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A prompt-based annotation approach to conducting mobile learning activities for architecture design courses

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A B S T R A C T

In this study, a prompt-based annotation approach is proposed for developing mobile learning systems for architecture design courses. To evaluate the effectiveness of the proposed approach, an experiment was conducted by assigning 56 freshmen randomly to an experimental group and a control group. The students in the experimental group adopted the mobile learning approach with a prompt-based annotation strategy, while those in the control group learned with the conventional in-field instruction and annotations. From the experimental results, it was found that the proposed prompt-based annotation strategy not only promoted the students' self-efficacy, but also improved their learning achievements. In the meantime, it is interesting to find that the experimental group students had medium cognitive load during the field trip, while the control group had rather low cognitive load. This implies that the prompt-based annotation approach engaged the students in mobile learning tasks with reasonable challenges and efforts.

1. Introduction

The aims of architecture design courses are to foster students' conceptions of construction, innovation and creation for designing architecture. In-field observations (e.g., observing target buildings in the real world) are important activities for engaging students in inspecting and learning from the work of recognized architects (Cao, He, & Pan, 1990; Liu, 1991). Many scholars have emphasized the importance of situating students in such in-field learning scenarios, which enables them to learn from the real contexts (Shih, Kuo, & Liu, 2012; Tan, Lin, Chu, & Liu, 2012). For example, Brown, Collins, and Duguid (1989) indicated that learning from the real-world environment can benefit students by improving their problem-solving competence. Chen and Huang (2013) further reported the effects of learning from real-world contexts on students' learning performance based on an experiment conducted in a museum.

On the other hand, researchers have pointed out the difficulties of conducting in-field learning activities. It is possible that students will be distracted by novel real-world contexts and pay less attention to the learning tasks (Kamarainen et al., 2013; Orion & Hofstein, 1994); moreover, it is difficult for the teacher to provide learning guidance or instant feedback to individual students (Shih et al., 2012). In the meantime, the limitations of traditional in-field instruction have also been identified. For example, it lacks effective facilities to help students organize and share the collected information during the field trip (Laru, Jarvela, & Clariana, 2012). Furthermore, the students can only refer to the limited printed materials provided by the teacher (Tan et al., 2012).

In an ideal in-field learning activity for architecture design courses, one-to-one instruction is preferred. However, owing to the limited number of instructors, a one-to-many instruction mode is usually adopted. Therefore, it is difficult to provide personalized guidance or supplementary materials during field trips. Moreover, in conventional field trips of architecture design courses, students need to take notes using paper and pencil, and record what they have observed with cameras. Such an approach is not only inefficient, but also ineffective since the notes and photos they take are dispersed (Roudavski, 2011; Roudavski & Walsh, 2011).

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The advancement and popularity of mobile technologies have provided an opportunity to overcome these problems (Hsu, Hwang, & Chang, 2013; Ruchter, Klar, & Geiger, 2010). Researchers have called such an approach that employs mobile technologies to facilitate students' learning "mobile learning" (m-learning) or "ubiquitous learning" (u-learning). The former focuses on the use of mobile technologies to support learning, while the latter emphasizes that learning can take place anywhere and at any time (Hwang, Tsai, & Yang, 2008; Milrad et al., 2013, chap. 9; Sharples, Milrad, Arnedillo, & Vavoula, 2009). With the help of mobile devices, such as smartphones or tablet computers, the students can take photos and notes on the same platform, which could be of great help in improving their learning performance (Liu, Lin, Tsai, & Paas, 2012).

2. Literature review

2.1. Mobile learning

In the past decade, mobile devices have been considered as a potential medium of providing anytime and anywhere access to learning materials (Chan et al., 2006; Looi et al., 2010). The portability of mobile devices not only enables students to learn across contexts, but also provides teachers and educators with opportunities to develop new learning models (Chang, Sheu, & Chan, 2003; Liu & Hwang, 2009). Researchers have used different terms to describe the use of mobile technologies in educational settings from different aspects, such as mobile learning (Sharples et al., 2009), seamless learning (Wong & Looi, 2011), and ubiquitous learning (Hwang et al., 2008). Mobile technology-enhanced learning activities could be indoors or outdoors, within a single context, or across contexts, depending on the objectives of the learning activities, the features of the learning content, and the needs of associating the learning content to real-world contexts.

