOVA test with 2 (instructional method: NR and convention) \times 2 (students' gender: boys and girls) and 2 (instructional method: NR and convention) \times 3 (score level:

higher, middle, and low) factorial designs were applied to investigate the differences between the NR and convention for students' learning achievement.

Results

Table 3 shows the results that the differences in post-test of the experimental group with the control one and the significant difference between two groups can definitely be found, $t(62) = 4.79, p < .01$. Also, the students who studied with the recorded video by the proposed method, on average, can have a better result. The mean of scores which was $88.87 (SD = 6.42)$ for the experimental group was higher than the $81.15 (SD = 5.64)$ for the control one. The results showed that the experimental group was more effective than the control one.

Table 3. The number (n), means (M), standard deviations (SD), and t value on the pre- and post-test with the ability of open courseware

	The proposed method			Conventional			t value
	n	M	SD	n	M	SD	
Pre-test	32	76.09	8.47	32	76.12	10.66	0.15
Final-test	32	88.87	6.42	32	81.15	5.64	4.79**

* $p < .05$; ** $p < .01$; ns = not significant

A 2 (instructional method) \times 2 (students' gender) ANOVA was performed and revealed that the scores of students trained by the proposed method were higher than those by conventional method, $F = 26.945, p < .01, \eta^2 = 0.314$ (Table 4, 5). According to Cohen (1988) defines large (.40), medium (.25), and low (.10), indicated that the gender differences in learning style with a medium effect. Also, another one 2 (instructional method) \times 3 (score level) ANOVA was performed and revealed that scores obtained by the proposed method were higher than those of conventional method, $F = 19.803, p < .01, \eta^2 = 0.258$ (Table 6, 7). According to Cohen (1988) indicated that the score level differences in learning style with a medium effect. Scheffe's post-hoc test ($p > .05$) indicates that all two students' sex or three score level groups differed from one another. Therefore, our method will not be gender and scores of students of different to create learning difference.

Table 4. The test scores of learning achievement as a function of recorded method and students' gender

	The proposed method			Conventional			Total		
	n	M	SD	n	M	SD	n	M	SD
Boys	15	89.74	6.707	15	81.33	4.685	30	85.4	7.03
Girls	17	88.35	6.324	17	81	6.51	34	84.68	7.339
Total	32	88.88	6.424	32	81.16	5.64	64	85.02	7.148

Table 5: Post-hoc test: recorded method and students' gender

Source	Type III Sum of Squares	Df	Mean Square	F	Eta Squared	Observed Power(a)
	Covariance		Gender		Method	Interaction
	147.327	1	147.327	4.124	0.065	0.515
	0.452	1	0.452	0.013	0.000002	0.051
	962.537	1	962.537	26.945**	0.314	0.999
	9.205	1	9.205	0.258	0.004	0.079
Error	2107.622	59	35.722			

* $p < .05$; ** $p < .01$; ns = not significant

Table 6. The test scores of learning achievement as a function of recorded method and score level

	The proposed method			Conventional			Total		
	n	M	SD	n	M	SD	n	M	SD
High	8	89.5	7.051	8	83.62	4.033	16	86.56	6.324
Middle	16	89.25	5.639	16	79.94	4.892	32	84.59	7.025
Low	8	87.5	7.874	8	81.13	7.936	16	84.31	8.316
Total	32	88.88	6.424	32	81.16	5.64	64	85.02	7.148

Table 7. Post-hoc test: recorded method and score level

Source	Type III Sum of Squares	Df	Mean Square	F	Eta Squared	Observed Power(a)
Covariance	221.022	1	221.022	6.455	0.102	0.705
Score	99.084	2	49.542	1.447	0.048	0.297
Method	678.045	1	678.045	19.803**	0.258	0.992
Interaction	97.482	2	48.741	1.424	0.048	0.293
Error	1951.665	57	34.24			

* $p < .05$; ** $p < .01$; ns = not significant

Conclusions

The concepts of open courseware and MOOCs have been widely accepted by several universities to expand their learning scale among classroom and internet (Frank, 2012; McFedries, 2012). The use of information technology can enrich the teaching and learning activities to enhance the interaction and quality of teaching in classroom and internet. Therefore, the requirement of contents is getting urgent and then the recorded content from classroom is getting important to satisfy the requirement. However, the quality of recorded data by a digital camera is not good enough for students' further learning. In this paper, a novel approach has been proposed to improve the quality of recorded data by applying the integration technology.

In order to specify the major contribution, two experimental designs have been developed. The clarity of streaming data by the technique of OCR was checked. The experimental results have demonstrated that the quality of recorded video from the proposed method has much better than that generated from conventional method. It also showed that the learning effectiveness of student by the presented method was more than that by conventional method. Therefore, the integration technology can play an important role to fulfill the effective learning situation both in c-Learning and e-Learning.

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A Meta-Relational Approach for the Definition and Management of Hybrid Learning Objects

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ABSTRACT

Electronic learning objects (LOs) are commonly conceived of as digital units of information used for teaching and learning. To facilitate their classification for pedagogical planning and retrieval purposes, LOs are complemented with metadata (e.g., the author). These metadata are usually restricted by a set of predetermined tags to which the classification schema must conform (e.g., IEEE LOM). In our experience, certain complex LOs need to be complemented with different types of domain-dependent information for their pedagogical planning and retrieval: (i) classification metadata for enhancing contextualisation, search and retrieval (e.g., the tagged structure of an archaeological site where an archaeological object has been found) and (ii) additional data that can enrich the LO (e.g., the weight and other dimensions of an archaeological artifact described in a podcast). We refer to LOs enhanced with domain-dependent information as hybrid learning objects (HLOs). However, most learning object repositories (LORs) only permit a predetermined, fixed set of metadata attributes to be used in the classification of LOs. This rigidity is inappropriate when domain-dependent information schemas are used for the browsing, retrieval, and domain-specific pedagogical sequencing of HLOs. Thus, custom software applications are needed to manage LOs that must be tagged with information belonging to specific domains. This paper presents a theoretical approach that permits the use of a single LOR for classifying and enriching LOs according to domain-dependent information schemas, which can be dynamically changed after their definition. The key issue in our approach is the presence of a meta-relational model for the dynamic definition of specific domain-dependent relational database schemas used for classifying and enriching LOs.

Keywords

Learning object repository, Metadata, Domain-dependent information schema, Classification

Introduction

In recent years, e-learning and LOs have significantly impacted education. According to Hodgins (Cisco, 1999), LOs are “a collection of content items, practice items, and assessment items that are combined based on a single learning objective.” LOs are built with the aim of being reused in various learning environments as pieces that can be assembled to create new LOs (Wiley, 2000). Although LOs have been criticised (Polsani, 2003), they increase the benefit that can be derived from the creation of high-quality learning resources (Gibbons et al, 2000).

To facilitate their use, LOs are stored in learning object repositories (LORs) (Tzikopoulos et al., 2009). These repositories often use a fixed set of metadata, such as IEEE LOM (IEEE, 2002), for classifying, retrieving, and building pedagogical sequences of LOs (Neven & Duval, 2002).

However, these repositories are not suitable for creating highly specialised LO collections. This type of LO collection is usually created and used in university’s virtual campuses by communities of teachers and students working within a knowledge domain and having specific educational and research needs. These communities use shared terminology to represent and search their LOs, need to describe the specific features of their LOs, and prefer to define their own organisational and navigational schemas to be compatible with their didactic models.

Thus, in these contexts, traditional LOs must be complemented with domain-dependent information that can be used as (i) classification metadata for enhancing scientific characterisations, searches, and retrievals (e.g., the tags used in an archaeological site to describe the structure of the cultural context where an archaeological object has been found)

and (ii) additional data that can enrich the LO (e.g., the weight and other dimensions of an artifact described in a podcast). We refer to LOs enhanced with domain-dependent information as *hybrid learning objects* (HLOs). To some extent, this domain-dependent information acts as both metadata, because it enables a user to browse an LO based on non-intrinsic information, and data, because it enriches LOs with intrinsic information regarding the item to which the LO refers. The question of whether to refer to such information as data or metadata is a metaphysical question that is outside the scope of this paper. Therefore, for HLOs, we use the term “domain-dependent information” instead of “data” or “metadata.” This domain-dependent information is structured using domain-dependent information schemas.

Figure 1 depicts the difference between a regular LO and a hybrid LO. The regular LO has an authoring process and is then tagged with a fixed set of metadata that are used to retrieve it (Figure 1.a). Once retrieved, these metadata are not used. However the authoring process of an HLO includes the definition of a domain-dependent information schema used to enhance the LO with specific contextual knowledge and data (Figure 1.b). The retrieval engine takes into account this variable domain-dependent information schema when searching the HLO. In addition, when retrieved, the domain-dependent information is used as content for the LO.

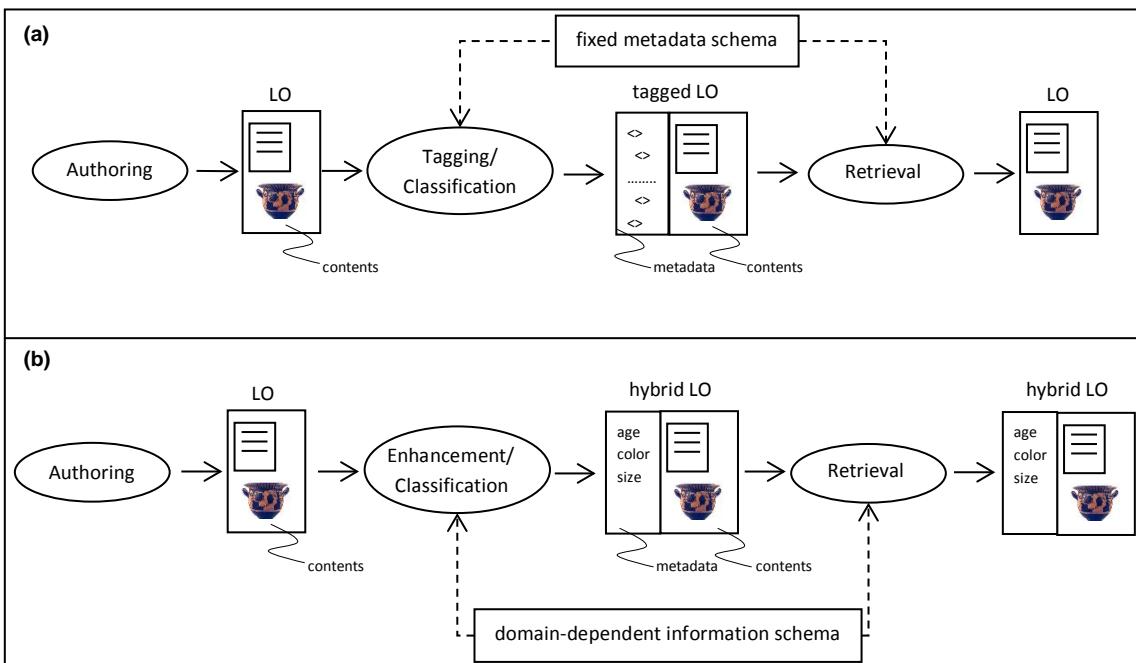


Figure 1. (a) In a regular LO, metadata are only used for retrieval purposes, and metadata schemas are fixed. (b) In a hybrid LO, domain-dependent information-schemas are used for both retrieval purposes and LO enhancements

However, HLOs present an important drawback: because domain-dependent information schemas vary from domain to domain (e.g., from archaeology to philology), specific repositories that enable the browsing and retrieval of HLOs according to all information schemas must be constructed for every case. This is an important disadvantage with regard to classic LO repositories (Ariadne, 2011; Merlot, 2011). These repositories do not permit the presence of domain-dependent schemas for browsing and retrieval, but they can be used for different LOs tagged according to a common metadata schema (IEEE LOM, 2011; DC, 2011; ISO/IEC MLR, 2011).

To overcome this problem, we have defined a meta-relational approach that permits the use of a single repository for different domains. Thus, the repository permits the definition of domain-dependent information schemas that can be used for both browsing and enriching the HLO. A previous version of the HLO approach was presented as virtual objects in Navarro et al., (2005) and Sierra et al. (2006). However, virtual objects are not supported by a strong theoretical model that defines the way in which relational databases can be dynamically defined in a single repository to characterise domain-dependent information. Thus, the domain-dependent information that was included in these virtual objects was much less structured, which forced the user to manually enforce the integrity restrictions. For example, if a painting was painted by an author, and this author was deleted, the painting had a reference to a null

author. Furthermore, it was not possible to import/export the domain-dependent information used to enhance the virtual object to or from a relational database because the underlying relational database schema was not explicitly codified in the virtual object model. We found the import feature very useful because, before many users started using our LOR, they used some type of relational database to structure their domain. Finally, the lack of a well-defined theoretical model made maintaining the LOR responsible for the management of virtual objects a complex task, which limited the understanding and evolution of the LOR.

