Yang, C.-C., Hwang, G.-J., Hung, C.-M., & Tseng, S.-S. (2013). An Evaluation of the Learning Effectiveness of Concept Map-Based Science Book Reading via Mobile Devices. *Educational Technology & Society, 16* (3), 167–178.

An Evaluation of the Learning Effectiveness of Concept Map-Based Science Book Reading via Mobile Devices

Che-Ching Yang[1], Gwo-Jen Hwang[2*], Chun-Ming Hung[3] and Shian-Shyong Tseng[4]
[1]Department of Computer Science, National Chiao Tung University, 1001 Ta Hsueh Road, Hsinchu, 300, Taiwan // [2]Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology 43, Sec.4, Keelung Rd., Taipei, 106, Taiwan // [3]Department of Information and Learning Technology, National University of Tainan No. 33, Sec. 2, Shulin St., Tainan city 70005, Taiwan // [4]Department of Applied Informatics and Multimedia, Asia University 500 Lioufeng Road, Wufeng, Taichung, 413, Taiwan // jerome@cis.nctu.edu.tw // gjhwang.academic@gmail.com // hcm@live.htps.tn.edu.tw // sstseng@asia.edu.tw
[*]Corresponding author

(Submitted May 09, 2012; Revised October 15, 2012; Accepted October 20, 2012)

ABSTRACT

Printed books have long been an important means for people to obtain knowledge; nevertheless, educators have pointed out problems of learning from some printed books, in particular, the lack of learning supports, such as supplementary materials and learning guiding tools. In this study, a concept map-oriented ubiquitous learning approach is proposed for supporting printed science book reading activities for children via mobile devices with QR-code facilities. A quasi-experiment has been conducted in an elementary school to evaluate the effectiveness of the proposed approach, in which 92 sixth graders participated. The experimental results show that the concept map-oriented ubiquitous learning approach is significantly more helpful to the students in reading printed books than traditional book reading and the conventional ubiquitous learning approach in terms of learning achievements; moreover, the students had a high level of acceptance of such a mobile technology-assisted learning system in terms of "ease of use", "usefulness" and "attitude and intention of future use."

Keywords

Concept maps, Ubiquitous learning, Printed book reading, QR codes

Introduction

Printed books have been advocated as an important learning resource (Fletcher & Reese, 2005; Ortiz, Stowe, & Arnold, 2001) and have been linked to language development (Whitehurst et al., 1988), emergent literacy (Allor & McCathren, 2003; Whitehurst & Lonigan, 1998), oral and written skills (Whitehurst & Lonigan, 1998), and even science learning (Chen, Teng, Lee, & Kinshuk, 2011). When reading books, children activate and integrate their prior knowledge with the book content, use strategic processes to identify key concepts, synthesize and summarize information, make inferences, and participate in the story (Paris & Paris, 2003). However, for learning content that is abstract, such as science or mathematics, children might lose interest in reading the books without learning supports (Mantzicopoulos & Patrick, 2010, 2011).

In the past decades, owing to the advancement and growing popularity of computer and network technologies, a considerable number of digital books have been developed to provide a more convenient channel for people to learn; however, numerous learners still prefer reading printed books (Ackerman & Goldsmith, 2008; Chao & Chen, 2009; Chen, Teng, Lee, & Kinshuk, 2011; O'Hara & Sellen, 1997). Furthermore, researchers have reported the benefits of learning with printed books; for example, O'Hara and Sellen (1997) pointed out the major advantage of printed book reading, including (1) free-text annotation, which helps learners highlight, underline, summarize, and/or annotate; (2) quick navigation, which helps learners navigate the text quickly and automatically; and (3) flexibility of spatial layout, which helps learners gain a sense of overall structure, cross referencing and interleaving of reading/writing. The study of Ackerman and Goldsmith (2008) showed that the learning achievement of students who learned with printed texts was better than that of students who learned with digital texts. That is, printed books remain an effective means of learning. On the other hand, researchers have pointed out some problems of reading printed books, including the lack of learning supports, such as supplementary materials and learning guiding tools (Dünser & Hornecker, 2007). Therefore, it remains an important issue to provide learning supports for printed book reading (Chen, Teng, Lee, & Kinshuk, 2011).