Many researchers have pointed out the benefits of mobile technology-enhanced learning, such as the provision of personalized learning schedules (Tatar, Roschelle, Vahey, & Penuel, 2003), individual learning objectives (Yau & Joy, 2009), instant learning supports (Hwang, Tsai, Chu, Kinshuk, & Chen, 2012), and peer communication facilities (Huang, Kuo, Lin, & Cheng, 2008). Hwang et al. (2008) have further indicated the benefits of employing mobile devices as a medium for conducting in-field learning activities with the assistance of sensing technologies, such as QR (Quick Response) codes, RFID (Radio Frequency Identification) and GPS (Global Positioning System). One benefit is that these technologies enable the learning system to detect the locations and other real-world status of students, and hence learning supports can be provided at the right place and at the right time; another benefit is that the students' physical locations and the time for arriving at the locations can be recorded for further analysis (Hwang, Wu, & Ke, 2011; Ogata & Yano, 2004; Tan et al., 2012).

In the past decade, many mobile learning activities have been conducted for various application domains (Abdous, Facer, & Yen, 2012; Chang, Lan, Chang, & Sung, 2010; Hall & Bannon, 2006; Hwang, & Chang, 2011; Lan & Huang, 2012; Ogata & Yano, 2004; Shih, Hwang, & Chu, 2010; Terras & Ramsay, 2012); however, to the best of our knowledge, the mobile learning approach has not been applied to architecture design courses or relevant activities. In several previous applications of mobile learning, the advantages and potential of the approach have been reported. For example, in the study of Ogata and Yano (2004), who developed a mobile learning system for Japanese practice using GPS and mobile phones, it was found that the students' learning interest and confidence were increased with the instant supports provided by the learning system during the field trip. Moreover, Shih et al. (2010), who conducted a butterfly ecology learning activity, also reported the advantage of the mobile learning approach. They indicated that, with the personal guidance provided by the learning system, the students had significantly higher learning motivation and better learning achievements in comparison with those who learned with traditional in-field instruction provided by the teacher. The study of Lan and Huang (2012), who employed the mobile learning approach in the field trip of a social studies course, further showed that mobile learning had high potential for improving students' learning achievement, attitudes and motivation. Therefore, it can be seen that mobile learning plays an important role in conducting in-field learning activities via providing personalized learning supports.

2.2. Annotation strategy

Annotation is a learning strategy that engages students in recognizing and recording key points in the learning materials. It not only helps students review what they have learned, but also improves their comprehension of the learning content. Marshall (1997) categorized annotations into Telegraphic and Explicit types based on their characteristics. Telegraphic annotations are usually marked on texts in the form of underlining, highlighting, or circles and boxes around words and phrases. Explicit annotations refer to the marks with brief notes written between lines, such as the translation of vocabulary in foreign language content. He further summarized the functions of annotations as procedural signals for future attention, aids to memory, *in situ* locations for problem-working, records of interpretive activities, visible traces of reading attention, and reflections on the material circumstances. McMahon and Oliver (2003) further proposed several annotation-related learning activities, including engaging students in taking notes, writing abstracts, proposing questions and highlighting key phrases or sentences.

On the other hand, researchers have identified the benefits of making annotations during the learning process. For example, Brown and Smiley (1978) indicated that, for a reading activity, students who made annotations appeared to have better learning achievements and retention than those who did not. Chun and Plass (1996) have also reported that annotations are helpful to students in identifying the structure of the reading materials, and hence improve their reading comprehension. Some other studies have further indicated that making annotations not only helps students have a whole picture of the learning content, but also encourages them to engage in critical thinking and meta-cognition activities (Grabinger & Dunlap, 1995; Hwang, Chen, Shadiev, & Li, 2011; Oscarson, 1989).

The advancement of computer technologies has provided a more efficient and effective way of making and using annotations. Several studies have further demonstrated the additional benefits provided by computerized annotations via collaborative annotation making and sharing (Chen, Chen, & Sun, 2010; Chen, Hwang, & Wang, 2012), including encouraging peer interactions and improving the learning achievements of students. For example, Nokelainen, Miettinen, Kurhila, Floréen, and Tirri (2005) have stated that annotation sharing allows students to observe the important concepts or leaning content highlighted by peers, which not only encourages them to discuss with peers, but also provides them with an opportunity to reflect on their comprehension of the learning content; thus, their learning performance is likely to improve.