Domain-dependent information schemas can be defined by communities of users, or they can be standardised in some domains. In both cases, specific LORs must be built for HLOs belonging to specific domains (e.g., archaeology vs. philology). With the approach presented in this paper, a single repository can be used to manage HLOs belonging to different domains and enriched with different domain-dependent information schemas. The need for single information schemas for specific domains and the use of different information schemas for the same domain are complex issues. In some cases, this results in the formation of information schemas by the aggregation of other information schemas or the presence of mappings that translate one information schema into another (Santacruz et al. 2010). This paper does not discuss the definition of one or several information schemas for structuring a specific domain; rather, it addresses the question of how to codify any information schema, which can be standardised or customised for a specific domain, into a single tool that can be reused across different domains.

In addition, in our experience, these schemas, once defined, can dynamically vary with time. Thus, after a specific schema for the archaeology domain is defined, this schema can be changed to include information about the country where the artifacts were found or about the artifacts' composition. Thus, it would be desirable to have an approach that enables dynamic modification of the underlying domain-dependent information schema.

This paper focuses on the theoretical approach that underlies HLOs. Section 2 describes previous studies related to LORs and highlights the advantages of our approach. Section 3 briefly describes OdA (OdA is a Spanish acronym that stands for *Objeto de Aprendizaje*, i.e., Learning Object), our custom LOR for HLO management. Section 4 provides a brief introduction to meta-modeling and describes the meta-relational level used in our approach. Section 5 describes the theoretical approach for managing HLOs. Finally, Section 6 presents conclusions and future work.

Related work

This section compares the characteristics of our OdA LOR with two LOR samples, ARIADNE and Merlot, and three open-source software applications for managing and accessing digital content, DOOR, DSpace, and Fedora. These are some of the most widely used software applications for managing LOs.

- *Ariadne* is a European association that has developed an open and scalable architecture based on standards for managing LOs in distributed repository networks (Ariadne, 2011). Currently, the Ariadne repository contains over 620,757 LOs. When GLOBE providers are included, this number is approximately 900,000 (GLOBE, 2011).
- MERLOT (Multimedia Educational Resource for Learning and Online Teaching) (MERLOT, 2011) is a well-known and recognised international LOR. It stores learning materials, learning exercises, comments, personal collections, and content builder web pages, designed to enhance the experience of using learning materials (Cechinel et al., 2010). Currently Merlot, a member of the GLOBE consortium, contains over 30,650 LOs. These characteristics make MERLOT an excellent LOR example.
- DOOR (Digital Open Object Repository) (DOOR, 2011) is an open-source application for creating LORs. DOOR permits users to search for, retrieve, and include LORs in courses or instructional units. DOOR is released under GPL.
- DSpace, an open digital repository (DSpace, 2011), is, together with Fedora, one of the largest open-source software applications for managing and providing access to digital content. Although DSpace is not a repository of LOs, it has been successfully used as such (Waller & Strunz, 2010).
- Fedora (Flexible Extensible Digital Object and Repository Architecture) was originally designed in 2001 at Cornell University and the University of Virginia as an open-source project (Staples et al., 2003). Fedora has a large international user community and is installed worldwide. It is a general digital content management system that supports the creation of LORs. Fedora provides a model for complex digital objects and an XML standards-based repository for managing and accessing them. The repository has a well-defined software architecture, and most of its services are presented as SOAP web services (Hansen, 2007).

- OdA LOR is our online database application designed for the definition and management of HLOs. OdA provides teachers, researchers, and students with a simple and flexible tool to disseminate their educational and research materials. Its primary goal is to treat the dynamic definition of domain-dependent information schemas used to enrich traditional LOs and thus transform them into HLOs.

These applications are powerful tools for managing traditional LOs, but, except for OdA, we have found them to be inappropriate for the dynamic definition of domain-specific information schemas for the browsing and enriching of LOs. They do not support the definition of these schemas, and most of these tools use standard metadata schemas (e.g., IMS LOM) that cannot be redefined by the user. Fedora is the only exception because it permits the definition of domain-specific information schemas. However, unlike our approach, it does not permit the dynamic modification of these schemas.

Table 1 compares OdA with the previously mentioned applications based on five characteristics:

- *Fixed metadata schema.* Presence of a fixed metadata schema for the classification of LOs.
- *Domain-dependent information schema.* Capability for dynamically defining domain-dependent information schemas for both browsing and enriching LOs.
- *Dynamic redefinition of information schema.* Capability for redefining a domain-dependent information schema.
- *Compound objects.* Presence of complex LOs, formed by the aggregation of other LOs defined in the LOR.
- *Import/Export.* Import/export capabilities according to some recognised standard (i.e., IMS CP [IMS, 2003]).
- *LMS integration.* LMS users can directly search the LO collection. In some cases, users can import the LO into the LMS and publish it.

The table shows that the most widely used LORs, Merlot, and ARIADNE, are based on a simple and fixed LO model. Consequently, their capacity to represent and manage highly specialised and complex HLOs is limited. Fedora uses proprietary standards, while OdA can use any metadata model when it is defined as a domain-dependent information schema.

Among the software applications used to create LORs, Fedora and OdA are the only tools that can define domain-dependent classification schemas for the management of HLOs. However, in Fedora, the LO model cannot be dynamically changed once the repository has been created. In addition, Fedora requires a substantial amount of installation and maintenance support because it is designed to create large institutional digital object repositories.

In contrast, OdA has been designed for the dynamic creation and maintenance of HLO collections. OdA can deal with different domain-dependent information schemas, allowing their dynamic redefinition as needed. Thus, the same repository can handle different LOs that belong to different domains. In addition, it can be installed easily and quickly, which is crucial if IT resources are limited. Thus, OdA has been widely tested in different knowledge domains at the Universidad Complutense de Madrid (UCM) by teachers, researchers, and students.

Only DSpace, Fedora and OdA allow the presence of compound LOs formed by the aggregation of other LOs. This is a key issue in OdA because HLOs often reference other HLOs that have been deployed.

All the analysed applications permit the import and export of LOs. Fedora uses its own proprietary format, and OdA allows the import and export of IMS CP.

Finally, only Ariadne, Merlot, and DOOR permit integration with LMSs. This feature enables users to search for LOs in the LOR. The LOs can then be automatically published in the LMS. In future versions, OdA will be integrated with different LMSs.

Table 1. Comparison of LO repositories and digital content management systems

Repository/Feature	(i) Fixed	(ii) Domain	(iii) Dynamic	(iv) Compound	(v) Import/Export	(vi) LMS
Ariadne	✓	✗	✗	✗	✓	✓
Merlot	✓	✗	✗	✗	✓	✓
DOOR	✓	✗	✗	✗	✓	✓
DSpace	✓	✗	✗	✓	✓	✗
Fedora	✓/✗	✓	✗	✓	✓/✗	✗
OdA	✓/✗	✓	✓	✓	✓	✗

-
- (i) Fixed metadata schema
 - (ii) Domain-dependent information schema
 - (iii) Dynamic redefinition of information schema
 - (iv) Compound objects
 - (v) Import/Export
 - (vi) LMS integration
-

The OdA Hybrid LO Repository

The OdA LOR has five main modules that permit the management of HLOs:

- The HLO authoring module allows domain-dependent database schemas and domain-dependent information that complements the HLOs to be defined. Only the super administrator has access to this module.
- The HLO presentation module allows HLOs to be published, searched, and browsed. Using the dynamically defined domain-dependent information schema, different types of browsing and searching can be performed. Only super administrators and administrators have access to the publication feature of this module. The registered info seekers have access to HLOs that the administrator has declared not accessible to the general public.
- The OdA export module is designed to export and import HLOs. Two types of export are allowed: (i) domain-dependent relational database export and (ii) HLO export of the LO to another repository or platform using a content packaging specification. Currently, only IMS Content Packaging export is supported. Super administrators and administrators, with some restrictions, have access to this module.
- The repository access control module manages user roles, including super administrator, administrator, and registered info seeker, repository access permissions, authentication, and HLO privacy features. Only the super administrator has access to this module.
- The persistence module houses application data based on the domain model in Section 5.

To support the definition and use of an HLO, three steps, which often comprise an iterative authoring process, must be performed using the authoring and presentation modules: (i) the domain-dependent information schema is defined by the super administrators; (ii) the domain-dependent schema is instantiated by administrators; in this step, the digital files that compose the LO are uploaded and the data are completed in accordance with the domain-dependent schema; and (iii) info seekers browse the HLOs using the domain-dependent information schema.

Following step (i), let us suppose that we are working with HLOs related to the domain of archaeology. The archaeologists decide to use a specific domain-dependent information schema. The information schema chosen by the archaeologists is depicted in Figure 2. This simplified domain model illustrates the remainder of the presentation.

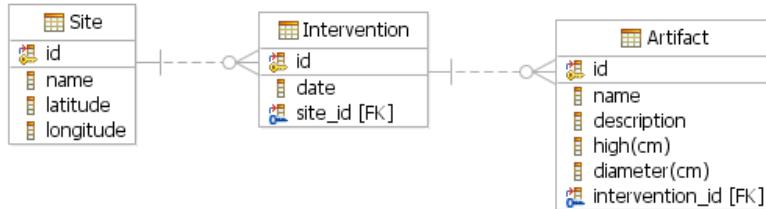


Figure 2. Simplified relational database schema for an archaeological site

This figure shows the definition according to the relational model of three interrelated tables: a `Site` that can have different `Interventions` where different `Artifacts` have been found. Once this schema has been defined as a domain-specific model for the HLO information schema, the user can define the HLO information schema based on the columns of these tables such as `Site.name`, `Intervention.date`, `Artifact.name`, `Artifact.high(cm)` and `Artifact.diameter(cm)`.

Using the OdA authoring module, the tables and columns depicted in Figure 2 are defined using the meta-relational model codified in OdA (Figure 3). Users must manually define these columns in the current version, but a graphical interface for defining this meta-relational model using relational schemas such as the one depicted in Figure 2 is planned for enhancing user experience.

Figure 3. Definition of database schema of Figure 2 in OdA

The three frame columns on the right in Figure 3 show that OdA allows the following aspects to be defined: (a) the data schema in Figure 2; (b) the display order of each table column of Figure 2; (c) whether or not a table column can be browsed in the navigation menu of the OdA Repository; and (d) whether or not the information in a table column will be visible to users other than the super administrator. These visualisation and navigation characteristics can be modified at any time.

Once the first step has been accomplished, step (ii) is performed. The domain-dependent schema is instantiated by populating it so that it represents the structured information of the HLOs, thereby completing the LO. In addition to this information, external resources, including the content files that compose the LO, are uploaded, and references to other HLOs are defined. Thus, the domain-dependent information of an HLO can be (El Caño, 01/02/2010, vessel, 7, 18.9), and its content can consist of several files that describe this vessel. Figure 4 shows the domain-dependent information for an HLO and its content, accessible under the tag “Recursos”. Finally, the HLO can be browsed using the domain-dependent information schema shown in Figure 5.

Currently, OdA is used at five institutional repositories at the Universidad Complutense de Madrid:

1. The historical collection of audiovisual materials for language labs (1940–1990), situated in the School of Languages, Linguistics, and Literatures (LLLS), with 120 Language LOs (OdALLS, 2012).
2. The newly created languages, linguistics and literatures LOs, also situated in the LLLS, with Language, Linguistics and Literature LOs (OdAPhilol, 2012).
3. The repository of pre-Columbian archaeology, Chasqui, situated in the School of Geography and History. It contains 2059 archaeological LOs and is the oldest OdA collection (OdAChasqui, 2012).
4. The historical collection of computers and computer equipment in the García Santesmases Museum in the School of Computer Science, with 115 IT LOs (OdAMIGS, 2012).

5. The collection of Physics Labs Instruments from the School of Physics. At present, it contains 544 Physics Labs LOs (OdAPhysics, 2012).

www.oda.vsf.es/oda2/view/cm_view_virtual_object.php?idov=12&seleccion=1

Buscar objetos

Objeto Digital 12

Anterior / Siguiente

Objeto Digital 12

Datos Recursos Metadatos

Recurso propio

Nombre del recurso: 74.jpg

Recurso propio

Nombre del recurso: Descripcion.pdf

Recurso propio

Nombre del recurso: MapaEsmeraldas.jpg

Nuevo Objeto Digital 12 Editar

Figure 4. HLO domain-dependent information and content (resources) definition in OdA

OdA v2.0

Contenedor de Objetos Digitales de Aprendizaje

Nombre Apellidos >> Salir

Acceso Clasificado a los Materiales Buscar Manual de ayuda Mantenimiento

- Acceso Clasificado a los Materiales

+ Tipo Colección

- Archeological Objects

- Site
 - name
 - El Caño(1)
 - Artifact
 - name
 - vessel(1)

Buscar

Manual de ayuda

Mantenimiento

Acceso Clasificado a los Materiales > Archeological Objects

Site	Intervention	Artifact
name	date	name

1-1 de 1 resultados 10 ▾ 1 Anterior / Siguiente

ID 12 - Acceso Público
Descripción: vessel
Archeological Objects: El Caño(1)

[Ver más]

1-1 de 1 resultados 1 Anterior / Siguiente

CC BY NC SA

Figure 5. HLO browsing according to domain-dependent information such as the site or artifact name

In addition, several repositories are under construction, including the Hispania Epigraphic collections in the LLLS, and a collection of Chemical LOs in the School of Pharmacy.

