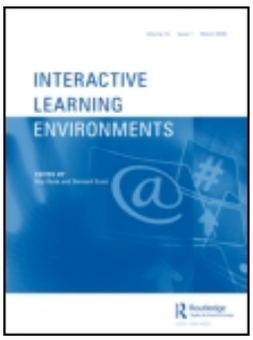

Interactive Learning Environments

ISSN: 1049-4820 (Print) 1744-5191 (Online) Journal homepage: http://www.tandfonline.com/loi/nile20

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To cite this article: Gwo Jen Hwang , Po Han Wu , Ya Yen Zhuang & Yueh Min Huang (2013) Effects of the inquiry-based mobile learning model on the cognitive load and learning achievement of students, Interactive Learning Environments, 21:4, 338-354, DOI: 10.1080/10494820.2011.575789

To link to this article: https://doi.org/10.1080/10494820.2011.575789

Published online: 22 Aug 2011.

Interactive Learning Environments, 2013
Vol. 21, No. 4, 338–354, http://dx.doi.org/10.1080/10494820.2011.575789

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Effects of the inquiry-based mobile learning model on the cognitive load and learning achievement of students

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(*Received 9 November 2010; final version received 24 March 2011*)

The advancement of mobile device and wireless communication technologies is having a great influence on the design concept of learning activities. In this study, we attempt to integrate field study into the inquiry-based mobile learning model; moreover, a mobile learning environment that allows students to access both physical and virtual resources is developed accordingly. During the in-field learning activity, the mobile learning system is able to present the learning tasks, guide the students to visit the real-world learning targets for exploration, and provide them with supplementary materials via the mobile devices. The aim of this research focuses on the effects of this mobile learning model on students' cognitive load and learning achievements. The 51 sixth graders who participated in this research were assigned to an experimental and a control group. From the pre and posttests as well as the cognitive load questionnaire, it was found that the students who learned with the inquiry-based mobile learning approach had better learning achievement and less cognitive load than those who learned with the traditional approach. Therefore, it is concluded that the mobile learning model has positive effects on elementary students in local culture learning.

Keywords: mobile learning; local culture learning; cognitive load; learning effects; learning attitude

Background and motivation

Brown, Collins, and Duguid (1989) argued that the effect of constructed knowledge might be limited if learning is isolated from an authentic context. Therefore, it is important for learners to experience in a real-world context the concepts to be learned (Lave & Wenger, 1991). Researchers have also indicated that learners can model the instructors' behaviors well when following and observing them in an authentic context (either in or outside of the classroom). Furthermore, such an approach provides a complete context that is helpful to the learners in promoting their learning interest as well as in developing new experiences, knowledge, and skills (Brown et al., 1989; Montague & Knirk, 1993).

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The popularity of mobile and wireless communication technologies has had a great influence on the design concept of learning activities. Hand-held devices, with a high degree of portability, have played an important role in both outdoor activities (e.g. ecological observations) and indoor activities (e.g. museum tours). Mobile learning integrates digital resources with authentic learning contexts. Such a learning environment not only enables students to learn in real contexts but also provides them with support from the digital world in the right place and at the right time (Chu, Hwang, Huang, & Wu, 2008; Chu, Hwang, Tsai, & Tseng, 2010; Hwang, Chu, Lin, & Tsai, 2011; Hwang, Kuo, Yin, & Chuang, 2010; Shih, Chu, Hwang, & Kinshuk, 2011). Scholars have applied the concept of mobile learning to the design of learning activities for various subjects, such as natural science, social science, and language learning (Chen, Hwang, Yang, Chen, & Huang, 2009; Chu, Hwang, & Tsai, 2010; Huang, Lin, & Cheng, 2010; Liu & Hwang, 2010; Peng et al., 2009).