Recently, the advancement of mobile and wireless communication technologies has further offered an opportunity for providing support for reading activities with digitalized supplementary materials. For example, several studies have demonstrated the convenience of using mobile devices in supporting and augmenting paper-based learning (Chao & Chen, 2009; Chen, et al., 2011; Ozcelik & Acarturk, 2011). Hwang, Tsai and Yang (2008) further defined the learning approach that employs mobile, wireless communication and sensing technologies to enable students to learn in real-world environments with access to digital resources as *context-aware ubiquitous learning* (u-learning).

On the other hand, scholars have emphasized the importance of providing scaffolding, a kind of instructional support, to help learners achieve goals that they cannot accomplish on their own (Kuo, Hwang, & Lee, 2012; Peng et al., 2009; Wood, Bruner, & Ross, 1976). For example, the studies of Chu, Hwang and Tsai (2010) and Hwang, Chu, Lin and Tsai (2011) showed the effectiveness of using knowlege construction tools in helping students conduct ecology observations for a natural science course. Chen et al. (2011) further indicated that the provision of scaffolding could benefit learners in reading. Among various learning strategies or tools, concept maps have been considered as being an effective tool for facilitating meaningful learning by helping students to link their prior knowledge with new experiences as well as organizing the accumulated knowledge (Liu, Chen, & Chang, 2010).

In this study, we augment paper-based reading activities in an elementary school natural science class by developing a reading system using smartphones in association with QR (Quick Response) code technology to provide students with a way of linking printed science books with corresponding digital materials and concept maps. Moreover, an experiment has been conducted to demonstrate the effectiveness of the proposed approach.

Literature review

Computer and mobile technologies in reading activities

The popularity of computer technologies has provided opportunities to conduct various kinds of learning activities. Earlier studies mainly employed multimedia technology to help students improve their reading comprehension (Garza, 1991; Hoven, 1999). Later, some researchers employed more advanced computer technologies, such as Virtual Reality (VR) or Augmented Reality (AR), to assist children in reading printed books by providing three-dimensional virtual content (McKenzie & Darnell, 2003; Yang et al., 2009).

The advancement of portable devices (e.g., PDAs, smartphones and e-books) and wireless communication technology has brought the learning technology into a new era, in which the potential of mobile and ubiquitous learning or one-to-one learning has been noted by researchers (Chan et al., 2006; Hwang, Tsai, & Yang, 2008). The benefit of using mobile and wireless communication technologies to provide learners with learning supports has been reported by many researchers, and includes learning guidance for in-field activities (Chiou, Tseng, Hwang, & Heller, 2010; Chu, Hwang, & Tseng, 2010; Hwang, Tsai, Chu, Kinshuk, & Chen, 2012) or in-class activities (Chang, Lan, Chang, & Sung, 2010; Wong, Chin, Tan, & Liu, 2010), as well as the provision of help-seeking (Yang, 2006) and assessment (Coulby, Hennessey, Davies, & Fuller, 2011; Hwang & Chang, 2011) mechanisms. Those learning systems have been applied to various practical applications, such as science learning (Hwang, Chu, Shih, Huang, & Tsai, 2010; Liu, Peng, Wu, & Lin, 2009; Rogers, Price, Randell, Fraser, Weal, & Fitzpatrick, 2005; Shih, Chuang, & Hwang, 2010), social science learning (Hwang & Chang, 2011) and language courses (Looi et al., 2010, 2009; Ogata, Matsuka, El-Bishouty, & Yano, 2009).

Chan et al. (2006) and Roschelle and Pea (2002) have indicated that such one-to-one learning has augmented physical space and leveraged topological space. They pointed out that the affordance of one-to-one learning using handheld devices is the latest trend in learning, whereby digital augmentation might break down many of the physical barriers to learning.