Due to the complexity of the meta-relational approach, we have selected a simple HLO example, an archaeological artifact, which is formed by a set of domain-specific attributes (El Caño, 01/02/2010, vessel, 7, 18.9) and a set of simple files. However, the HLOs depicted in these repositories can be complex, such as the one depicted in Figure 6. This HLO is a work of art that represents Cicero. The object comes from a collection of HLOs, created

by professors and students of the Philology School at UCM, which collects works of art representing Greco-Roman authors. Other examples of complex HLOs include multimedia LOs for language labs and LOs of standard Arabic.

The screenshot shows a digital object interface titled "Objeto Digital 13". At the top left is a search bar labeled "Buscar objetos". To the right is a thumbnail image of a painting and a "Ampliar" (Zoom) button. Below the title are tabs for "Datos", "Recursos", and "Metadatos", with "Datos" selected. The main content area contains the following information:

Identificador: 13
Descripción: "Joven Cicerón leyendo" de V. Foppa (siglo XV)
• OBRA DE ARTE
 • CONTENIDO DE LA OBRA
 Autor o autores antiguos representados: Marco Tullio Cicerón / M. T. Cicero
 Identificación:
 Inscripción con el nombre.
 Iconografía:
 4.- Este bello fresco, en realidad un fragmento, conocido como "Joven leyendo a Cicerón", conservado en la Wallace Collection de Londres, fue pintado por Vincenzo Foppa (1430-1515), en torno a 1464, y procede de Milán, precisamente de la Banca Medici. Read more: <http://www.readperiodicals.com/201001/2200760141.html#ixzz1xWPMfMnZ> El vestido es contemporáneo al pintor. El niño lee un libro y cerca hay otro cerrado. Aparece una inscripción con el nombre M. T. CICERO.
 • CIRCUNSTANCIAS DE LA CREACIÓN
 Nombre del Artista: Vincenzo Foppa
 Lugar de creación: Brescia. Banca Medici de Milán
 Datación: 1464
 Motivación:
 Si muy pocos años después Botticelli, al rebufo de la filosofía florentina, pintara su homenaje a la Urbs Flora con su

Figure 6. HLO representing information about Arts and Greco-Roman literature

The screenshot shows the "Contenedor de Objetos Digitales de Aprendizaje" (ODA) v2.0 interface. The top navigation bar includes links for various institutions like INAC, Varadero Software Factory, and Fundación El Caño. The main menu has tabs for "DOCUMENTOS", "MANTENIMIENTO", and "ENLACES". On the left, there's a sidebar with categories like "ACCESO ODA's", "SECUCIAL", "CLASIFICADO", and "BUSQUEDAS". The main content area displays a hierarchical classification tree under "COLECCIONES ARQUEOLÓGICAS". The tree structure is as follows:

- ARTEFACTOS
 - METALES
 - CERÁMICAS
 - Periodo
 - Caracteres de decoración
 - Estilo
 - Decoración
 - Caracteres de forma
 - Caracteres de pasta
 - ESCRULTURAS
 - LITICA
 - PARALELOS

Below the tree, it says "1-10 de 44 resultados". To the right, there's a list of items with descriptions and thumbnails, such as:

- ID 1 - Con permiso: Descripción: El objetivo general del proyecto arqueológico es determinar el grado... ARTEFACTOS: Aves(1), Carafe Monocromo(1), Cubitá(1), Decoración en forma...(1), Diseños geométrico...(1), Efigie Zoomorfa(1), Ejemplo de Split Rep...(1), Especial interés son...(1), Espirales yc con gar...(1), Este tipo de cerám...(1), Este tipo de hojas m...(1), Este tipo de vajilla...(1), NEGRO Y BLANCO SOBRE...(1), Podemos observar dep...(1), Políclromo(1)
- ID 42 - Con permiso: Descripción: Plato polícromo ARTEFACTOS: (1)
- ID 45 - Acceso Público: Descripción: prueba de objeto registrado ARTEFACTOS: (1)
- ID 46 - Acceso Público: Descripción: Plato de borde alzado y acanalado ARTEFACTOS: (1)

Figure 7. Complex browsing according to the full archaeological information schema that appears extremely simplified in Figure 2 and Figure 3

In addition, the domain-dependent information schema can provide complex browsing capabilities, such as the one depicted in Figure 7. In this figure, archaeological artifacts can be browsed according to a domain-dependent information schema that accounts for the material of an artifact, its decoration, and the style of this decoration. These browsing items are defined according to the domain-dependent information schema that is presented in a simplified version in Figure 2, codified in Figure 3, and used to provide the data instances that complement the LOs in Figure 4. This section has described the use of OdA, in which the meta-relational approach is codified and is thus not made explicit to the user of the LOR. However, the ability of OdA to treat the dynamic definition of domain-dependent information schema is inspired by a complex relational meta-model enhanced to treat the definition and management of HLOs. The following sections describe this meta-model.

Meta-relational level

Models can be defined as semantically complete abstractions of systems (Rumbaugh et al., 2004). Therefore, we can use relational models (Codd, 1970) to describe the domain-dependent information schemas of HLOs. For example, Figure 2 describes a relational model for part of the simplified database of an archaeological site. This case is used as an example of structured HLO data.

Figure 2 shows the definition of three interrelated tables: a `Site` that can have different `Interventions` where different `Artifacts` have been found. Figure 8 shows an example of an instance of such a database schema.

Site		<u>id</u>	name	latitude	longitude
		s1	El Caño	8.58N	79.32W

Intervention		<u>id</u>	date	site_id
		i1	01/02/2010	s1
		i2	06/01/2010	s1

Artifact	<u>id</u>	name	description	high(cm)	diameter(cm)	intervention_id
	a1	vessel	Decorated vessel...	7	18.9	i1
	a2	crown	Crown found...	10	60	i1
	a3	bracelet	This bracelet...	15	20	i2

Figure 8. Example of an instance of the database schema defined in Figure 2

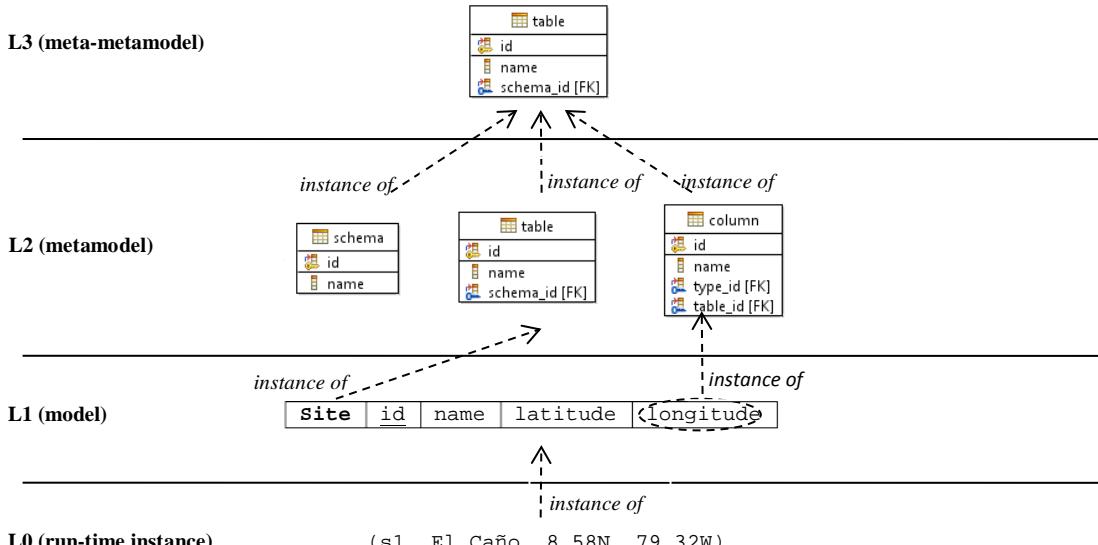


Figure 9. OMG's four-layer meta-model hierarchy

Models can adequately describe data and applications. However, if we want to use a common model to describe different data and applications, operating at the meta-level may be the best choice (OMG, 2003). Thus, meta-models can be defined as semantically complete abstractions of models, or models of models. Figure 9 describes the four-layer architecture for meta-modeling, defined by the Object Management Group (OMG) (OMG, 2010).

In this figure:

- Level 3 (L3) is the meta-meta-level. It describes the properties that meta-models can have at L2.
- Level 2 (L2) is the meta-level. Models that describe models of systems are defined at this level. For example, the meta-model for the relational model (Figure 10), which describes the elements that a relational database schema can have, can be defined at this level.
- Level 1 (L1) is the model level. Models of concrete applications are defined at this level. For example, relational database schemas, such as the one depicted in Figure 2, are defined at this level.
- Level 0 (L0) is the data level or run-time level. Specific elements are defined at this level. For example, the tuples that populate a relational database, such as the one depicted in Figure 8, are defined at this level.

The languages used in meta-modeling are reflective. Therefore, we can use the relational model to define a database schema at L1, or we can use it to define itself at L2. Figure 10 describes a simplified relational model defined at L2, using the relational model itself. For example, another language, such as Unified Modeling Language (UML), can be used to define the relational model at L2 (OMG, 2011). Indeed, the relational model defined in Figure 10 was defined considering the UML definition of the relational model provided in the *QVT Specification* (OMG, 2011).

The meta-model defined in Figure 10 has the following elements:

- schema represents the database schema. For example, a database schema for an archaeological site.
- table represents the tables that populate this schema. For example, the table *Artifact*.
- column represents the columns of the tables defined in the schema. For example, the column name of the table *Artifact*.
- type represents the type of the columns of the table. For example, the column name can be *varchar[50]*.
- key represents the primary and unique keys of the tables. For example, the column *id* of *Artifact* is a key. Therefore, no repeated values can exist in this column.
- key_column represents the columns that are part of a key. For example, the key of the table *Artifact* is formed by its *id* column.
- foreign_key represents the foreign keys of a table. For example, the *intervention_id* of an *Artifact* has to be defined in the column *id* of the table *Intervention*.
- foreign_key_column represents the columns of the foreign key. For example, the column *intervention_id* in the table *Artifact* references the column *id* in the table *Intervention*.

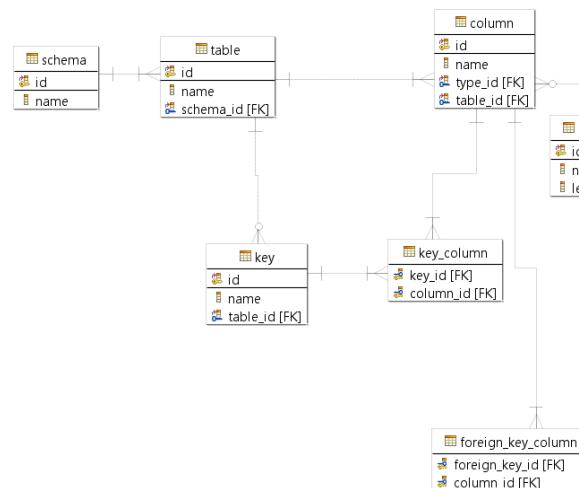


Figure 10. Simple relational meta-model for relational model

Using this meta-relational model, domain-dependent relational database schemas, such as the one depicted in Figure 2, can be represented as instances of the meta-relational model of Figure 10, as shown in Figure 11.

schema	<u>id</u>	name		
	sch1	archaeological site		
table	<u>id</u>	name	schema_id	
	t1	Site	sch1	
	t2	Intervention	sch1	
	t3	Artifact	sch1	
column	<u>id</u>	name	<u>type_id</u>	table_id
	c1	id	ty2	t1
	c2	name	ty3	t1
	c3	latitude	ty3	t1
	c4	longitude	ty3	t1
	c5	id	ty2	t2
	c6	date	ty3	t2
	c7	site_id	ty3	t2
	c8	id	ty2	t3
	c9	name	ty3	t3
	c10	description	ty3	t3
	c11	high(cm)	ty3	t3
	c12	diameter(cm)	ty3	t3
	c13	intervention_id	ty3	t3

Figure 11. Part of the relational schema for the domain-dependent relational database depicted in Figure 2, represented as an instance of the simple relational meta-model for the relational model defined in Figure 10

Meta-relational solution

Our goal is to define HLOs with domain-dependent content extracted from the instances depicted in Figure 8, with references to external resources (i.e., content files) and other HLOs. Thus, as Figure 4 depicts, we can have an HLO that provides information about a vessel, such as a picture or a video, with domain-dependent content formed by the values (El Caño, 01/02/2010, vessel, 7, 18.9). These values correspond to two joins and a projection of the tables Site, Intervention and Artifact depicted in Figure 2 and Figure 8.