In the past few years, several studies concerning mobile learning with young people have been conducted, in particular, in museums (Hall & Bannon, 2006). For example, Vavoula, Sharples, Rudman, Meek, and Lonsdale (2009) presented ''Myartspace,'' a mobile service that supports inquiry-based learning in a museum and connects it with learning in the classroom. With this learning service, the students are able to gather information during a field trip in the museum. The information is automatically sent to a website where the students can browse and share it in the classroom or at home. Later, Reynolds, Walker, and Speight (2010) presented several trials of using mobile devices in a museum. They offered students a range of ways of exploring the museum environment and collections. In some learning activities, the students were encouraged to interpret objects and museum spaces in expansive and imaginative ways. In the meantime, Chiou, Tseng, Hwang, and Heller (2010) developed an adaptive navigation support system for conducting learning activities in museums with mobile devices.

In the meantime, the advance of sensing devices [e.g. Radio Frequency Identification (RFID)] has motivated researchers to develop context-aware learning environments, in which the ubiquitous learning system is able to detect the real-world status (e.g. location) of individual students as well as the environmental parameters (e.g. temperature) such that guidance or hints can be provided actively (Hwang, Tsai, & Yang, 2008; Jeng, Wu, Huang, Tan, & Yang, 2010; Tan, Liu, & Chang, 2007). For example, Chu et al. (2008) conducted a butterfly-ecology learning activity, comprising an outdoor butterfly garden and indoor butterfly specimen library, with Personal Digital Assistants (PDAs) embedded with sensing and wireless network technologies; Hwang, Yang, Tsai, and Yang (2009) developed a context-aware u-learning environment for guiding inexperienced researchers to practice single-crystal X-ray diffraction operations at any time; and Chen and Li (2009) proposed an English vocabulary learning system based on learners' locations. Such an innovative approach not only promotes the learning efficacy of students but also alleviates the work load of senior researchers.

However, it is worth exploring the question ''During the process of introducing a new technology, is this technology beneficial to all students, or does it in fact create students' learning difficulty and pressure?'' When employing new technologies to provide richer content, the effects of the technology or learning environments on the learning performance of the students with different backgrounds and personal features need to be thoroughly investigated (Shih et al., 2011). Researchers have indicated that the cognitive load of students is a good indicator to represent the

impact of new teaching methods and educational technologies on the conceptual acquisition and cognitive state of the students (Sweller, Van Merriënboer, & Paas, 1998; Van Merriënboer & Sweller, 2005). Cognitive load has been defined as "the load generated by the assignation of specific work to individual cognitive systems." That is, the greater the cognitive burden, the lower the users' satisfaction with the learning (Segall, Doolen, & Porter, 2005). Therefore, lowering the cognitive burden of students during the process of the teaching activity design is an important factor for consideration. Paas, Tuovinen, Tabbers, and Van Gerven (2003) further argued that cognitive burden is not only a product of the learning process but also the main factor influencing learning results. Therefore, the investigation of cognitive load and its effect on the learning achievement of students in mobile learning activities has become an interesting and challenging issue.

To cope with this problem, in this study, a mobile learning environment is developed for students to observe the local cultural heritage. Via hand-held devices, students are able to interact with the learning system in real contexts; meanwhile, the influence of mobile learning on the students' cognitive load and learning achievement is investigated in depth.

Method

This study aims to investigate the shifts in students' learning achievement and learning attitude, as well as their cognitive load, after taking part in an inquiry-based mobile learning activity. Several definitions of inquiry-based learning have been proposed, such as "the process by which teachers and others involved in the support of learning to arrive at a plan or a structure or design for a learning situation" (Beetham & Sharpe, 2007, p. 6), "the planning and documentation of a learning activity, session or curriculum in advance of delivery" (Falconer & Littlejohn, 2007, p. 42), or "the learning activities that provide students with a means of actively engaging with the questions and problems of their discipline and of developing a range of inquiry-related capabilities and skills" (Little, 2008). Researchers have indicated that "questions" are the fundamental point of starting out on inquiry-based learning, no matter whether they are posed by the students, the teachers, or by negotiation among them (Levy, Aiyegbayo, & Little, 2009). In this paper, inquiry-based learning refers to the pedagogic approaches that engage students in exploring and investigating the learning targets via providing questions, learning guidance, and resources to support the inquiry process (Levy et al., 2009).