The recent developments in mobile technologies have brought computerized annotations to a new stage. With the help of mobile technologies, students are able to take notes while interacting in real-world contexts with the learning targets during field trips (Hoff, Wehling, & Rothkugel, 2009; Su, Yang, Hwang, & Zhang, 2010). Moreover, annotations can be a strategy for helping students highlight and organize what they have observed during the note taking process in the field. The annotation strategy in the study refers to the learning strategy that helps students identify important features of the target architecture, and to link the features to relevant learning materials by adding annotations to the photos (i.e., the notes) they take in the field. In the meantime, researchers have also pointed out the difficulties encountered and the importance of developing new annotation strategies in such an environment since the learning materials are not only digitalized texts, images or videos, but also real-world targets. In an in-field activity of architecture design courses, the students are situated in a real-world learning environment to observe the structure, style and design details of a set of target buildings. Moreover, they need to collect data regarding critical features, and take notes on their own, instead of only taking notes or making observations. Such learning scenarios and contexts are quite different from conventional in-class or m-learning activities. Researchers have further indicated that, without careful learning design, students' cognitive load could be too high since they need to face much information from both the real world and the digital world at the same time (Chu, 2014; Hwang, Wu, Zhuang, & Huang, 2013; Liu et al., 2012); moreover, students' self-efficacy could be significantly affected if they do not receive instant prompts or assistance when they encounter difficulties during the field trip (Chen, Looi, Sha, & Zhang, 2012; Hwang, Wu, & Ke, 2011).

Therefore, in this study, a prompt-based annotation strategy is proposed for developing mobile learning systems for architecture design courses. Moreover, several research questions are investigated to evaluate the effectiveness of the proposed approach:

(1) Can the prompt-based annotation mobile learning approach promote the students' self-efficacy of learning the architecture design course content?
(2) Can the prompt-based annotation mobile learning approach improve the students' learning achievements of the architecture design course?
(3) What are the effects of the prompt-based annotation mobile learning approach on the learning achievements of students of different self-efficacy levels in the architecture design course?
(4) Does the prompt-based annotation mobile learning approach affect the students' cognitive load in learning the architecture design course content?

3. Mobile learning system with a prompt-based annotation strategy

In architecture design courses, observing the structure, style and design details of representative buildings plays an important role in fostering students' good design conceptions and inspiring their ideas of creation (Carpenter, 1997; Turkey, 2003). Students need to collect data from the real-world targets and take notes on particular or important features of the targets based on what they have learned from the textbooks, which is rather a challenging task (Heylighen & Verstijnen, 2002; Nicol &, Pilling, 2000). That is, the learning activity conducted in this study (i.e., having the students to observe physical architecture and take notes) is part of the existing curriculum for the architecture design course. In this study, a mobile learning system was developed based on a prompt-based annotation strategy to assist students in collecting data and taking notes in an efficient and effective way.

The mobile learning system for architecture design courses was developed by the researchers of this study using http://ASP.net, Sequel server, and Evernote. It consists of an annotation system, a learning system, a student profile, a learning materials database, and an annotation database, as shown in Fig. 1. The annotation system consists of a prompting unit and a photo-acquiring and note-taking unit, while the learning system provides a discussion area, a learning material browsing area, and a homework area.

Fig. 2 shows the prompt-based annotation procedure guided by the m-learning system. The prompting unit first briefs the students about the learning tasks and guides them to find the corresponding real-world targets. Following that, several questions are proposed to prompt the students about some "key issues" for observing the learning targets.

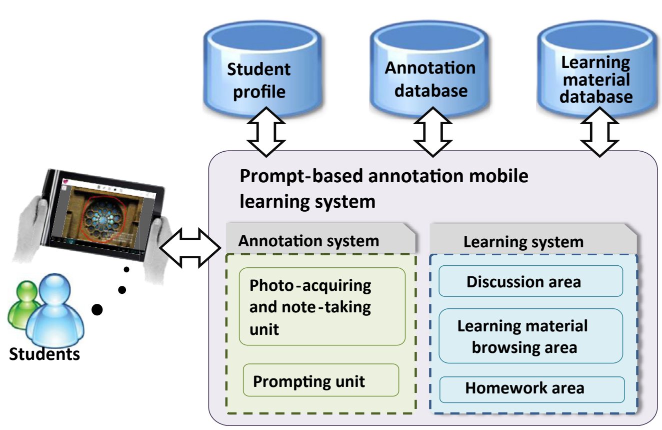


Fig. 1. Structure of the mobile learning system.