This section describes the domain-model solutions to this problem, using the meta-relational level defined in Figure 10. These domain models can be directly used as a persistence model of a repository of HLOs, as any domain model in a software project can be used as a persistence model for the software application (Rumbaugh, 2004).

The proposed domain model describes both the domain-dependent database schema at L1 and its instances at L0 and at the meta-relational level L2. The L1 information stored at the meta-level permits the implicit definition of the domain-dependent database schema, including information about primary and foreign keys. The persistence schema for this solution remains constant for every domain, easing the definition of the database schema used by the repository.

In our approach, the database schema instances are hidden from the user. The repositories based on this solution allow high-level manipulation of these data using the meta-relational information, as shown in Figure 4. This instance is included to illustrate the meta-relational model and the codification of the relational level at the meta-relational level.

The model defined in Figure 10 permits the definition of domain-dependent relational database schemas at L1. However, it does not permit the definition of schema instances at L0. To cope with these instances, the meta-model defined in Figure 10 can be extended as shown in Figure 12.

The new elements included in this meta-model are:

- table_instance, which takes into account the tuples of a table. For example, a tuple for the table t1, Site.
- column_instance, which takes into account the instances of the columns that compose the components of a tuple in a table. For example, the values for a tuple instance of the table t1, Site.

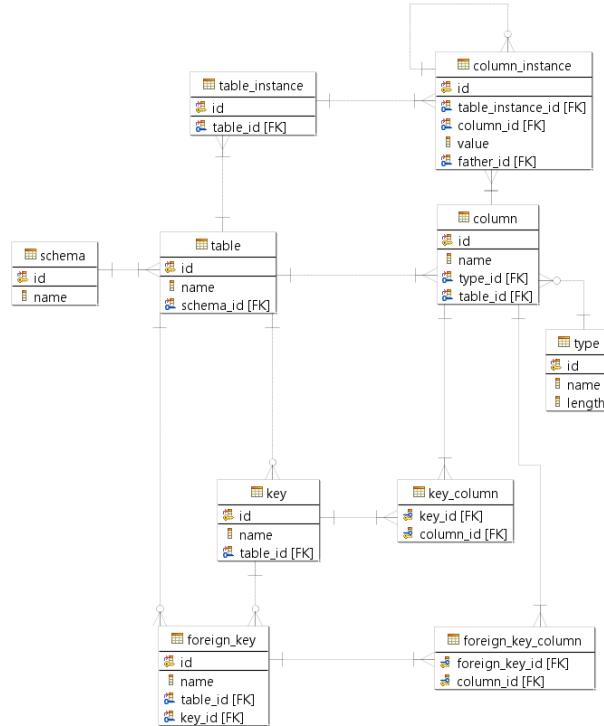


Figure 12. Simple relational meta-model for relational model extended to deal with instances at L0

table_instance		id		table_id
		til		t1
		ti2		t2
		ti3		t2
		ti4		t3
		ti5		t3
		ti6		t3

column_instance		id	table_instance_id	column_id	value
		cil	til	c1	s1
		ci2	til	c2	El Caño
		ci3	til	c3	8.58N
		ci4	til	c4	79.32W
		ci5	ti2	c5	i1
		ci6	ti2	c6	01/02/2010
		ci7	ti2	c7	s1
		ci8	ti3	c5	i2
		ci9	ti3	c6	06/01/2010
		ci10	ti3	c7	s1
		ci11	ti4	c8	a1
		ci12	ti4	c9	vessel
		ci13	ti4	c10	Decorated...
		ci14	ti4	c11	7
		ci15	ti4	c12	18.9
		ci16	ti4	c13	i1
				

Figure 13. Part of the instance of the database schema depicted in Figure 8 and codified at the meta-level, according to the meta-model depicted in Figure 12. This instance complements the instance depicted in Figure 11

Using this extension, relational database schema instances, such as the one depicted in Figure 8, can be represented as instances of the meta-relational schema of Figure 12, as shown in Figure 13.

The domain-dependent tables (`Site`, `Intervention` and `Artifact`) defined in Figure 11 and their instances defined in Figure 13 are created when the user interacts with the system. The user is isolated from the meta-relational level, which interacts with the user in terms of tables, columns, and their instances. Thus, the user does not know if the provided information is used to codify the domain-dependent tables at the meta-relational level. The same applies to instances of these domain-dependent tables.

To characterise HLOs, the model depicted in Figure 12 must be enhanced with new elements. Figure 14 depicts the meta-model of our approach, which enhances the meta-model defined in Figure 12.

The meta-model defined in Figure 14 has the following new elements:

- `learning_object` defines the domain-dependent information structure of the LO in terms of columns of the relational database schema codified. For example, we can define the LO as archaeological artifact.
- `learning_object_column` defines the specific columns that compose a LO information schema. This is only structural information about the LO. For example, the LO archaeological artifact may consist of the columns `Site.name`, `Intervention.date`, `Artifact.name`, `Artifact.high(cm)` and `Artifact.diameter(cm)`. At the meta-relational level, these columns are those with `id` values of `c2`, `c6`, `c9`, `c11` and `c12` in Figure 11.
- `learning_object_instance` defines the instances of the LO domain-dependent information schema. For example, according to the structure defined in the preceding tables, three instances are formed by the join of the tuples of the tables `Site`, `Intervention` and `Artifact`, and the projection according to the columns defined in the table `learning_object_column`. This join and projection are made at the meta-relational level (Figure 13), not at the relational level (Figure 8).
- `learning_object_instance_column_instance` defines the values of the domain-dependent columns that compose a LO. For example, taking into account the LO defined in the example of `learning_object_column`, this table shows the values of its columns in terms of references to `column_instance` (Figure 13) of the LO instances defined in the example of `learning_object_instance`. In terms of the relational model, this table shows at the meta-relational level the instances (`El Caño`, `01/02/2010`, `vessel`, `7`, `18.9`), (`El Caño`, `01/02/2010`, `crown`, `10`, `60`), (`El Caño`, `06/01/2010`, `bracelet`, `15`, `20`). This is the domain-dependent content of the HLOs.
- `external_resource` defines the external resources of a LO (i.e., its content files), such as photos, videos and audio files. For example, the external resource `photo145.jpg` can be located at `%PAHT%/oda/external_resources/`.
- `learning_object_external_resource` defines the specific external resources of a LO. For example, an instance of the LO archaeological artifact can be linked to the external resource `photo145.jpg`.
- `learning_object_instance_learning_object_instance` defines the references that an LO can have with other LOs.

In Figure 14, tables containing attributes for content packing export have been omitted for the sake of conciseness. Using this meta-model, any HLO can be defined. Its domain-dependent content is defined using instances of the domain-dependent database codified at the meta-level (`column_instance`, `learning_object_instance_column_instance` and `learning_object_instance` tables). Content is stored as an external resource (`external_resource` and `learning_object_external_resource` tables) and other HLOs are referenced (`learning_object_instance_learning_object_instance` table).

Figure 15 depicts instances of HLOs (`lo11`, `lo12`, `lo13`) that are defined in the `learning_object_instance` table and represented according to the model depicted in Figure 14. This instance complements the instance defined in Figure 13, which also complements the instance depicted in Figure 11. The domain-dependent information for `lo11` codified at the meta-relational level (`learning_object_instance_column_instance` table) is (`ci2`, `ci6`, `ci12`, `ci14`, `ci15`), which corresponds to the tuple (`El Caño`, `01/02/2010`, `vessel`, `7`, `18.9`) at the relational level (`column_instance` table in Figure 13).

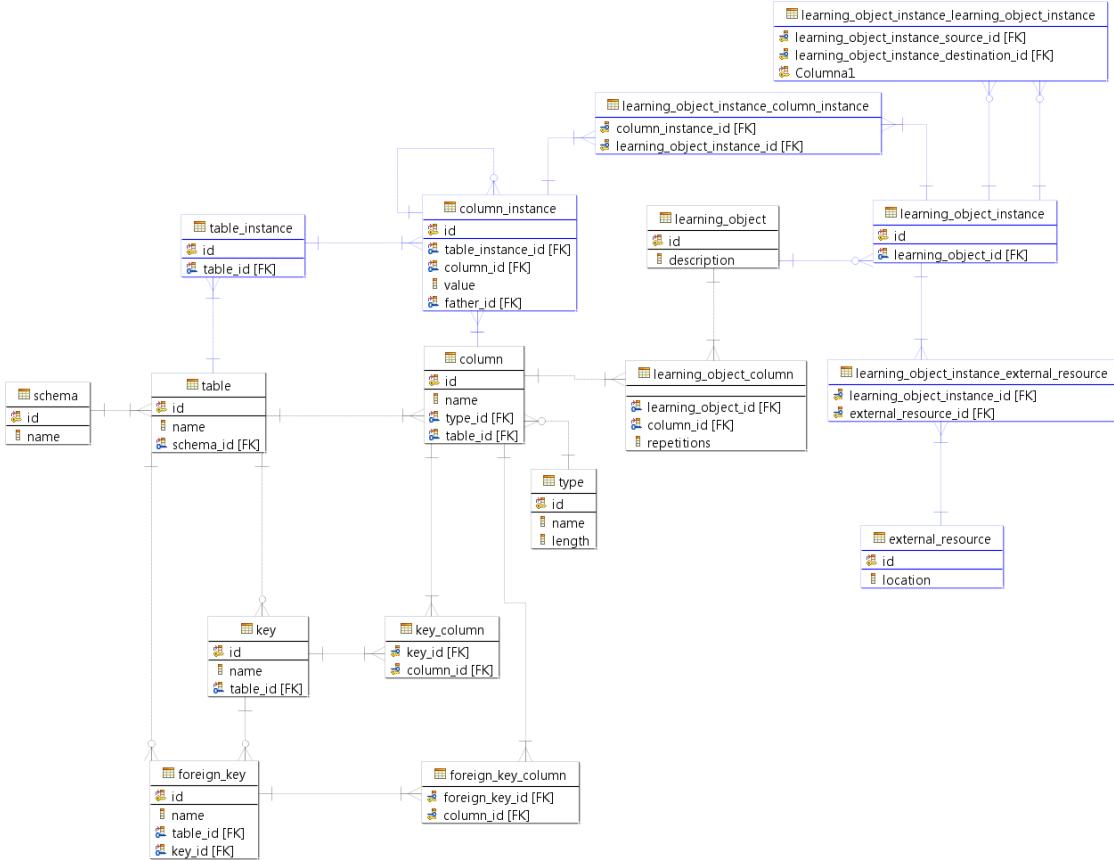


Figure 14. Representation at the meta-relational level of the domain-dependent database schema, its instances, the HLOs, and their instances. Tables containing attributes for content packing export have been omitted for the sake of conciseness

In our approach, a single database schema is defined for the HLO repository. However, some tables of this schema defined at L2 store information that describes domain-dependent relational schemas defined at the L1 level (depicted in black in Figure 14), while others store information that describes their instances at the L0 level (depicted in blue in Figure 14). Some of the tables that store information for instances at the L0 level store structured domain-dependent content for HLOs (`table_instance` and `column_instance`), while others store information for external resources and references to other HLOs. Table 2 shows the type of information stored in the tables defined in Figure 14.