In recent years, several studies incorporating mobile devices with printed documents have been carried out. For example, Yeh et al. (2006) developed a mobile learning system which integrated paper notes with in-field ambient information, including digital photos of the surrounding learning targets and the data collected from the real-world environment. Chao and Chen (2009) proposed a learning support system in which a mobile phone was incorporated with printed books and a web-based discussion forum. Bederson, Quinn and Druin (2009) presented a zoomable user interface on mobile phones to support reading scanned multi-lingual printed books. Chen et al. (2011) and Ozcelik and Acarturk (2011) further demonstrated the use of mobile devices and QR code technology as a complement to printed course materials. A QR Code is a two-dimensional barcode, which consists of black modules arranged in a square pattern on a white background. Within this barcode can be encoded a URL (web address), text, or other information which can be read by a QR code scanner (e.g., Smartphone apps) (Chao & Chen, 2009; Chen, et al., 2011). QR code technology can link offline information to online content, effectively providing additional information and even multimedia resources (Chao & Chen, 2009; Chen, et al., 2011; Ozcelik & Acarturk, 2011).

The previous research not only demonstrated the potential of using mobile technologies to support printed book reading, but also revealed the need to develop adequate Mindtools or knowledge construction tools to assist students in organizing knowledge obtained from books (Liu, Chen, & Chang, 2010). For example, Hwang, Shi and Chu (2011) have reported that the students who learned with concept maps in ubiquitous learning environments have significantly better learning outcomes than those who learn with the traditional tour-based ubiquitous learning approach. The study of Hung, Hwang, Su, and Lin (2012) in an in-field ecology observation activity has also shown that the use of concept maps in ubiquitous learning activities is helpful to students in improving their learning outcomes. Consequently, in this study, we have developed a ubiquitous learning system to support printed science book reading by providing supplementary learning materials to complement the printed content, and a concept map facility to assist students in organizing their knowledge learned from the books.

Computerized concept maps

Novak and Gowin (1984) have indicated that meaningful learning can be formed by helping students connect their old cognitive structures with the new ones during the teaching process. Among various knowledge organizing tools, concept maps have been recognized by researchers as being an effective tool for externalizing students' knowledge and reorganizing both their old and new knowledge (Akinsanya & Williams, 2004; Hwang, Shi, & Chu, 2011). In the past decades, concept maps have been used as a knowledge organizing tool for supporting meaningful learning by helping students represent and visualize their knowledge structures (Hwang, Wu, & Chen, 2012; Lim, Lee, & Grabowski, 2009; Novak, 2002; Trundle & Bell, 2010).

The popularity of computer technology has brought the use of concept maps into the computerized era. Several studies have shown the effectiveness of computerized concept mapping systems in comparison with paper-and-pencil concept maps (Liu, Chen, & Chang, 2010; Kim & Olaciregui, 2008; Wu, Hwang, Milrad, Ke, & Huang, 2012). Researchers have indicated that the computerized approach has simplified the process of creating and revising concept maps; moreover, it has enabled more flexible presentations of the learning content as well as interactions among teachers and students (Hwang, Wu, & Ke, 2011; Reader & Hammond, 1994; Shin et al., 2000). Kim and Olaciregui (2008) have further reported that students seem to recall more ideas when they learn from a concept map than from a textual presentation.

Computerized concept maps have played different roles in various applications in the past decade, including the roles of knowledge construction and organizing tools (Erdogan, 2009), knowledge structure measuring tools (Chang, Sung, Chang, & Lin, 2005), and learning guidance tools (Hwang, 2003; Panjaburee et al., 2010).

Concept map-oriented ubiquitous learning system for supporting science book reading (CMULS)

Figure 1 shows the structure of the concept map-oriented ubiquitous learning system for supporting printed book reading. The ubiquitous learning system consists of three parts: printed science books, mobile devices, and learning resources (i.e., digital learning materials and concept maps). The printed science books are provided with QR codes, which are a type of bar-code containing web addresses of supplementary materials. By using smartphones with wireless communication, learners can scan the QR codes on the printed books to access additional supplementary learning resources from the learning system, including concept maps and learning materials.