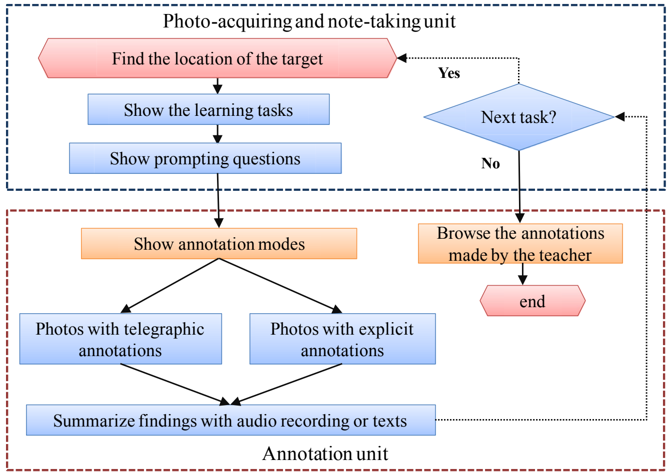


Fig. 2. Flow of the prompt-based annotation strategy.

When observing the learning targets following the prompts, the photo-acquiring and note-taking unit is invoked to take photos and notes by providing two annotation modes, that is, taking photos with telegraphic annotations and taking photos with explicit annotations (i.e., drawings and notes). Following that, the students are asked to abstract what they have observed in audio or text format. After completing all of the annotation tasks, the students are allowed to browse the annotations made by the teacher.

Fig. 3 shows the student interface of the mobile learning system, which provides a discussion area, supplementary materials, and links to the teachers' and students' annotations in accordance with the learning tasks as well as their work. In the illustrative example given in Fig. 3, the students select the "Make or modify annotations" function, and hence the learning system presents the list of task items and the corresponding annotations made by the student so far. The student can select a task item to start taking photos and making annotations, or modify the existing annotations. In the meantime, the students are allowed to interact with their peers via the "discussion area." After the learning activity, they are allowed to browse the teacher's annotations.

Fig. 4 shows the interface of the annotation function. In this illustrative example, the student is asked to observe and collect data when visiting the Cathedrale Notre-Dame de Chartres (a famous church in France). The mobile learning system shows a series of prompting questions to guide the student to take photos and notes and abstract their findings during the learning process. Moreover, some supplementary materials related to the learning task are also provided. It should be noted that, in the illustrative example given in Fig. 4, the photos as well as the notes are taken by students during the real-world observations. The learning material database only provides supplementary materials related to the content of the textbook to help students liken what they have observed to what they have learned from the textbook.

Fig. 5 shows the interface of uploading and browsing students' work. In this illustrative example, the student uploads a work of designing a Baroque-style church.

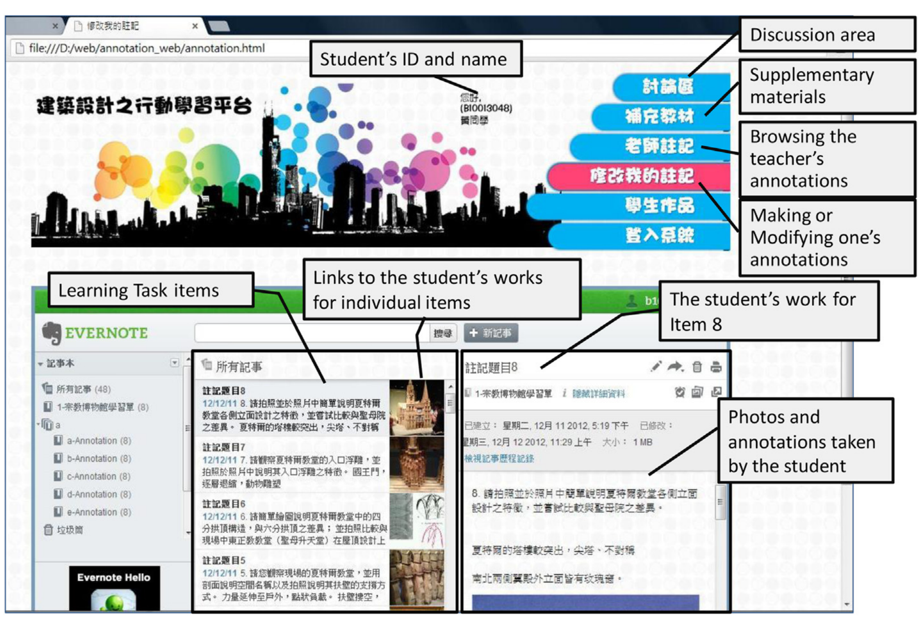


Fig. 3. Interface of the mobile learning system.

Fig. 4. Illustrative example of the annotation guiding mechanism.

4. Methodology

In this study, an experiment was conducted to investigate the effects of the prompt-based annotation approach on students' learning achievement and self-efficacy for a university architecture course. The learning activity was conducted in the world architecture museum located in northern Taiwan. The students were asked to observe the target buildings in the museum, annotate the critical features of the buildings, and design several parts of an architectural work assigned by the teachers. The learning activity is part of the formal architecture design curriculum of the university.