Participants

The participants were two classes of sixth grade students of an elementary school. Their ages ranged from 11 to 12. One class that included 26 students (12 males and 14 females) was assigned to be the experimental group, while the other class that had 30 students (15 males and 15 females) was the control group. None of the students had any experience in using mobile devices to learn.

Research setup

The learning activity was conducted in the Sheng-Mu temple in Tainan city, and the learning content was the "local culture" unit of the social science course. The

students in the control group were guided by the human tutor, while the students in the experimental group were guided by a mobile learning system via a PDA. During the learning process, the students in both groups were asked to explore the Sheng-Mu temple and observe the learning targets to find the answers to a series of questions designed by the teacher.

For the students in the control group, the human guide first introduced the learning environment and the learning missions to the students; afterward, a learning sheet and the supplementary materials were given to the students to show them the questions and the hints about the learning missions. During the learning process, the students could raise questions to ask the human guide or the workers in the temple. Such an approach to inquiry-based learning has been conducted by most of the schools in Taiwan for years.

On the other hand, the students in the experimental group were guided by the mobile learning system, which guided the students to the learning targets and displayed the questions, hints, and supplementary materials on the PDA. If the students failed to correctly answer some questions, the learning system would give them hints for making further observations or searching for supplementary materials on the Internet.

Figure 1 shows the research design of this study. Before the experiments, the two groups of students received a "local cultural" pretest and a questionnaire concerning "attitudes toward tour-based local cultural learning" and "local cultural identity." At the beginning of the 3-h learning activity, a 30-min orientation was given to both groups of students. For the experimental group, the orientation included the introduction to the use of the mobile devices, the learning tasks, and the authentic learning environment; on the other hand, for the control group, the orientation included the introduction to the learning sheet, the supplementary materials, and the

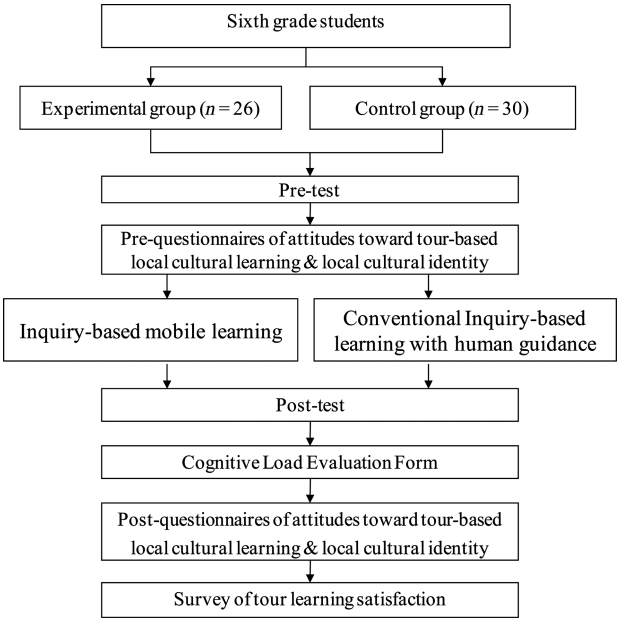

Figure 1. Research framework.

learning environment. After participating in the learning activity, the students took a posttest and completed the same questionnaire. In addition, a ''cognitive burden evaluation'' was used to evaluate the learning load of individual learners.

Figure 2 shows the learning scenario of this study. The Sheng-Mu temple consists of three main locations, namely, the Palace of King Wu, the Palace of Holy Ma Zu, and the Palace of Buddha. The planned teaching contents include eight features of the temple, such as ''stone carved lions'' and ''pillars of a stone carved dragon.'' Every feature has its own meanings or history.

As shown in the lower left-hand corner of Figure 2, when guided by the PDA to learn in the temple, the students in the experimental group needed to answer a series of questions in order to proceed to the next learning target. To distribute the students equally in every learning area, they were guided to observe different learning targets and collect data to answer the questions based on the predesigned learning paths. No matter which location they started at, each student was asked to complete the learning tasks for all eight parts.