Figure 2 shows an example of a printed science book with QR codes. The title of the book is “Lost in the Solar System” (Cole & Degen, 1990), from the Magic School Bus series, which tells the story of a class field trip into outer space during which the students visit each planet in the solar system. By using the smartphone "photo" function to read the QR codes on the book, the corresponding web addresses are accessed and the learning materials as well as the concept maps are thereby presented to the learners.

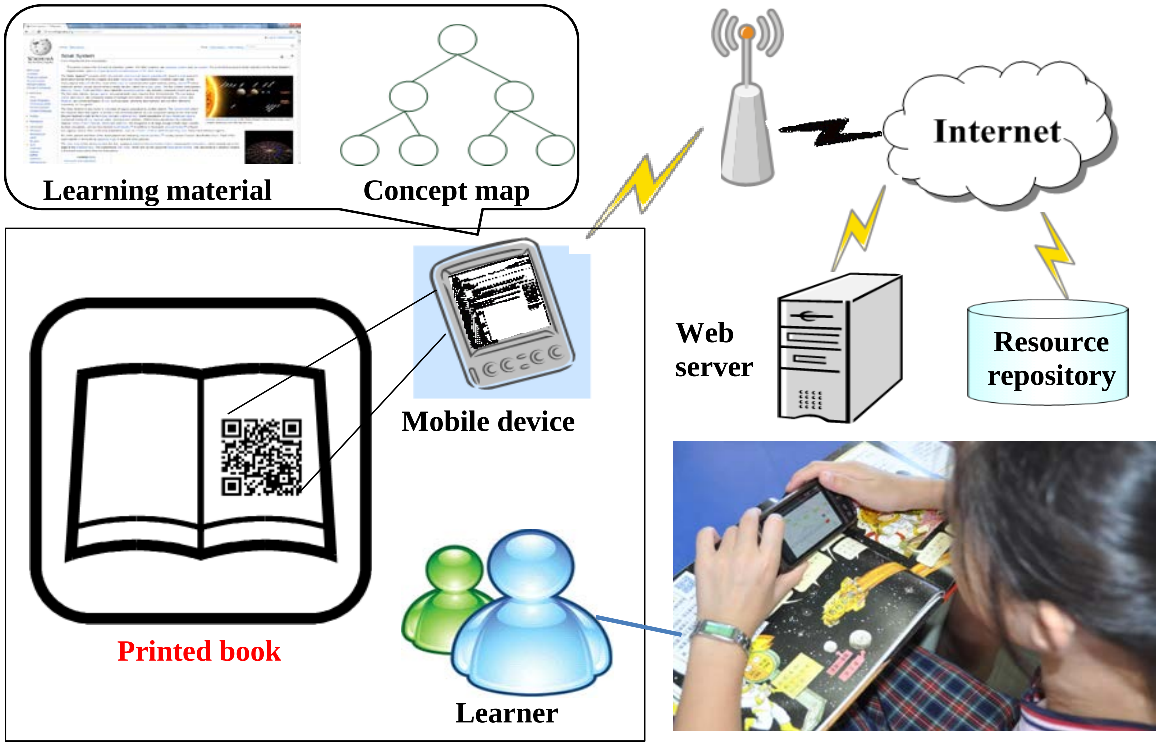

Figure 1. System framework of CMULS

Figure 2. Illustrative example of reading printed science books with concept maps and supplementary materials using mobile devices

In this illustrative example, the concept map is used to help the students organize the information, identify the important concepts and the relationships between concepts, and perceive their learning status related to the "solar system" unit in the science book via visualizing the learning content and learning status information. In the upper right of Figure 2, the concept map shows different planets (in order of distance from the sun). The different colors in the bottom of the screenshot represent the reading progress status. The red node is the planet (e.g. Saturn) that is introduced on the current page, the light blue nodes are the planets that were introduced on the previous pages, and the grey nodes are the planets that will be introduced in the following pages. The left of the screenshot is a QR code icon. By touching the icon, a built-in camera is directly activated and learners can move on to scan other QR codes. The bottom right of Figure 2 shows the learning scenario of reading printed science books with concept maps and supplementary materials using mobile devices.