4.1. Experiment design

4.1.1. Participants

A total of 56 university students taught by the same teacher were randomly assigned to an experimental group and a control group. The average age of the participants was nineteen. The experimental group, including 28 students, learned with the mobile learning approach with the prompt-based annotation mechanism, while the control group students ($n = 28$) learned with the conventional paper-and-pencil

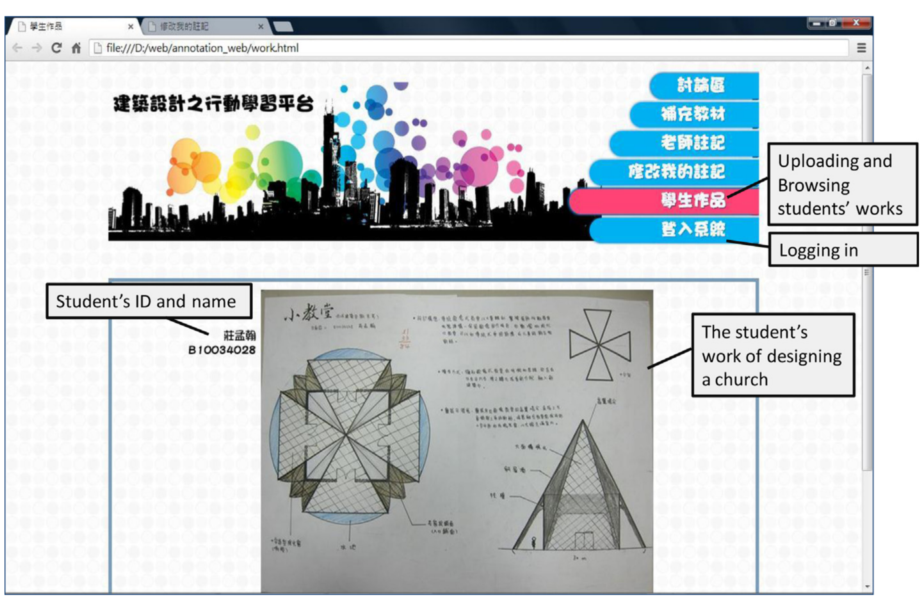


Fig. 5. Interface of uploading and browsing a design work.

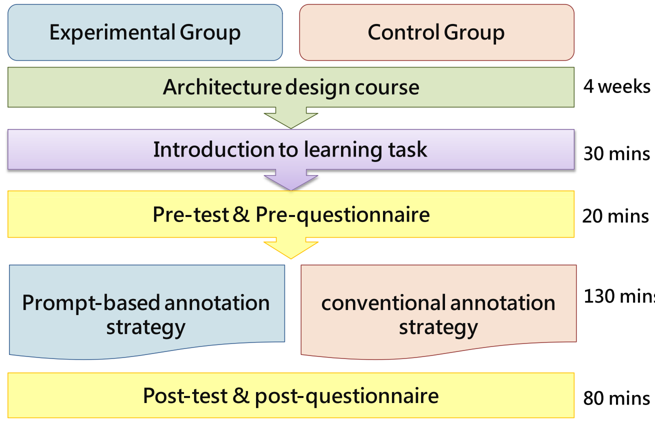


Fig. 6. Diagram of experiment design.

annotations. All of the students were taught by the same instructor who had taught that particular architecture design course for more than ten years. As five of the control group students did not participate in the entire experiment (i.e., they did not take the pre-test or post-test owing to some personal reasons), the following analysis was conducted based on the 21 control group students who had fully participated in the experiment.

4.1.2. Experimental procedure

Fig. 6 shows the experimental procedure. Before the experiment, the students took a four-week course on the basic knowledge of architecture design. Following that, they took the pre-test and completed the self-efficacy questionnaire.

During the learning activity, the students in the experimental group learned with the mobile learning approach with the prompt-based annotation strategy. On the other hand, those in the control group learned with the conventional annotation strategy. That is, they were guided by the teacher to observe the real-world targets and complete the learning tasks; in the meantime, they took photos using digital cameras and took notes with paper and pencil. The notes were then used as the annotations for highlighting the important features of the architecture in the photos. After completing the learning tasks, the students in both groups were allowed to browse the annotations made by the teacher via the tablet computers.