Table 2. Type of information stored in tables according to meta-modelling levels

Tables that store information of domain-dependent database schema at L1	Tables that store information of domain-dependent database schema instances and external resources at L0
<ul style="list-style-type: none"> - schema - table - column - type - key - key_column - foreign_key - foreign_key_column - learning_object - learning_object_column 	<ul style="list-style-type: none"> - table_instance - column_instance - learning_object_instance - learning_object_instance_column_instance - external_resource - learning_object_external_resource - learning_object_instance_learning_object_instance

learning_object	<u>id</u>	<u>description</u>
	lol	archaeological artifact
learning_object_column	<u>learning_object_id</u>	<u>column_id</u>
	lol	c2
	lol	c6
	lol	c9
	lol	c11
	lol	c12
learning_object_instance	<u>id</u>	<u>learning_object_id</u>
	loi1	lol
	loi2	lol
	loi3	lol
learning_object_instance_column_instance	<u>learning_object_instance_id</u>	<u>column_instance_id</u>
	loil	ci2
	loil	ci6
	loil	ci12
	loil	ci14
	loil	ci15
	loi2	ci2
	loi2	ci6
	loi2	ci18
	loi2	ci20
	loi2	ci21
	
external_resource	<u>id</u>	<u>location</u>
	er1	%PATH%/oda/external_resources/photo145.jpg
	er2	%PATH%/oda/external_resources/text99.jpg
	er3	%PATH%/oda/external_resources/video37.mp4
learning_object_instance_external_resource	<u>learning_object_instance_id</u>	<u>external_resource_id</u>
	loil	er1
	loil	er2
	loil	er3
	

Figure 15. Instances of HLOs (loi1, loi2, loi3) defined in the table learning_object_instance and represented according to the model depicted in Figure 14. This instance complements the instance defined in Figure 13, which also complements the instance depicted in Figure 11

Conclusions and future work

Current LORs have powerful capabilities. However, most of them cannot handle the dynamic definition of domain-dependent information schemas used to both classify and enrich LOs. This type of LO, referred to here as a hybrid LO, is common in specialised knowledge domains, and is very useful in the development of virtual academic museums.

Because current LORs do not permit the custom definition of specific domain-dependent information schemas or modifications of these schemas following their definition, the use of domain-dependent information requires the development of ad-hoc LORs. Therefore, to overcome this problem, we have developed an approach that permits the

definition and management of different domain-dependent database schemas using a single LOR. This approach supports efficient and dynamic definitions, searches and visualisations of HLOs.

The key issue of our approach is the definition of specific domain-dependent databases at the meta-relational level. Information stored at the meta-level permits the implicit and dynamic definition of domain-dependent database schemas, including information about primary and foreign keys, which are essential for maintaining data consistency. The persistence schema for this solution remains constant for every domain, easing the definition of the database schema used by the repository.

This approach underlies the learning object repository developed by our group called OdA. This LOR has been successfully used as a repository for HLOs in the domains of IT, physics, archaeology, pharmacy, and philology. In addition, we have used it to develop three virtual academic museums in the domains of physics, archaeology, and computer science.

This repository simplifies the definition of the underlying domain-dependent database schema while also facilitating the collaborative authoring, searching and visualising of HLOs according to this domain-dependent information schema. In addition, OdA requires a limited amount of IT resources, making it attractive for the development and use of specialised LO collections in academic environments.

In future work, our repository, OdA, will be enhanced to enable the use of an API, web services and multilingualism. Further, OdA will be integrated with different learning management systems. Finally, the repository will be used in the context of an international agreement between the Universidad Complutense de Madrid and La Fundación El Caño, which is responsible for an important archaeological excavation in Panama (Owen, 2011).

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The Effects of Peer-Like and Expert-Like Pedagogical Agents on Learners' Agent Perceptions, Task-Related Attitudes, and Learning Achievement

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ABSTRACT

The present study examined the impact of peer-like and expert-like agent stereotypes, as operationalized by agent's image and voice, on learners' agent perceptions, task-related attitudes, and learning achievement. 56 university freshmen (23 males and 33 females) interacted with either the peer-like agent (female college student) or the expert-like agent (female college lecturer) in computer-based multimedia lesson on C-Programming. Consistent with similarity-attraction hypothesis, expert hypothesis, and interference hypothesis, it was found that: (1) learners assigned higher ratings on lesson enjoyment with peer-like agent than with expert-like agent, (2) female learners assigned higher trust to the lesson presented by expert-like agent than to the lesson presented by peer-like agent, (3) female learners reported less anxiety in learning task with expert-like agent than with peer-like agent, and (4) learners who were more attracted to virtual agent were more likely to score lower in learning achievement. Additionally, results from this study suggest that gender bias affects learner's perception on virtual agent. Implications are discussed in terms of how stereotypes of expert-like and peer-like agent can be effectively utilized in e-learning environment.

Keywords

Pedagogical agent, Stereotype, Expert-like agent, Peer-like agent, Gender

Introduction

Pedagogical agents are virtual characters embedded in multimedia learning environment that simulate human instructional roles (Johnson et al., 2000). In today's multimedia technology, virtual agents are incorporated in several e-learning systems such as AutoTutor (McCauley et al., 1998), Herman the Bug (Barlow et al., 1997), and Steve (Rickel & Johnson, 2000). Advocates of pedagogical agent cited the benefits of the *persona effect* (Barlow et al., 1997), which posit that the social cues exhibited by pedagogical agents can increase learner's motivation (Barlow et al., 1997), cognitive engagement (Johnson et al., 2000; Mayer, Sobko, & Mayer, 2003), self-efficacy (Atkinson, 2002) and transfer achievement (Moreno et al., 2001) in learning tasks.

The persona effect is somewhat related to the idea of media equals real life in human-computer interaction. That is, people will tend to apply the same social rules of human to human communication to computer agents (Reeves & Nass, 1996). For example, it was shown that college students' perceptions on virtual agents were "knowledgeable, nice and friendly," which reflected the learners' social expectations of human instructors (Kim, 2007). Furthermore, users tend to perceive computer agents to be more appealing and intelligent when computer agents matched their personalities (Nass et al., 1995).

The activation of social expectations is triggered by the visual and voice characteristics of a virtual agent (Haake & Gulz, 2008; Kim et al., 2003; Veletsianos, 2010). Specifically, agent features such as voice inflection, hairstyle, clothing, ethnicity, and gender form the basis of first impressions on agent usefulness, credibility, and intelligence. A number of researchers have highlighted the importance of agent design (Moreno et al., 2001; Haake & Gulz, 2008). In a review done by Heidig & Clarebout (2011), it was concluded that the choice of agent design reflects the social perceptions such as competency and appeal, which in turn promote or hinder learning.

However, it seems that the importance of agent design has not been acknowledged accordingly in a number of studies. Veletsianos (2010) argued that researchers are failing to regard the effects of agent design on learner's stereotypic beliefs, which in turn, affect learning performance and task-related attitudes. In his study, the researcher cited some examples in which virtual agents were designed without considering the impact of visual stereotypes. For

example, sorcerers have been employed to teach economics (Craig et al., 2002) and cartoon-like characters have been depicted as physics experts (Mayer, Dow, & Mayer, 2003).

One possible reason as to why agent design is often neglected in research is that much of the research on virtual agents is technologically driven; hence, the cognitive and psychology aspects are often disregarded. In addition, the choice of agent design is not an easy task (Haake & Gulz, 2008). The researchers cited an example of a virtual character that was designed for a legal information system in Italy (de Rosis et al., 2004). The virtual agent was originally modeled upon a very attractive young female assistant, since the developers anticipated that the typical user would be a male lawyer. However, after realizing that the lawyer's (female) secretary was the one who most frequently used the system, they became aware that the appearance and behavior of the character distracted these users. Therefore, the designers remodeled a new virtual agent with more professional communication style and more classical attire. From the cited example, it was apparent the choice of agent design is contextual to the subject domain and the target user.

Stereotypes of expert-like and peer-like virtual agents in multimedia learning

The objective of this research is to investigate the effects of expert-like and peer-like agent stereotypes on learning outcome and behaviors. Expert-like agents are virtual models that portray advanced knowledge and competence in a subject domain (Baylor & Kim, 2005). From the design perspective, an expert-like agent can be operationalized through the image of a professor in his/her forties, who speaks in formal, authoritative, and professional manner. Peer-like agents are virtual models whose social characteristics are similar to learners' own attributes. Peer-like agents can be operationalized through the image of a casually-dressed student in his/her twenties, who speaks in friendly and emphatic manner (Baylor & Kim, 2005; Kim & Baylor, 2006; Kim, 2007).

The rationale to investigate the expert-like and peer-like agent stereotypes is straightforward. Arguably, expert-like and peer-like personas are two of the most commonly implemented agent stereotypes in multimedia learning environments (Kim, 2007; Baylor & Kim, 2005). Apart from the traditional role of teacher/expert virtual agent, peer-like agents such as learning companions has been increasingly integrated in e-learning environments (Kim, 2007; Baylor & Kim, 2005). On the one hand, it has been suggested that peer-like agents can benefit learning by simulating social aspects that are predominantly found in peer-to-peer interaction such as behavioral modeling, empathy relations, and positive influence on self-efficacy (Baylor & Kim, 2005). On the other hand, expert-like agents depicting teachers often exude expertise and confidence that may positively influence the learning outcome and behavior. Therefore, these developments raised a central question: Do expert-like and peer-like agents differently affect learning achievement and learning behavior?

There seemed to be a lack of research investigating on this notion. From the literature, only three empirical studies comparing the effects of peer-like and expert-like agent are found. In the first study (Kim et al., 2003), participants were exposed to either the peer-like or the expert-like agent. From the result, it was shown that the visual stereotypes of peer-like and expert agents did not affect learning performance. Participants however, correctly perceived the role of agent (i.e., expert or motivator) based on the visual features of the agents, which were consistent with the learners' stereotypic expectations. No measures for examining learners' task-related attitudes such as enjoyment, self-efficacy and anxiety were included in the study.

In another study (Veletsianos, 2010), participants were assigned to four experimental conditions differing by expert-like or peer-like agent (i.e., visual representation of punk-rock artist or scientist) and subject domain (i.e., nanotechnology or punk rock). Across the subject domains, it was found that participants in peer-like agent condition outperformed participants in expert-like agent condition. Interestingly, regardless of subject domains, participants rated the punk-rock artist agent as being more knowledgeable than the scientist agent. The researcher suggested that these counter-intuitive observations could be attributed to the similarity-attraction hypothesis. That is, participants could identify themselves better with the peer-like agent (i.e., artist agent); hence, they gave higher ratings and paid more attention to the artist agent than to the scientist agent. The study however did not include any measures for examining learners' task-related attitudes.

Finally, Rosenberg-Kima et al. (2008, Experiment 2) compared the effects of peer-like agent (i.e., young and "cool" female virtual model) and expert-like agent (i.e., male virtual model that resembled a prototypical engineer) on agent

perceptions and task-related attitudes of female participants. It was found that the visual stereotypes of pedagogical agents influenced different set of learning behaviors. Specifically, the peer-like agent enhanced the learners' self-efficacy and willingness to enroll in engineering courses while the expert-like agent influenced the learners' beliefs in the subject domain (i.e., perceived utility of engineering). No measures however, were included to examine the learning outcome.

Of the two studies that compared the effects of agent stereotypes on learning outcome, one study showed no difference in learning while the other demonstrated that peer-like agent promoted learning. Concerning the effects of agent stereotypes on learning behaviors, only one of the three studies included measures on task-related attitude (e.g., self-efficacy and perception in subject). Hence, the overall findings remain inconclusive. Therefore, this paper aims to extend the investigation by attempting to answer the following research questions: (1) How do expert-like and peer-like agents differently affect learning achievement? (2) How do expert-like and peer-like agents differently affect agent perceptions? (3) How do expert-like and peer-like agents differently affect task-related attitudes? In order to provide theoretical groundings for this study, three central hypotheses, which are the similarity-attraction hypothesis, expert hypothesis, and interference hypothesis, are reviewed in the following sections.

Similarity-attraction hypothesis

The similarity-attraction hypothesis indicates that people are more likely to be attracted and pay more attention to social models whose characteristics and attributes are similar to their own (Berscheid & Walster, 1969). In human-computer interaction, participants perceived computer voice as more attractive, credible, and informative, when the computer agent matched the participants' personalities (Nass et al., 1995). Additionally, agents whose characteristics matched the college learners' attributes were shown to have influenced the learners to assign more positive reviews on the books presented by the computer (Nass & Lee, 2000).

In the context of multimedia learning environment, the similarity-attraction affects learner's consideration when choosing pedagogical agents. It was found that students of color were more likely to choose pedagogical agents that share the same ethnicity with them (Moreno & Flowerday, 2006), and college students preferentially chose agents whose gender and ethnicity matched their own (Kim & Wei, 2011). On the basis of similarity-attraction principle, Rosenberg-Kima et al. (2008) pointed out that learner's interest and self-efficacies in domain task will be enhanced when they observe virtual models whose characteristics resembled them successfully perform a particular task. Their experiment showed that female college learner' interests and self-efficacies in the subject domain were positively influenced by the presence of peer-like agent (i.e., young and "cool" female virtual model).

Based on the similarity-attraction principle, three hypotheses were proposed:

H1: Learners will assign higher ratings on lesson enjoyment with peer-like agent than with expert-like agent.

H2: Learners will be more attracted to peer-like agent than to expert-like agent.

H3: Learners will assign higher self-efficacy in learning task with peer-like agent than with expert-like agent.