As shown in the lower right-hand corner of Figure 2, the students in the control group were guided to learn by a human guide who conducted the tour-based learning from the first to the eighth part. After explaining the construction features and cultural history of each learning target, a learning sheet and the supplementary materials were given to the students, by means of which the students could complete their learning tasks.

Measuring tools

In this study, several questionnaires were used to evaluate the cognitive load, learning attitude, and local cultural identity of the students. Moreover, all of the terms used in the questionnaire items were modified and examined by one of the

Figure 2. Environment and scenario of the mobile learning activity.

researchers and an experienced school teacher to consider their suitability for elementary school children.

A ''cognitive load questionnaire'' was developed to evaluate the students' cognitive load when participating in the tour-based local cultural learning activity based on the evaluation form proposed by Sweller et al. (1998). Such techniques were designed to provide more effective, reliable, and sensitive measurements than those with physiological approaches. The questionnaire consisted of four questions, including aspects of intellectual effort and intellectual load. The answer to each question was represented by a seven-point scale, where ''7'' represented high agreement (i.e. high cognitive load) and ''1'' represented high disagreement (i.e. low cognitive load).

In addition, the ''learning attitude questionnaire'' developed by Mishra and Panda (2007) for investigating the learning attitude of students while introducing new technologies into the learning environment was adopted. In this study, mobile technology (PDA) was the main concern for exploring the learning attitude of students in local cultural tour-based courses. The questionnaire consisted of 33 questions pertaining to four different aspects, including nine questions for ''outer performance,'' seven questions for ''learning interest,'' 11 questions for ''viewpoints on the value of local cultural learning,'' and six questions for ''viewpoints on the preservation of local culture.'' A five-point scale was used to represent the rating of each item, where ''5'' represented high agreement (i.e. positive learning attitude) and ''1'' represented high disagreement (i.e. negative learning attitude).

With regard to the evaluation form of local cultural identity, this study consulted Salleh and Dhindsa's (2009) cultural learning environment questionnaire (CLEQ). Local cultural identity is divided into three parts, including protection of the natural/human environment, a sense of participation, and a sense of belonging. With respect to the protection of the natural human environment, Udaya Sekhar (2003) mentioned that India, with the support of local citizens' management of protected areas, preserved endangered animals using a variety of protection methods. In terms of sense of participation, the active attitude of local citizens toward participation enables the protection of the environment. In addition, the concept of everlasting management brings a positive influence on the protection of wild animals and local tourism (Udaya Sekhar, 2003). Hence, for the protection of the natural human environment, local cultural education should always be preserved. With regards to a sense of belonging, Yuen (2005) found that Singaporean people identified with their living environment and thus had a sense of belonging. It was found that the more people identify with their environment, the higher degree of sense of belonging they have. Accordingly, local identity cannot be separated from a sense of belonging to the environment.

The researchers of this study modified the CLEQ to explore whether using PDAs in local cultural tour-based courses had any influence on students' local cultural identity. The local cultural identity questionnaire consisted of 20 questions pertaining to three aspects, including eight questions for ''protection of the natural human environment,'' five questions for ''sense of participation,'' and seven questions for ''sense of belonging.'' The answer to each question was represented by a five-point scale, where ''5'' represented high agreement (i.e. the highest local cultural identity) and ''1'' represented high disagreement (i.e. the lowest local cultural identity).

In addition, a ''satisfaction survey'' was developed by modifying the questionnaire proposed by Chu et al. (2008) to explore the students' degree of satisfaction

with learning using the different approaches. The questionnaire consisted of 11 items with a five-point rating scale, where "5" represented strong agreement (i.e. high satisfaction) and "1" represented high disagreement (i.e. low satisfaction). In addition, two open questions were added at the end to elicit from the students the most impressive part of the different teaching methods in the local culture learning activity, and the future applications that they hope the teaching methods can be adopted for.