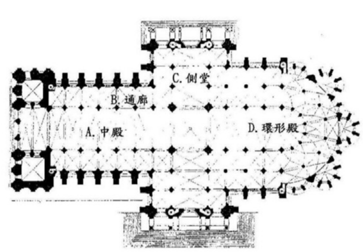
After the learning activity, the students took the post-test and filled out the post-questionnaires to measure their learning achievements, learning self-efficacy and cognitive load. Finally, the researchers interviewed the teachers and students to collect their opinions and perceptions about using the annotation strategies. The interview questions are listed in Appendix.

4.2. Instruments

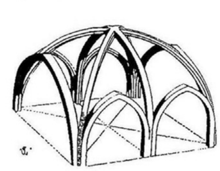
The measuring tools of this study included a pre-test, a post-test, the self-efficacy questionnaire, and the cognitive load measure.

Both the pre-test and the post-test were designed by two experienced teachers who had taught the architecture design course for more than ten years. The pre-test aimed to evaluate whether the two groups of students had an equivalent prior knowledge of architecture history

6. (   ) In this plan, which interior feature is incorrectly labeled?



14. (   ) What is this structure called?



A. barrel vault B. double layer dome C. sexpartite vault D. groin vault

Fig. 7. Sample items from the pre-test.

Table 1
The *t*-test result of the post-test scores of the two groups.

Variable	Group	*N*	Mean	S.D.	*t*	*d*
Post-test	Experimental group	28	77.89	5.16	2.70*	0.71
	Control group	23	73.96	5.21		

*$p < 0.05$.

Table 2
The two-way ANOVA result of the learning achievement.

Variables	*SS*	*df*	*MS*	*F*	*p*	η^2
Learning approach	196.03	1	196.03	8.62	0.01	0.16
Self-efficacy	120.98	1	120.98	5.32	0.03	0.10
Learning approach* Self-efficacy	101.15	1	101.15	4.45	0.04	0.09
Error	1069.20	47	22.75			

and design principles before participating in the learning activity. It consisted of 25 multiple-choice items with a perfect score of 100. Fig. 7 shows two sample items from the pre-test.

The post-test aimed to evaluate the students' knowledge and design ability of Gothic architecture. It consisted of five design items for the "architecture design" dimension with a perfect score of 100. For each design item, the students needed to design a part (e.g., windows or doors) of an example of Gothic architecture and describe the conception and innovation of their work. For example, one of the design items is "Please design a building with Gothic church-style windows based on the principles of classical architectural design. Please explain your design concept and the new idea of the design." The post-test results of both groups were evaluated by two experienced teachers based on five dimensions, that is, "design concept" (20%), "innovation" (20%), "integrity of the architecture" (20%), "presentation of Gothic architecture features" (20%) and "appearance" (20%). The Cronbach's alpha value was 0.84, showing a high inter-rater reliability of the post-test scores.

The self-efficacy questionnaire consists of seven items with a five-point Likert scale. It was modified from the questionnaire developed by Schwarzer and Jerusalem (1995) for measuring the students' self-efficacy in learning the subject unit, that is, their expectations and confidence regarding learning the architecture design course well. The Cronbach's alpha value of the questionnaire was 0.78, implying that the questionnaire is reliable.

The cognitive load was measured based on the perceived cognitive load reported by the participants. The questionnaire was developed by Hwang, Yang and Wang (2013) based on the cognitive load measures proposed by Paas (1992) and Sweller, van Merriënboer, and Paas (1998). It consists of eight items with a seven-point Likert rating scheme, including five items for mental load and three for mental effort. The Cronbach's alpha values of the two dimensions were 0.87 and 0.89, respectively.

5. Results

5.1. Analysis of learning achievement

The mean values and standard deviations of the pre-test scores were 61.21 and 17.20 for the control group, and 65.14 and 16.10 for the experimental group. The *t*-test result ($t = 0.84$, $p > 0.05$) shows that there was no significant difference between the two groups, confirming that the two groups of students had equivalent prior knowledge before the learning activity.

After the learning activity, the post-test was conducted to evaluate the students' knowledge and design ability by asking them to design a part (e.g., windows or doors) of a Gothic building. Table 1 shows the *t*-test result of the post-test scores of the two groups. The means and standard deviations were 77.89 and 5.16 for the experimental group, and 73.96 and 5.21 for the control group. According to the *t*-test result ($t = 2.70$, $p = 0.01 < 0.05$), there was a significant difference between the two groups with $d = 0.71$, showing a medium to large effect size (Cohen, 1988). This implies that the mobile learning approach with the prompt-based annotation strategy benefited the students more than the conventional approach.