Expert hypothesis

The expert hypothesis suggests that expert-like agent may positively influence learners' stereotypic perceptions and expectations of the agent, as the agent appear to be expert in the particular subject domain (Veletsianos, 2010). From the social psychological perspective, the idea of expert hypothesis can be related to people's social expectations of expert power and legitimate power (French & Raven, 1959). Pedagogical agents that resemble experts will be perceived as being competent and intelligent (Kim et al., 2003). Since people are also persuaded by those whom they perceive as experts (Chaiken & Maheswaran, 1994), learners will assign higher confidences and trust to the information that is presented by expert-like agent. That is, learners' beliefs in a particular subject domain may be more persuaded by expert-like agent, as they perceive the information source as being trustworthy and credible. This notion was prevalent in a recent study by Rosenberg-Kima et al. (2008). It was found that agents who appear to resemble male prototypical engineers (i.e., expert-like agent) were effective in influencing female college learner's beliefs in the subject domain (i.e., perceived utility of engineering).

Based on the expert hypothesis, two hypotheses were submitted:

H4: Learners will perceive expert-like agent to be more knowledgeable than peer-like agent.

H5: Learners will assign higher trust to the lesson presented by expert-like agent than to the lesson presented by peer-like agent.

Interference hypothesis

The interference hypothesis argues that the social cues exhibited by pedagogical agents can distract learners' attention away from learning materials (Moreno & Flowerday, 2006). This notion is related to the idea that interesting but irrelevant elements (i.e., seductive details) may lead learners' attention away from important information. The interference effect was evident in a study by Moreno & Flowerday (2006). It was found that learners scored lower in learning achievement, when they chose to interact with pedagogical agents that were similarly attributed (i.e., same ethnicity) with them. According to the researchers, the learners might have focused their attention on how the pedagogical agent represented them, rather than the salient information presented in the multimedia environment. Hence, the social cues presented by pedagogical agent exhibited seductive details that influenced the affective behaviors of learners, but at the same time interfered with the learning process of instructional materials. As pointed out in Moreno & Flowerday's study (2006), the effects of similarity-attraction led learners to choose pedagogical agents whose characteristics were similar to their own, but these attractions were harmful to the learning performances of learners.

Based on the interference hypothesis, the following hypothesis was proposed:

H6: Learners who are more attracted to agent will be more likely to score lower in learning achievement.

The role of learners' gender

The role of learners' gender must be taken into account in examining the effects of pedagogical agent, as male learners and female learners react differently to computer agents in human-computer interaction. For example, it has been shown that as compared to male learners, female learners were more likely to assign better positive ratings for pedagogical agents (Baylor & Kim, 2004; Kim & Wei, 2011). Therefore, learners' gender may potentially influence the effects of peer-like agent and expert-like agent on learners' perceptions, task-related attitudes and learning achievement.

Method

Participants

56 business major students from a university in Malaysia participated in the present study in exchange for partial course credits. The students were made up of different ethnicities (43% Malays, 43% Chinese and 14% Indians). In an effort to generate a sample of novice learners, all participants recruited were university freshmen and had not taken any programming-related subjects. However, the participants had taken the subject of basic computer applications; hence, they were aptly proficient in computer usage. Among the participants, 23 students were male while 33 were female; and the overall average age was 18.5.

Instructional materials

The computer-based multimedia environment was developed using Microsoft PowerPoint 2010 to deliver multimedia slide shows (i.e., ppsx format) on program comprehension. Crazy Talk Animator Pro was used to develop the image animation of the pedagogical agents. As for agent speech, narrations were created and extracted from IVONA text-to-speech software (<http://www.ivona.com/en/>). Agents' lip movements were then synchronized with the extracted speech using Crazy Talk Animator Pro; and the resulting video files were exported and embedded into the multimedia learning environment (i.e., Microsoft PowerPoint 2010 ppsx format). *Figure 1.* illustrates the screen captures of the multimedia learning environments.

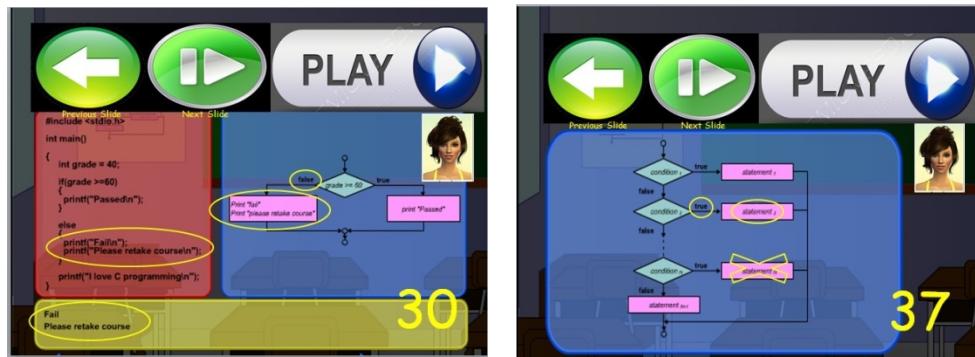


Figure 1. Multimedia learning environments

Subject domain

Participants were required to learn how to (1) comprehend computer algorithms of *if-statement*, *if-else statement* and *nested-if statement* and to (2) predict the output from C-Programming statements. Within the e-learning environment, participants must first study the fundamental program concepts such as *initial value*, *condition* and *statement*. To be able to predict program outputs, participants must form correct mental models on program algorithms by grasping the relationship between the *initial value*, *condition* and *statement*. Sample programs and flowcharts were included to highlight these relationships, and subsequent working demonstrations were presented on how to predict the program output (see Figure 1). The ability to identify programming concepts and to predict program outputs are consistent with the cognitive skills of *knowledge retention* and *comprehension* of Bloom's taxonomy in computer sciences (Thompson et al., 2008).

Independent variables

The independent variables were two different agent personas—peer-like agent and the expert-like agent. Both agents were conceptualized by visual appearance and voice inflection. For the peer-like agent, the visual appearance resembled a female college student in her 20s, and her speech featured a soft and calm voice (IVONA-American English, Salli). As for the expert-like agent, the visual appearance resembled a female college lecturer in her 40s, and her speech featured a strong and authoritative voice (IVONA-American English, Kendra). Prior to the main study, 6 students were invited to simultaneously evaluate the agents based on their visual appearance and voice. The results of the pilot study were satisfactory; the peer-like agent was perceived as “resembling a college peer” while the expert-like agent was perceived as “resembling a college instructor.” Additionally, to increase the likelihood that participants in the main study will relate to the agents, both agents introduced themselves prior to the lesson modules. The peer-like agent introduced herself as Linda, a 20 years old college sophomore while the expert-like agent introduced herself as Dr. Linda, a 42 years old college lecturer. Other than the self-introduction dialogues, the remaining scripts for the learning modules were similar for both agents. Figure 2 presents the two agents used in the study.

Peer-like agent



Expert-like Agent



Figure 2. Agent personas used in the learning environment

Dependent measures

In the present study, the dependent measures were learners' agent perceptions, task-related attitudes and learning achievement.

Learners' agent perceptions

Four items, each scaled from 1 (*strongly disagree*) to 7 (*strongly agree*) measured learners' perceptions on agent's attractiveness (*I like Linda*), agent's friendliness (*Linda is friendly*), agent's knowledge (*Linda is knowledgeable*) and agent's lesson credibility (*I can trust the lesson that is presented by Linda*). Instructions to fill up the surveys were inserted at three intervals within the multimedia lesson. Hence, for data analysis, the mean scores were calculated for each item.

Learners' task-related attitudes: Enjoyment, self-efficacy and anxiety

Three items, each scaled from 1 (*strongly disagree*) to 7 (*strongly agree*) measured learners' task related attitudes, such as lesson enjoyment (*I enjoy this lesson*), self-efficacy in learning task (*I am confident that I can understand this lesson*), and anxiety in learning task (*I feel anxious when listening to this lesson*). Instructions to fill up the surveys were inserted at three intervals within the multimedia lesson. Hence, for data analysis, the mean scores were calculated for each item.

Learning achievement

Learning achievements of participants were measured as total scores of retention and comprehension post-tests. The retention test required learners to label three terminologies (e.g., initial value, condition and statement) and relate them to the correct segments in a sample program code. The comprehension test asked learners to predict the output of twelve short program statements. These measures were consistent with the cognitive skills of *knowledge retention* and *comprehension* of Bloom's taxonomy in computer sciences (Thompson et al., 2008). The highest possible score for learning achievement was 15.

Procedures

Participants ($n = 56$) were randomly assigned to either one of the two computer laboratories—peer-like agent condition or expert-like agent condition. Both groups of participants were unaware of the different environments. Participants studied the multimedia presentation on their respective computer and headsets for 40 minutes. There were three intervals within the multimedia presentation; at each interval, computer-based instructions were given to participants to fill up the surveys for measuring learners' perceptions on agent and task-related attitudes. After the multimedia lesson, participants were given 30 minutes to complete the learning post-tests. Learning measures were scored blind with respect to experimental condition by two authors of this study. The observed difference between the scoring of both raters was minimal and easily resolved after discussion.

Results

Learner's perceptions on agent

The four items measured were learners' perceptions on agent's attractiveness (*I like Linda*), agent's friendliness (*Linda is friendly*), agent's knowledge (*Linda is knowledgeable*) and agent's lesson credibility (*I can trust the lesson that is presented by Linda*). The 2 (gender) X 2 (agent persona) ANOVA conducted on the items indicated:

- A significant main effect of agent persona on agent's perceived friendliness [$F(1,52) = 5.278, p = 0.03$, partial eta squared = 0.09]; learners perceived peer-like agent ($M = 4.95, SD = 1.30$) to be more friendly than expert-like agent ($M = 4.18, SD = 1.27$).
- A significant main effect on learners' gender on agent's perceived knowledge [$F(1,52) = 5.611, p = 0.02$, partial eta squared = 0.097]; female learners ($M = 5.26, SD = 1.13$) perceived agents as more knowledgeable than did male learners ($M = 4.42, SD = 1.35$).
- A significant interaction effect between learners' gender and agent persona on agent's lesson credibility $F(1,52) = 5.473, p = 0.02$, partial eta squared = 0.095]. Subsequent t-test [$t(28) = 3.112, p = 0.004$] revealed that female learners ($M = 5.37, SD = 0.94$) were more trusting to the lesson presented by expert-like agent than did male learners ($M = 4.36, SD = 0.79$). Additional t-test [$t(31) = 2.034, p = 0.05$] also showed that female learners were more trusting to the lesson presented by expert-like agent ($M = 5.37, SD = 0.94$) than to the lesson presented by peer-like agent ($M = 4.71, SD = 0.93$).

Hypothesis 2, which predicted that learners will be more attracted to peer-like agent than to expert-like agent was not supported. In addition, hypothesis 4, which predicted that expert-like agent will be perceived to be more knowledgeable than peer-like agent, was also not supported. However, it was found that female learners significantly perceived agent as more knowledgeable than did male learners. Hypothesis 5, which predicted that learners will assign higher trust to the lesson presented by expert-like agent than to the lesson presented by peer-like agent, was supported only for female learners.

Learner's task-related attitudes: Lesson enjoyment, self-efficacy, and anxiety

The three items measured were learner's enjoyment on lesson (*I enjoy this lesson*), learner's self-efficacy in learning task (*I am confident that I can understand this lesson*), and learner's anxiety in learning task (*I feel anxious when listening to this lesson*). The 2 (gender) X 2 (agent persona) ANOVA conducted on the items revealed:

- A significant main effect of agent persona on lesson enjoyment [$F(1,52) = 5.071, p = 0.029$, partial eta squared = 0.09]. Learners assigned higher ratings on lesson enjoyment to the lesson presented by peer-like agent ($M = 5.04, SD = 0.81$) than to the lesson presented by expert-like agent condition ($M = 4.43, SD = 1.32$).
- A significant interaction effect between learners' gender and agent stereotype on learners' anxiety in learning task [$F(1,52) = 4.719, p = 0.034$, partial eta squared = 0.083]. Subsequent t-test [$t(28)=2.257, p = 0.032$] revealed that female learners ($M = 2.29, SD = 1.19$) were less anxious in learning task with expert-like agent than did male learners ($M = 3.31, SD = 1.26$). In addition, t-test [$t(28) = 2.257, p = 0.032$] also showed that female learners were less anxious in learning task with expert-like agent ($M = 2.29, SD = 1.19$), than with peer-like agent ($M = 3.39, SD = 1.31$).

The results supported hypothesis 1, which predicted that learners will assign higher ratings on lesson enjoyment to the lesson presented by peer-like agent than to the lesson presented by expert-like agent. Hypothesis 3, which predicted that learners will assign higher self-efficacy in learning task with peer-like agent than with expert-like agent, was not supported. In addition, it was shown that female learners were significantly less anxious in learning task with expert-like agent than did male learners; and female learners were significantly less anxious in learning task with expert-like agent than with peer-like agent.