Development of an inquiry-based mobile learning system

A mobile learning system with guidance and "question and answers" functions has been developed with wireless communication technology and mobile learning devices (i.e. PDA), as shown in Figure 3. This system is implemented with Microsoft's Data Platform (MS SQL 2005), Microsoft's web application framework (ASP.NET) and Internet Information Server. The functions of the server include user (student) management, subject materials management, question management, and learning portfolio management. The learning system interacts with the students in the real world, such as guiding the students to learn, testing, and giving feedback to the students, via a PDA.

Figure 4 shows the user interface of the mobile learning system. The PDA on the left shows the supplementary materials for the tour-based local culture learning activity, while the one on the right demonstrates an example of inquiry-based learning, which guides the students to observe the real-world learning targets by asking some questions.

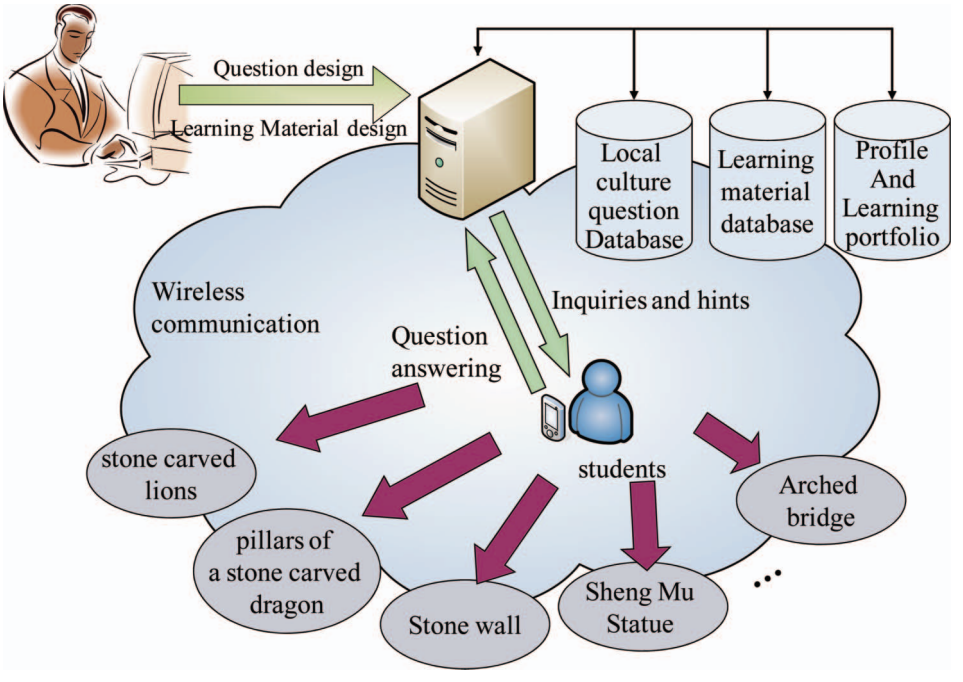

Figure 3. Framework of the mobile learning system.

The system first offers hints about observation focus, and asks questions based on those observation focuses. The students can answer the questions via the PDA interface after observing the target objects, such as a statue, as shown in Figure 5.

During the learning process, questions are continually posed as the students are guided to visit a learning target. The students need to observe the learning objects in order to answer the questions. If the answer is correct, the student can proceed to the next section; if wrong, the system will guide the student to review the material and then answer the same question again, or show some hints to the students, as shown

Figure 4. Users' PDA interface.

Figure 5. Inquiry-based learning via PDA – description of the learning target.

in Figure 6. These steps enable the students to think more in the learning process and to receive immediate feedback.

When encountering special construction materials within the permitted range of construction design, the students are requested to touch those materials to physiologically understand them, as demonstrated in Figure 7.

Results

This study investigates the cognitive load as well as the shifts in learning achievement, and the learning attitude of students after taking part in the inquiry-

Figure 6. Inquiry-based learning via PDA – hints for the incorrect answers.

Figure 7. Tour-based learning on PDA – touching the target object.

based mobile learning activity. Tools such as the "learning attitudes questionnaire," the "local cultural identity questionnaire," and the "learning achievement test" are used before and after the experiment. In addition, the "cognitive load questionnaire" and the "satisfaction survey" are filled out after the experiment.