To further realize the effects of the prompt-based annotation approach on the learning achievements of the students with different self-efficacy degrees, the participants were classified into high and low self-efficacy groups based on their post-test ratings. The students in the top 50% were categorized as high self-efficacy, while the others were low self-efficacy. Two-way mixed analyses of variance (ANOVA) were employed. At the inception of interpreting the significance of the results, the probability value α was set to 0.05. The independent variables are the two learning strategies and two levels (i.e., higher and lower) of self-efficacy, while the dependent variable is the learning achievement.

Table 3
Simple main-effect analysis results of self-efficacy levels on students' learning achievement.

Variables		*SS*	*df*	*MS*	*F*	*p*	η^2
Prompt-based annotation (Experimental group)	Between groups	246.04	1	246.04	13.53	0.001	0.52
	Within groups	472.64	26	18.18			
	Total	718.68	27				
Conventional annotation (Control group)	Between groups	0.40	1	0.40	0.01	0.91	
	Within groups	596.55	21	28.41			
	Total	596.96	22				

Table 4
Simple main-effect analysis results of annotation approaches on students' learning achievements.

Variables		*SS*	*df*	*MS*	*F*	*p*	η^2
Higher self-efficacy	Between groups	7.60	1	7.60	0.37	0.55	
	Within groups	470.57	23	20.46			
	Total	478.16	24				
Lower self-efficacy	Between groups	296.48	1	296.48	11.89	0.002	0.50
	Within groups	598.63	24	24.94			
	Total	895.12	25				

Table 2 shows the two-way ANOVA results. It was found that significant effects were observed for the learning approaches ($F = 8.62$, $p = 0.01$, $\eta^2 = 0.16$), self-efficacy ($F = 5.32$, $p = 0.03$, $\eta^2 = 0.10$), and the interaction between them ($F = 4.45$, $p = 0.04$, $\eta^2 = 0.09$) on the students' learning achievements. The effect size of η^2 was measured based on Cohen's criteria. Cohen (1988) has indicated that $\eta^2 \geq 0.059$ represents a moderate effect size and $\eta^2 \geq 0.138$ represents a large effect size; that is, the effect sizes of the ANOVA results are moderate to large.

A simple main-effect analysis was conducted to investigate the effects of the self-efficacy on the learning achievements of the students who learned with different annotation approaches, as shown in Table 3. It was found that the students with different self-efficacy levels in the experimental group showed significantly different learning achievements ($F = 13.53$, $p = 0.001 < 0.01$, $\eta^2 = 0.52$), while no significant difference was found between the low and high self-efficacy students in the control group ($F = 0.01$, $p = 0.91 > 0.05$, $\eta^2 = 6.71$). The results indicate that self-efficacy could be an important factor related to the learning achievements of the students who learned with the prompt-based annotation approach.

Table 4 shows the analysis results of the effects of the learning approaches on the learning achievements of the students with different self-efficacy levels. It was found that the lower self-efficacy students showed significantly different learning achievements when learning with different approaches ($F = 11.89$, $p = 0.002 < 0.01$) with a large effect size ($\eta^2 = 0.50$). On the other hand, no significant difference was found between the high self-efficacy students with different approaches ($F = 0.37$, $p = 0.55 > 0.05$, $\eta^2 = 0.02$). This implies that the prompt-based annotation approach could benefit low self-efficacy more than high self-efficacy students.

Fig. 8 shows the interaction between the annotation approaches and the self-efficacy levels of the students' learning achievements. It was found that engaging students in the prompt-based annotations using mobile devices showed significantly better effects on the students' learning achievements regarding architecture design than learning with the conventional annotation approach. More specifically, the lower self-efficacy students (Mean = 80.86, SD = 3.66) benefited significantly more than the higher self-efficacy students (Mean = 74.94, SD = 4.80) while learning with the prompt-based annotation approach.

5.2. Cognitive load

In this study, two cognitive load dimensions were measured, that is, mental load and mental effort. The former is concerned with the cognitive load caused by the amount of information presented to the students simultaneously. The latter is related to the cognitive load caused by the way the learning content is organized or the adopted learning strategy (Sweller et al., 1998; Wu, Hwang, Su, & Huang, 2012).