Learning achievement

Participants' learning achievements were assessed as total scores of retention and comprehension tests. The 2 (gender) X 2 (agent persona) ANOVA on learning achievement did not reveal any significant main effect or interaction effect. Hence, peer-like and expert-like agent did not differently affect learning performance.

Based on the interference hypothesis, it was predicted that learners who are more attracted to agent will be more likely to score lower in learning achievement (hypothesis 6). To test hypothesis 6, participants were categorized into two groups—*High Attraction* and *Low Attraction* learners, based on participant's rating on agent's attractiveness (i.e., as measured by item “*I like Linda*”). High Attraction learners assigned ratings greater than 1/2 standard deviation above the score mean, while Low Attraction learners assigned ratings less than 1/2 standard deviation below the score mean. A 2-Way ANOVA relating agent condition (i.e., peer and expert agent) and learner group (i.e., High Attraction and Low Attraction learners) on learning scores revealed a significant main effect for learner group [$F(1,39) = 6.569, p = 0.015$]. Subsequent t-test [$t(37) = 2.446, p = 0.019$] indicated that *High Attraction* learners [$M = 6.6, SD = 3.84$] performed significantly lower than *Low Attraction* learners [$M = 3.9, SD = 2.73$] in learning achievement. This result supported Hypothesis 6.

Discussion

The purpose of this study was to examine the effects of peer-like agent and expert-like agent on learners' agent perceptions, task-related attitudes, and learning achievement. Three central hypotheses, which are the similarity-attraction hypothesis, expert hypothesis and interference hypothesis were posited as theoretical groundings of this study. Table 1 presents the summary of the results of the hypotheses tested in the present study.

Table 1. Summary of results of the hypotheses tested in this study

Hypotheses	Results
<i>Similarity-attraction hypothesis</i>	
1. Learners will assign higher ratings on lesson enjoyment with peer-like agent than with expert-like agent.	Supported.
2. Learners will be more attracted to peer-like agent than to expert-like agent.	Not supported.
3. Learners will assign higher self-efficacy in learning task with peer-like agent than with expert-like agent.	Not supported.
<i>Expert hypothesis</i>	
4. Learners will perceive expert-like agent to be more knowledgeable than peer-like agent.	Not supported.
5. Learners will assign higher trust to the lesson presented by expert-like agent than to the lesson presented by peer-like agent.	Supported only for female learners.
<i>Interference hypothesis</i>	
6. Learners who are more attracted to agent will be more likely to score lower in learning achievement.	Supported.

Hypothesis 1, 2, and 3 (Similarity-attraction hypothesis)

Hypothesis 1 predicted that learners will assign higher ratings on lesson enjoyment with peer-like agent than expert-like agent. This hypothesis was supported in the present study. Possibly, this is because the peer-like agent was regarded as more friendly than expert-like agent (Kim, 2007). The peer-like agent that served as a social model for the participants might have simulated a sense of human-peer interaction (Kim & Baylor, 2006); which in turn, led to an increased satisfaction and enjoyment in the multimedia lesson of this study.

The prediction that learners will be more attracted to peer-like agent than to expert-like agent was not supported (hypothesis 2). However, this is possibly due to the fact that the participants were unable to make comparisons (i.e., of visual appearance and voice inflection) between the peer-like agent and the expert-like agent simultaneously. Hence, the results may differ, under other environments in which learners are able to visually consider different agents (Moreno & Flowerday, 2006; Kim & Wei, 2011).

The results of this study did not support the expectation that peer-like agent will enhance participants' self-efficacy in learning task (hypothesis 3). Hence, this study failed to replicate the findings by Rosenberg-Kima et al. (2008). In Rosenberg-Kima's experiment, the subject domain (i.e., Five Benefits of Engineering) was *motivational* rather than

cognitive in nature. That is, the objective of the presentation was to *motivate* female participants to enroll in future engineering courses. Secondly, in the experiment, the participant's enhanced self-efficacy (e.g., "I am confident that I could do well in math classes") was regarding *future* tasks (i.e., when and if they enroll to engineering courses), rather than *occurring* learning tasks. From the results of this study, the effects of peer-like agent on self-efficacy may not be robust enough, when the subject domain is *cognitively* focused (rather than *motivational*) and when the learning task is *occurring* (rather than *future* learning task).

Hypothesis 4 and 5 (Expert hypothesis)

It was predicted that participants will perceive expert-like agent to be more knowledgeable than peer-like agent (hypothesis 4). This hypothesis, however, was not supported in the present study. In line with previous finding (Kim et.al., 2003), image / voice stereotypes of peer-like agent and expert-like agent did not affect participants' perception on agent's knowledge. Rather, the perceptions on agent's knowledge are affected by scripts in the learning instructions (see Kim, 2007). Since the lesson presentation from both agents were similar, learners perceived the peer-like agent to be equally competent and knowledgeable as the expert-like agent. However, it was shown that female learners gave significantly higher ratings on agents' perceived knowledge than did male learners.

It was expected that learners will assign higher trust to the lesson presented by expert-like agent than to the lesson presented by peer-like agent (hypothesis 5). However, the results showed that the hypothesis was supported only for female learners. This scenario can be attributed to the prevalent gender bias in male participants (Carli, 1999). For instance, it was demonstrated that male audiences were less influenced by female expert; while female audiences were equally persuaded by male and female experts (Rhoades, 1981). Since the agent gender was female, the male participants might have resisted the informational influence by the expert-like agent.

This notion was also empirically proven by prior studies in human-computer interaction. In one study (Lee et al., 2000), it was shown that men demonstrated less conformity to the female-voiced computer than to the male-voiced counterpart whereas women did not show the corresponding tendency. In another experiment (Lee, 2004, Experiment 1), it was shown that female participants were persuaded more by virtual male representation than virtual female representation when the subject domain was masculine in nature. Lee concluded that the female learners displayed higher conformity to virtual characters that they perceived as expert in the particular subject domain. Male participants, however, were more persuaded by male characters than female characters, regardless of whether the subject domains were masculine or feminine in nature. The researcher argued that this observation was attributed to the tendency of male participants to resist female influence. This hypothesis was confirmed in the subsequent experiment by Lee (2004, Experiment 2). It was shown that though the subject domain was gender-neutral, male participants continued to be less persuaded by female virtual characters than male characters. In sum, it was found that the participants' gender moderated the social influence by virtual agents, and "while men exhibited greater conformity to the male-charactered partner [virtual agent] than to the female-charactered counterpart [virtual agent], women did not differentiate between male and female partners [virtual agents]" (Lee, 2004, pp.794).

Hypothesis 6 (Interference hypothesis)

Grounded on the interference hypothesis, it was predicted that participants who are more attracted to peer-like agent will be more likely to score lower in learning achievement (hypothesis 6). The results of this study supported this hypothesis. Regardless of agent type (i.e., peer or expert agent), learners who reported higher attraction to agents scored significantly lower in learning achievement than learners who reported less attraction to agents. One interpretation is that the participants who were more attracted to the agents were more likely to focus their attention on the social characteristics of the agents, thereby interfering with the learning process (Moreno & Flowerday, 2005).

Implications for instructional design

From the instructional design perspective, a number of inferences can be made from this study. Firstly, visual and voice characteristics of agent will influence learners' stereotypic expectations of the agent. For example, the agents' visual and voice inflection led participants to perceive peer-like agent to be more friendly; while expert-like agent

were perceived to be more credible. Additionally, agent stereotypes affect different types of task-related attitudes from learners. Hence, to tap into effectiveness of virtual stereotypes, instructional designers must target the learning behaviors that they hope to affect.

Though the visual and voice characteristics of peer-like agent and expert-like agent did not directly affect learning performance in this study, there were certain effects on learners' psychological behaviors. For instance, the results from this study suggests that expert-like agent invokes better credibility, as well as reducing subject anxiety particularly for female learners. Plausibly, it might be that learners who interacted with expert-like agent might have gained perceived support that comes from an authoritative relationship (i.e., college lecturer), which reduced the level of task-related anxiety (Huang et al., 2010). On the other hand, peer-like agents whose social characteristics are similar to learners' attributes can increase enjoyment during learning tasks.

It should be cautioned that agents may potentially distract learners' attention away from the learning content. Hence, for subject domains which are focused on *cognitive* rather than *affective* processes, instructional designers should carefully limit the amount of social cues presented in software agents rather than add them for reasons of appeal or entertainment (Moreno & Flowerday, 2006). This notion is supported by Kim & Wei (2011), who pointed out that "when an application is geared toward improving users' cognitive tasks, the presence of an agent might not be warranted. However, for applications that are focused on users' affect and choice (e.g., promoting ideas and products), agent presence can be a viable option in the design."

The final implication is that the social influence by virtual agents is moderated by learner's gender. For instance, female learners tend to give favorable agent ratings than do male learners. Also, due to the tendency of male participants to resist female influence by computer agents (Lee et. al., 2000, Lee, 2003), the displayed credibility by female virtual agents may not be effectively imposed on male learners. Additionally, previous study showed that learners working with the male agents were more satisfied with their performance and reported that the agents better facilitated self-regulation (Baylor & Kim, 2003). Moreover, learners perceived the persona of the male agents more favorably than that of the female agents, which reflect the stereotypic expectations than men are generally more influential than women in terms of expertise and legitimate power (Kim, 2005). Combining the findings of this study and the reviews of literature, the general recommendation here is that male virtual characters may be more advantageous for both female and male learners in an e-learning environment, particularly when the learning task is focused on technical domain that involves potentially verifiable facts (e.g. computer programming).

Conclusion

In sum, the results of this study showed that learners' social stereotypes and expectations of pedagogical agents mirrored the human to human relationship in the real world, which affects learners' perceptions, task-related attitudes and learning achievement. Additionally, this study lent support to the premise that different agent stereotypes may have different roles in activating stereotypic beliefs in learners' mind, which may be beneficial in influencing different sets of learning behaviors. Hence, the effectiveness of agents' personas and their stereotypic influences on learning behaviors are dependent on the learning context, learning goals and the target learners.

There were limitations of this study that can be controlled in further research. The limited sample size and the short duration of treatment (e-learning) might have contributed to the results of this experiment. Therefore, increasing the sample size and duration of treatment may provide a more realistic representation of results. Additionally, similar research should be extended to participants with other ethnicities and cultural backgrounds. Also, the participants of this study were selected because they lacked domain knowledge. Whether similar results would be obtained with more knowledgeable participants remains to be addressed. Lastly, further studies should confirm if the effects of virtual agents on male and female learners would vary, if agent gender and subject domains are manipulated. As pointed out by Moreno & Flowerday (2006) that the "psychology of design is a lot more complex than the technology of design," evidently this line of research should be extended to further explicate the relationship between agent's design and learners' psychological behaviors and cognitive outcome.

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Research on E-Learning and ICT in Education

(Book Review)

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Edited by Athanassios Jimoyiannis of University of Peloponnese, Korinthos, Greece, *Research on e-Learning and ICT in Education* features compilation of 22 chapters written by international academics from Bulgaria, Canada, Cyprus, Greece, Italy, Spain and the United Kingdom. The papers included in the book were originally presented at the Seventh Pan-Hellenic Conference on Information and Communication Technologies in Education (HCICTE 2010). The book is divided into four parts: Part I: Twenty-First century education and e-learning (five chapters); Part II: E-learning and teachers' professional development (five chapters); Part III: ICT-enhanced learning (six chapters) and Part IV: Learning environments and technologies (six chapters).

Part I of the book covers aspects of twenty-first century education and e-learning and it begins with a chapter by Neil Selwyn in which he discusses the relationship between technology and the structure and processes of schools and schooling. He introduces three possible forms, namely technology and virtual schooling, technology and re-schooling and technology and de-schooling. In Chapter 2, Christina Preston and John Cuthell introduce the project MarindaMod to explore the emerging professional issues and collaboratively create new knowledge among like-minded educators. The MirndaMod joins education professionals across institutional and national boundaries with the use of communication technologies in the United Kingdom. Stewart Martin in Chapter 3 describes a project about teaching citizenship in secondary schools in England using virtual environment. The project uses immersive virtual worlds as a technological tool to develop conceptualization of citizenship. The InnovaScuola project introduced in the Italian schools is the topic of discussion in Chapter 4 by Antonio Cartelli. The chapter reports the difficulties that students encounter in some of the discipline topics and importance of digital literacy in helping the students to overcome the problems. The digital divide has been a major issue in the use of ICT in schools between haves and have-not. But according to Sianou-Kyrgiou and Tsiplakides (Chapter 5), the issue is not the access to the ICT, it is the use of ICT that divide the users.