Analysis of cognitive load

After the learning activity, the "cognitive load questionnaire" originating from the study of Sweller et al. (1998) was used to evaluate the students' cognitive load. For example, one of the questionnaire items was "I feel that I need to put in great effort in order to understand the objective of this learning activity and the instructions given during the learning process." Table 1 shows the independent *t*-test results of the cognitive load questionnaire. Significant difference in cognitive load was found between the students in the two groups ($t = -2.87$, $p < 0.01$); moreover, the average cognitive load of the students in the control group was larger than that of the students in the experimental group; that is, the students who learned with the traditional approach had significantly higher cognitive load than those who learned with the PDA-based approach.

From the interview and the questionnaire results, it was found that the use of PDAs provided a personalized learning scenario, and hence the students were able to learn according to their own schedule and needs; moreover, using PDAs allowed the students to efficiently search for the needed supplementary materials. On the other hand, the students in the control group were guided to learn by a human tutor in a one-to-many manner; therefore, it might take time for them to understand the learning targets and the learning environment if they failed to catch up with the instructions given by the human tutor. In addition, according to the students' feedback to the interviews, it was found that they felt that searching for data from the printed materials was inefficient, which could be another factor contributing to the increase in their cognitive load.

This finding conforms to the reports from previous studies that "intrinsic cognitive load," which represents the amount of different types of information that students need to consider in order to obtain or understand new information, could be increased if the instructional materials are poorly structured, difficult to read, or too complex (Hwang & Chang, 2011; Van Merriënboer & Sweller, 2005). It is related to how much information the working memory needs to deal with at the same time. In this study, the students were arranged to face the same learning materials, learning targets, and learning tasks; therefore, it makes sense that the cognitive load originated from the way they were able to access and deal with the learning materials.

Table 1. *t*-Test for cognitive load of the experimental and control groups for the intellectual efforts perspective.

Group	*N*	Mean	SD	*t*
Experimental	26	7.54[a]	4.40	−2.87*
Control	30	11.37[a]	5.42	

Note: *$p < 0.01$. [a]Out of a total of 4 questions asked, a low mean score of 4 would indicate low cognitive load to a high score of 28 indicating that all participants had high cognitive load.

Analysis of learning achievement

To understand whether the inquiry-based mobile learning is helpful in terms of the students' learning achievement, analysis of covariance (ANCOVA) is used to analyze the pre and posttest scores of the two groups. Table 2 summarizes the ANCOVA results, from which it is found that the learning achievement of the experimental group was significantly better than that of the control group ($F = 4.36$ and $p < 0.05$), showing that inquiry-based mobile learning is more helpful to students for learning local culture courses in the field than the traditional approach.

Analysis of learning attitude

To study if a difference exists between the two groups in promoting learning attitudes after the local culture tour-based learning, the students were asked to fill out the learning attitude questionnaire before and after the experiment. One of the questionnaire items concerning "outer performance" was "I would actively collect local cultural data related to my hometown;" another example for the "learning interest" aspect was "I look forward to taking more local culture courses." In the analysis, we adopted analysis of variance, in which the teaching methods are independent variables, while the posttest scores of the evaluation form of learning attitude are the dependent variables, and the corresponding pretest scores are the covariance. Table 3 summarizes the analysis of the covariance. The influence of the pretest scores (covariants) on the posttest scores (independent variables) is excluded, and the effect test of independent variables to dependent variables, $F = 6.76$, $p < 0.05$, shows significant difference. This means that the difference in the posttest scores results from the different teaching methods.

In addition, the mean score of the experimental group is higher than that of the control group ($4.21 > 4.09$), indicating that the learning attitude of the experimental group in the tour-based teaching is significantly higher than that of the control group after the experiment.

Table 2. Analysis of learning achievement of the two groups for the local culture course unit.

Group	*N*	Mean	SD	Adjusted mean	SE	*F*
Experimental	26	71.08[a]	11.10	71.12	2.41	4.36*
Control	30	64.27[a]	13.73	64.23	2.25	

Note: *$p < 0.05$. [a]Out of a total of 25 questions asked, a low mean score of 0 would indicate low learning achievement to a high score of 100 indicating that all participants had high learning achievement.