Table 5 illustrates the *t*-test result of the cognitive load ratings of the two groups. It is found that the experimental group had significantly higher mental load and mental efforts than the control group with $t = 2.87$ ($p = 0.006 < 0.01$) and $t = 3.96$ ($p = 0.000 < 0.001$) with large effect sizes $d = 0.82$ and $d = 1.10$, respectively. For the experimental group, the means (SDs) of the mental load and mental effort ratings were 4.44 (1.05) and 4.26 (1.04), while those for the control group were 3.65 (0.88) and 3.13 (0.98), respectively. As the total score of mental effort ranges from 1 to 7, the medium is 4; that is, the mean of mental load and mental effort of the students in the experimental group (4.44 and 4.26) was close to the medium score, while that of the students in the control group (3.65 and 3.13) was relatively lower (Chu, 2014; Hwang & Chang, 2011).

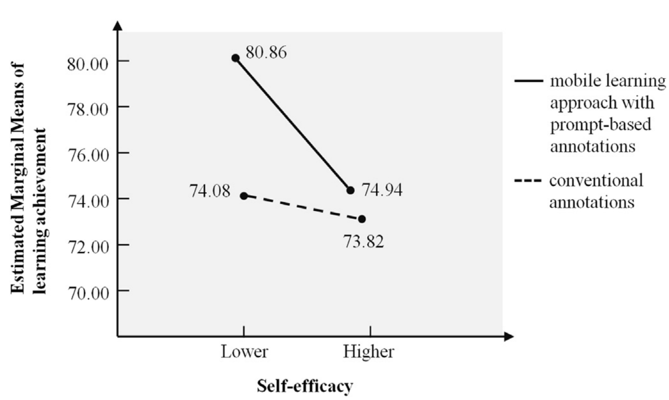


Fig. 8. Interaction between self-efficacy and learning approach.

Table 5
The *t*-test result of mental load and mental effort for the two groups.

Variables	Group	N	Mean	S.D.	*t*	*d*
Mental load	Experimental group	28	4.44	1.05	2.87**	0.82
	Control group	23	3.65	0.88		
Mental effort	Experimental group	28	4.26	1.04	3.96***	1.10
	Control group	23	3.13	0.98		

**$p < 0.01$; ***$p < 0.001$.

6. Discussion and conclusions

In this paper, a prompt-based annotation approach was proposed for conducting mobile learning activities for architecture design courses. An experiment was conducted in a university architecture design activity to evaluate the performance of the proposed approach. The experimental results showed that, in comparison with the mobile learning approach with conventional annotations, the proposed approach significantly improved the students' learning achievements and self-efficacy of learning the architecture design course.

This finding provides evidence for what has been proposed by researchers, namely that self-efficacy could be an important indicator of predicting learning achievements (Schunk, 1989). It also conforms to the theory proposed by Bandura (1986) that self-efficacy could be trained and improved. Schunk (1996) and Zimmerman (1998) further indicated that self-efficacy could be improved via applying proper learning strategies or tools to learning activities. The finding in this study not only evidences the idea, but also encourages several future studies, including the use of other learning strategies or tools in architecture design activities, and the analysis of students' learning patterns.

On the other hand, the analysis result of the cognitive loads of the two groups revealed their learning efforts. Those students who learned with the mobile learning system showed medium-level mental load and mental effort, while those who learned with the traditional approach had significantly lower cognitive loads. Researchers have emphasized the importance of guiding learners to engage in cognitively demanding and constructive learning activities in order to use as much working memory as possible for effective cognitive load (Huk & Ludwigs, 2009). Kalyuga (2009) has further indicated that learning strategies aiming to increase germane cognitive load (the cognitive load that helps students learn in a more effective way) might lead to intrinsic cognitive load owing to the complexity and difficulty levels of the learning materials for the learners. Therefore, medium-level mental load and mental effort seem to benefit the experimental group students, while the low-level loads might indicate insufficient learning efforts on the part of the control group students. This implies that the proposed mobile learning approach engaged the experimental group students in learning tasks with reasonable challenges, which could be the reason why they had better learning performance and higher self-efficacy (Paas, van Merriënboer, & Adam, 1994; Zheng, 2009).

Although the proposed mobile learning approach is effective in helping students improve their learning performance for architecture design courses, several students indicated the difficulty in making annotations using the hand-writing input function or the virtual keyboard provided by the tablet PCs. Therefore, in future applications, it is suggested that students make annotations with short texts and voice recording.

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Appendix. The Interview questions

1. Do you think taking notes when observing buildings is helpful to you in improving your learning performance in the architecture design course? Why?
2. In this learning activity, do you like the way (or tools) you used for taking notes in the field trip? Why?
3. Please address the advantages and disadvantages of the note taking approach you used in the field trip.
4. What difficulties did you encounter during the field trip with the learning approach? How can these difficulties be overcome in the future?
5. How can this learning activity be improved? Please provide suggestions for future learning activity design.

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