Part II of the book includes five chapters dealing with e-learning and teachers' professional development. This part opens with the chapter by Dimitriadis that describes how to support teachers in the CSCL classrooms. In Chapter 7, Makrakis presents the creation of a wiki named WikiQuESD with the aim of using as a scaffolding hypermedia tool to enhance pre-service teacher education. Karsenti and Collin in the next chapter report the use of ICT in practical teacher training and professional induction in Canada. The results from two pilot studies identify the difficulties that the novice teachers faced and how to overcome these with the use of ICT. In the next chapter Eteokleous-Grigoriou and colleagues describe a case study conducted in Cyprus regarding the pre-service elementary teachers' use of online dictionary. The study found the usefulness and difficulties of the ICT tool and explanations are provided with the use of Technology Acceptance Model (TAM). The last chapter in Part II describes the study conducted by Charalambous and Papaioannou to explore self perceived competence and use of ICT by the primacy school principals in Cyprus. The study shows that the principals do not feel competent in using ICT for personal, teaching and administrative purposes except for word-processing.

Part III in this book deals with ICT-enhanced learning. Six chapters in this part describe empirical studies related to the innovative use of ICT and e-learning in various contexts. The first to report is by Hadjileontiadou and colleagues and in the chapter they describe the study conducted with the undergraduate students in CSCL setting in Greece and introduce the illusionary adaptive support and instructional design model. The study found that the group who received an illusionary type of support produces better collaborative performance. In Chapter 12, Karasavvidis and

Theodosiou elucidate the design and development of a Wiki task in undergraduate education. Their study involves longitudinal research that uses the design experiment method and aims at the progressive refinement of a Wiki task.

Angelaina and Jimoyiannis in Chapter 13, deals with introduction of blogs with the use of Community of Inquiry framework in an attempt to developing ICT literacy skills in the form of information access, managing, integration and communication skills. The analysis shows that the blog supports the development of a community of inquiry and achieved higher cognitive levels and other communication skills. Latsi and Kynigos in Chapter 14 draw attention to the readers how mathematical meaning-making can be integrated with spatial navigation and orientation in 3D digital media and used with the sixth grade students in a public primary school. In Chapter 15 Karatrantou and Panagiotakopoulos give details on the affordances of educational robotics in teaching introductory programming. They present a case study where Lego Mindstorms educational kits are used. The findings from this study provide promising outcomes in using such kits to teach computer programming to junior high school students. In the last chapter in Part III, Taramopoulos and the team report the study to compare the learning outcomes of 15-16 years old students to teach simple electronic circuits. It was found that when the students were introduced with teaching-by-inquiry in real and virtual environments, greater conceptual improvement was detected.

Similar to the parts mentioned above Part IV of the book covers learning environments and technologies. The first chapter in this part is presented by Stanfield and his colleagues in the United Kingdom. The chapter provides examples of game-based learning in business, teaching software development and teaching language and outline the advantages of such approaches in education as a whole. In Chapter 18 Vrellis and the team report their study about collaborative science learning activity in Second Life. The study, with the use of Temple Presence Inventory (TPI) investigates the sense of presence both spatial and social when students engaged in collaborative problem-based physics activity with the use of Second Life as a platform for learning.

In Chapter 19 Chatzara and team present the emotional interaction in e-learning. Computers and other technological devices have been often criticised for not being able to represent emotion in their interaction with the users. In order to overcome this problem Chatzara and the team use an ‘agent’ that has animated synthetic character. Boytchev in Chapter 20 presents how the concept of conic sections can be taught by using virtual models. In this chapter the author uses software applications such as Dynamic Geometry Software (DGS) that affords virtual reality and represent mathematical concept of conic sections to make the non-mathematician easy to understand. The Chapters 21 and 22 are in technical nature. Sampson and his colleagues explain the IEEE standard Learning Objects Matadata (LOM) as a commonly accepted way for describing educational resources. Such standardization allows sharing and reusing of the digital resources. In the final chapter Kazanidis and Satratzemi present about the restrictions and abilities of Shareable Content Object Reference Model (SCORM) in creating learning resources.

A number of edited books have been published on the topic of e-Learning and ICT in education in the past decades. For example Goodyear et al. (2004), Conole & Oliver (2006), Holms & Gardner (2007), Andrews & Haythorwaite (2007), and Iskander (2008) are among the few. The field of e-Learning and ICT are evolving and continuing work in this area provides valuable information to the practitioners and policy makers.

The crucial question for the reviewer is how this volume differs from and compares with those that have been published in the past decades. In the first place, the chapters included in the books were conference papers similar to the selected conference proceedings. However the editor stated that the papers went through a blind review process with at least two independent reviewers, similar to the publication in the referred journals. The focus of this book seems to be deliberately wide. A number of issues, both pedagogical and technological are addressed by the researchers in their own settings. Transferability and scaling of those findings to wider context need to be further scrutinized. The issues related to e-Learning and ICT applications in education are diverse and multi-faceted. To name a few – theory, policy and practice, design, assessment, experiments, subject specific teaching and learning, student participation, technological developments, innovative ideas, and standardization issues are some of the many educators are confronting. It is clear that the technology itself as well as applications develop over time.

Some researchers indicate that e-learning and ICT are over marketed and under use and critical review of effectiveness need to be investigated (Njenga & Fourie, 2010). Chen and Fang (2013) also note that there are some discrepancies between the latest development in learning technologies and actual usage in the education sector. More research and experiments are needed to narrow the gap. The process of e-learning and ICT involve many

stakeholders including developers, instructional designers, course administrators, instructors and students. It is a challenging task to bring harmony and collaborations among them in order to be successful.

For the most part this book covers wide ranging topics with a mixture of theoretical concepts, methodological issues, empirical studies and technical development. The strength of the book is being able to bring together scholars from diverse backgrounds and present the contemporary understanding of e-learning and ICT in education from the perspective of six European countries, and Canada. There are still much that we do not know about these topics. The contributors in this book are to be valued as they offer body of recent findings and how we might find better answers to the research on e-learning and ICT.

But a few weaknesses can be noted in providing the direction of the research in each theme. The editorial covers synopsis of the chapter without any comments on the issues raised in the chapters. It would have been more beneficial if the editor provides cross-analysis of the chapters to craft the book more cohesive and help the reader make sense of the information being presented in the book and describes the reasons for splitting the book into different parts. Some chapters are too technical to understand for the novice readers. Nevertheless the book provides a valuable contribution to the existing literature and it will be a key reference book to have it in the libraries.

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Digital Games in Language Learning and Teaching (Book Review)

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Digital Games in Language Learning and Teaching

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There is an increasing interest in the use of digital games in language learning and teaching. Unsurprisingly this book was published simultaneously with *Language at Play: Digital Games in Second and Foreign Language Teaching and Learning (Theory and Practice in Second Language Classroom Instruction)* (Sykes et al., 2012). In a way, both intend to cover a gap in language learning that was grasped by different researchers (Garcia-Carbonell et al, 2001; Gee, 2003) but required a conceptual framework of application. In this sense, the book has been clearly divided into two different but mutually dependent parts: part I, “From theory to practice”, which comprises chapters one to four, and Part II, “From practice to theory” that includes chapters five to ten. The approach is rather academic and more oriented towards general language arts – with some exceptions- than towards foreign or second language learning and teaching, so some of the readers may somehow be surprised by the fact that it would have been more appropriate to mention that it was intended for first languages than for second. Said so, the book is quite well theory-practice balanced and one may feel that there is a clear practical purpose in this volume.

Some of the outstanding premises in the book are, first, that learning through games, especially through the multiplayer online role-play ones and the commercial off-the-shelf ones, is mostly a problem based approach; second, that it is necessary to provide learners “tools with which to solve the problems” (page xii); and, third, that learning, like gaming, is a circular process of error-feedback-reconstruction which requires the continuous reconstruction of the learner’s knowledge. Thus, the book is clearly cognitive-oriented. Indeed, like any other cognitive approaches (p. 64) it also pays some attention to how learning is constructed through interaction especially through communities of practice (chapter 3). This is especially remarkable and visible when multiplayer modes occur (chapter 4). One of the ideas that is basic to this cognitivist approach is that games provide the player (or student) with a rich environment from which cognition is developed but is also enriched by the provision of rich input provided within the scenario itself (Smith, 2004). Thus self-directed learning is facilitated by “the adequate support, scaffolded reflection and critical thinking” (p. 55). One of the criticisms that can be done is that although chapter three intends to support some constructivist approach to learning, Filsecker and Bundgens-Kosten – the authors- recognize “finding a game that closely matches the PBL pedagogy or constructivist learning theory is not easy” (p. 56). The problem that can be understood from this perspective is that computer games are limited to suggest the kind of problems the students face, and also the limited role of human-computer interaction as mediator in human learning. It may also be valuable, however, for teachers or games in which behaviorism plays a significant role in self-learning, say by the interaction of stimulus-response dyads. Chapter four intends, on the other hand, to suggest how multiplayer interaction has the potential to improve learning through interaction. Again the problem is that mediation in this chapter is not clearly defined and although the author, Mark Peterson, somehow suggests how the interaction is done through the students’ capacity to “adapt” their language by interacting with their peers, the impact of the Zone of Proximal Development (Vygotsky, 1978; Kim & Blankenship, 2013 among many others) and its function in learning is neglected when, in fact, it could enhance the potential of the learners’ interaction in

learning. Overall, this chapter four acknowledges the importance of the social factor in increasing cognition and facilitating language learning, especially, in situations of second language acquisition.

The second part begins by the attractive chapter five which intends to show some findings obtained from digital gaming in foreign language learning which includes the type of multiplayer interaction in which gamers take part and the kind of games that promote more communication, and subsequently learning. It also stresses the potential of discussion forums and language advising (the reader may not want to miss the theoretical underpinnings presented on pages 108-111). One of the most interesting chapters, seven, addresses the importance of Intelligent Tutoring Systems in serious games. Serious games have potentially acquired a significant role in education -more in other subjects than in foreign language- over the years. Surprisingly enough, after a well done research in a Southern American university the authors conclude that “the results of the study indicated that learning is better for the non-game environment (Coached Practice), but engagement is better for the game-based system (Showdown)” (p. 133). This statement has some significant potential implications. First, it may mean that scenarios have a potential influence on interaction and practice but not as much on learning itself, as well as that learning is probably more productive by individual or one-on-one means (whether computer mediated or not). The consequence challenges the old theory that practice leads to learning (Widdowson, 1978). However, it seems difficult to understand if this only happens in computer game scenarios or in other applications as well. According to this, tutors have a more valuable role than productive online practice which may be mediated by error-feedback. It may also imply that both serious games and educational websites require of some tutoring devices if learning is to happen. Chapter seven analyzes the procedural effects of memory in playing games and language learning. In so doing, the author, Reichle, looks again into the cognitivist approach that tends to prevail in most papers in the volume. As complementary to the previous chapter, this author really believes that “practice of coupling morphosyntax with gameplay mechanics could also prove fruitful in real-world language learning settings” (p. 139). It is certainly true that mechanics was considered as the key in language learning back in the 1960’s (Chastain, 1976; Dillers, 1978) and then rejected by communicative approaches (Savignon, 1983). However, revisionists tend to believe that by so doing the role of memory had been ignored in language learning (Durrant & Schmitt, 2010). Interesting enough, this chapter goes back to this issue and suggests that some scenarios could be more valuable than others in promoting language learning. The fact that computer based games tend to reproduce the same language patterns in form of pre-fabricated lexical and grammatical structures (like instruction or computer responses) may trigger the use of memory to solve the situations presented to the player. These patterns can be practiced online and so students would not need to practice them in face-to-face communication especially when personality issues happen such as hesitation processes or problems for introverted or non-self-confident students (Wood, 2009). That is why, as indicated in chapter eight, students need to have the opportunity to interact with other players (or speakers) online and the willingness to participate in social acts through games is undoubtedly desirable in language learning both on voice- and text-based chats. In our opinion, one valuable finding in this chapter is that learners tend to communicate more freely because they do not have the pressure of the face-to-face interaction. Although the implications in terms of personality and the old narrow approach of the gamer as some kind of isolated person with limited contact with the exterior world are self-evident, this discussion goes beyond the scope of this book review. The book concludes with two chapters on the learning of vocabulary and collocations which are valuable to understand the potential benefits of adequate input in language learning. The potential problem in both cases is that most interactive games (which tend to be the most common) tend to reproduce real situational speech which may be natural for native speakers but not as desirable for second language learners.

As a conclusion, we should say that although we found that the book tends to show the dominant cognitive trend with limitations in aspects as the human-computer interaction or the prevalence of vocabulary as the cornerstone of language learning (which limits the influence of other aspects), we considered this book potentially positive because of the importance attributed to autonomous learning and because of the revision of repetition and mechanics in language learning. It really does not matter if you are for or against the positions presented in the book, what seems evident is that teachers and researchers will surely find it full of food for thought.

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