The supplementary learning materials as well as the demonstrative concept maps were developed by consulting two teachers each with more than five years experience teaching natural science courses and who were informed of the importance of designing term/phenomenon explanations and more realistic illustrations (Ganea, et al., 2008; Tare, et al., 2010). Accordingly, such additional learning materials were developed, including digital text, images, and video clips, to help the students comprehend the learning content. Moreover, different types of learning supports can be accessed via the different colored QR-codes. For example, the blue QR codes link to concept maps (upper right of the figure) while the black codes link to learning materials (bottom right of the figure).

Research design

This study aims to investigate the effects of the concept map-based u-learning approach on students' learning achievement, cognitive load, and technology acceptance while reading printed science books with handheld devices. The learning content is the subject unit "the Solar System" of an elementary school natural science course.

Participants

The participants were 92 sixth graders from three classes of an elementary school in southern Taiwan. Two classes were assigned to be Experimental group 1 (N=28) and Experimental group 2 (N=31), while the third class was the control group (N=33). Note that all participants used the same books. The difference between the three groups was the learning treatments. The students in Experimental group 1 were instructed and guided to read printed books with access to concept maps and supplementary learning materials via smart phones; those in Experimental group 2 read printed books with access to supplementary learning materials via smart phones, but without access to concept maps; and those in the control group read the printed books with those supplementary digital materials presented by the teacher. It should be noted that the participants in Experimental groups 1 and 2 did not have a teacher providing further instruction.

Experimental procedure

Figure 3 shows the experimental procedure, which consists of three stages, that is, conducting the pre-tests, introduction to the tools and learning missions, and conducting the post-tests and the post-questionnaire.

In the first stage, all of the students took the natural science course pre-test. The total time for this stage was 30 minutes. In the second stage, the students in the three groups were instructed with the tools and missions of the learning activity. The time for this stage was 10 minutes.

Following the instruction, a 60-minute learning activity was conducted. During this activity, the students in Experimental group 1 were guided to read the printed books with access to the corresponding concept maps and supplementary learning materials via handheld devices. The students in Experimental group 2 were supplied with supplementary learning materials via handheld devices. On the other hand, the students in the control group used the traditional approach to reading printed books with instruction from the teacher.

In the final stage, the students completed a cognitive load questionnaire, the technology acceptance model questionnaire, and the natural science course post-test. The total time for this stage was 40 minutes.