Table 3. Analysis of covariance for the learning attitude questionnaire of the two groups of students in the local culture tour-based teaching.

Group	*N*	Mean	SD	Adjusted mean	SE	*F*
Experimental	26	4.21[a]	0.62	4.29	0.08	6.76*
Control	30	4.09[a]	0.67	4.02	0.07	

Note: *$p < 0.05$. [a]Out of a total of 33 questions asked, a low mean score of 1 would indicate low learning attitude to a high score of 5 indicating that all participants revealed high learning attitude.

Analysis of local cultural identity

This study employs the local cultural identity questionnaire to test the students' identity. The questionnaire consists of three aspects: protection of the natural human environment, participation in community activities, and sense of belonging. The contents of the pretest differ from those of the posttest, and the interval between the two tests is 2 weeks. The experimental results were analyzed by *t*-test. As shown in Table 4, the identification of local culture of the two groups shows a significant difference ($t = 2.12$, $p < 0.05$), indicating that the two ways of learning, mobile learning and human-guided learning, lead to a significant difference in local cultural identification in our local cultural courses. In the analysis of the three aspects of local cultural identification, the two groups show a highly significant difference ($t = 2.90$, $p < 0.01$) in the second aspect, participation in community activities, as indicated in Table 5.

Teaching via mobile devices created a significant difference in the local cultural identification between the two groups of students. In local cultural education, mobile learning has a significant influence on the overall local cultural identification. Furthermore, among the three aspects, participation in community activities shows a particularly significant difference.

Analysis of satisfaction

After the experiment, the two groups of students were asked to fill out the "satisfaction survey," from which we can understand if a difference exists in the

Table 4. Local cultural identification of the two groups.

Group	*N*	Mean	SD	*t*
Experimental	26	4.52[a]	0.34	2.12*
Control	27	4.29[a]	0.44	

Note: *$p < 0.05$. [a]Out of a total of 20 questions asked, a low mean score of 1 would indicate low local cultural identification to a high score of 5 indicating that all participants revealed high local cultural identification.

Table 5. Analysis of the three aspects of local cultural identification of the two groups.

Group	*N*	Mean	SD	*t*
Protection of natural/human environment				
Experimental	26	4.58[a]	0.32	1.36
Control	27	4.43[a]	0.47	
Participation in community activities				
Experimental	26	4.50[b]	0.39	2.90*
Control	27	4.14[b]	0.50	
Sense of belonging				
Experimental	26	4.47[c]	0.41	1.36
Control	27	4.29[c]	0.53	

Note: *$p < 0.01$. [a]Out of a total of 8 questions asked, a low mean score of 1 would indicate low local cultural identification to a high score of 5 indicating that all participants had high local cultural identification for the aspect of protection of natural/human environment. [b]Out of a total of 5 questions asked, a low mean score of 1 would indicate low local cultural identification, to a high score of 5 indicating that all participants had high local cultural identification for the aspect of participation in community activities. [c]Out of a total of 7 questions asked, a low mean score of 1 would indicate low local cultural identification to a high score of 5 indicating that all participants had high local cultural identification for the aspect of sense of belonging.

students' degree of satisfaction in terms of the learning approach. The survey included 11 multiple choice and two open-ended questions. For example, one questionnaire item for the experimental group was "I like to learn in the field with this approach (i.e. using PDAs to access the learning guidance and supplementary materials)," while the corresponding item for the control group was "I like to learn in the field with this approach (i.e. following the guidance of the human tutor and learning with the learning sheet and printed supplementary materials)." In the *t*-test of the multiple choice questions of the two groups, the degree of satisfaction for the two groups shows a significant difference ($t = 2.62$, $p < 0.05$), as Table 6 illustrates. During the course about the construction features of Sheng-Mu temple, the degree of satisfaction of the students who used PDAs to experience the tour-based learning was higher than that of the students who had human guidance.

Furthermore, the "satisfaction survey" of the two groups of students was analyzed, and the percentages of the two options, "strongly agree" and "agree," for the experimental and control groups were added together. From the statistical analysis of the answers of the students in the experimental group, about 90% of the participants agreed that students, via the guidance of PDAs, can be motivated to learn about local cultural objects and better focus on learning. The use of PDAs broadens their horizons and thus they look forward to using PDAs in local cultural courses again.

However, in the control group, only 60% of the students liked the human guidance of the local cultural tour, felt that they were motivated to learn, and hoped to continue with this way of learning. This percentage is much less than that of the experimental group.

Feedback from interviews

In order to have a deeper understanding of the degree of satisfaction of the two groups, we carried out face-to-face interviews to find out the thoughts of the two groups of students involved. Concerning the question, "Do you hope that teachers can use PDAs to conduct local cultural teaching?" all of the students in the experimental group gave a positive answer. The reason why the students liked to use this approach was because each student could learn via one PDA at his/her own pace without the influence of other classmates. In such conditions, students could better concentrate on their learning. Six students indicated that, compared with a human guide explaining at the front, it was more fun to use a PDA. Four students thought that the text on the PDAs enabled them to better understand the contents of the cultural tour. Three students held the view that using PDAs broadened their horizons. Also, two students indicated that this type of tour taught them a lot.

Table 6. *t*-Test of satisfaction survey between the two groups.

Group	*N*	Mean	SD	*t*
Experimental	26	4.46[a]	1.05	2.62*
Control	30	3.75[a]	0.98	

Note: *$p < 0.05$. [a]Out of a total of 11 questions asked, a low mean score of 1 would indicate no satisfaction to a high score of 5 indicating that all participants were totally satisfied.

On the other hand, for the question ''Do you hope that teachers can use the same approach to conduct local cultural teaching in the future?'' most of the students in the control group gave a positive answer. However, 11 of the control group students mentioned that sometimes they were unable to keep up with the instructions given by the human guide. They indicated that the influence of other classmates was one of the reasons. They also believed that one-to-one instructions would be very helpful to them for understanding the background and features of each learning target. Moreover, many of them felt the in-field inquiry-based learning approach with learning sheets and printed supplementary materials was inefficient. For example, one of the students stated that ''It took me a long time to find the supplementary materials from the printed materials and to take notes on the learning sheets while observing the learning targets.'' In addition, three students shared the same opinions that ''It would be more efficient to use a computer to search for those supplementary data.''

It can be seen that the results of interviewing the two groups conform to their feedback to the questionnaires and their learning achievement, showing that the inquiry-based mobile learning approach was more helpful to the students in comparison with the traditional approach.

Conclusions

This study aims to investigate the effects of the mobile learning model that integrates real world and digital world resources on the cognitive load and learning achievement of students. The learning activity was designed for the local culture course of an elementary school by arranging the students to learn and collect data in the Sheng-Mu temple. From the experimental results, it was found that the students who learned with the blended mobile learning model had significantly better achievement and lower cognitive load than those who learned with the traditional approach (i.e. guided by a human tutor). Moreover, from the questionnaire survey and interview results, the students showed greater interest and enjoyment in using PDAs to learn. To sum up, this innovative approach is helpful to students from both the aspects of learning attitude and learning achievement.

Some elementary school teachers have mentioned their concern that using new technologies to learn might increase the load of the students. However, this study shows that the learning load of the students can be decreased, even in a rich technology environment, as long as the learning system as well as the learning activities can be appropriately designed. In this case, the use of RFIDs that helped the students to efficiently find the supplemental materials while they were learning in the real-world environment might be the reason why their cognitive load was significantly decreased.

In addition, this paper presents a case study for local culture learning in elementary school, and the participants were sixth grade students. Therefore, one of the future tasks is to extend this model to other subjects or students of different ages to gain more experimental results.

Acknowledgements

This study is supported in part by the National Science Council of the Republic of China under contract numbers NSC 99-2511-S-011-011-MY3 and NSC 99-2631-S-011-002.

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