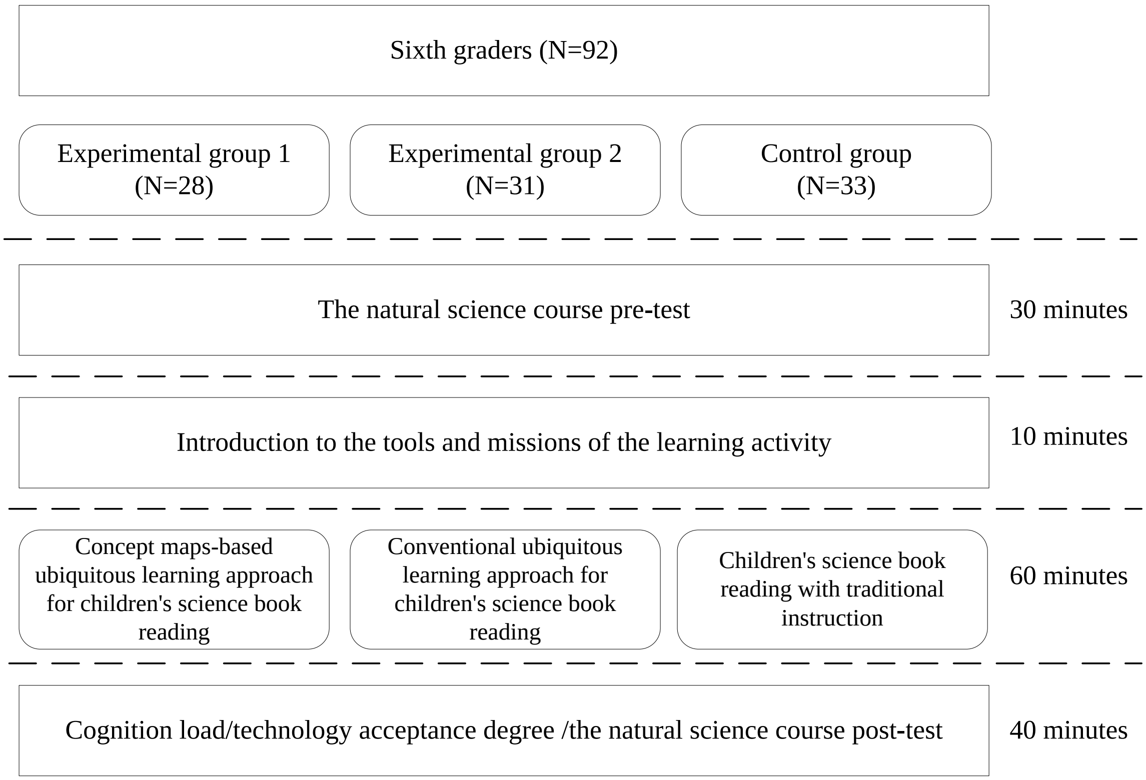

Figure 3. Experimental procedure

Measuring tools

The pre-test was conducted to evaluate the students' prior knowledge before reading the printed science books. It consisted of 15 true-false questions, 15 multiple-choice questions, 4 matching questions and 5 fill-in-the-blank questions, giving a total score of 100. For example, two of the pre-test items are "Why are we unable to see the constellations of Scorpio and Orion at the same time? (1) Because Scorpio is much brighter than Orion; (2) Because the two constellations move to the same area at different times; (3) Because Scorpio moves faster than Orion; (4) Because Scorpio is closer to the earth" and "When we operate the planisphere (a device to show the locations of constellations), the position of Polaris changes from time to time (1) Yes; (2) No."

The post-test aimed to evaluate the learning achievements of the students after using different treatments to read the printed science books. It consisted of ten multiple-choice questions, with a total score of 10, about the subject unit "the Solar System". The post-test was developed by consulting two teachers who had taught the natural science course for more than five years. For example, two of the post-test items are "Which planet in the Solar System is farthest from the earth? (a) Neptune; (b) Uranus; (c) Mars; (d) Venus; (e) Mercury" and "Why is the temperature on Venus higher than that of the other planets in the Solar System? (a) Because of the ozone layer depletion; (b) Because of the greenhouse effect; (c) Because of its shortest distance to the Sun; (d) Because of the effect of its satellites; (e) Because of its high moving speed."

The cognitive load questionnaire was developed based on the cognitive load measure proposed by Sweller, van Merrienboer and Paas (1998). It consisted of 4 questionnaire items (e.g., "I feel great pressure in learning with this instructional approach" and "I need to put lots of efforts into understanding the learning content") with a 7-point Likert scale, where '7' represented 'strongly agree' and '1' represented 'strongly disagree.' The greater the cognitive burden, the lower the user's satisfaction (Segall, Doolen, & Porter, 2005). The Cronbach's alpha value of the questionnaire was 0.88, showing adequate internal consistency in evaluating the cognitive load of the students.

The questionnaire of technology acceptance was modified from the questionnaire items developed by Davis (1989). It was used to explore how students came to accept and use the mobile technology while reading the printed books with a 7-point Likert scale, where ‘7’ represented ‘strongly agree’ and ‘1’ represented ‘strongly disagree.’ The questionnaire included three subscales: 6 items for "usefulness of reading printed books with support from the mobile learning system" (e.g., "The supplementary materials provided by the learning system are quite clear and effectively assist me in understanding the learning content" and "Combining the smartphones and the printed book is helpful to learning"), 7 items for "ease of use" (e.g., " It is easy to operate the learning system via the smartphones and QR codes" and "I learned to operate the learning system quickly") and 6 items for "attitude and intention of future use" (e.g., "I like to learn in this way" and "I would like to recommend this learning system to others"). The Cronbach’s alpha values of those three subscales were 0.94, 0.95 and 0.91, respectively, indicating high internal consistency. The students in both of the experimental groups were asked to complete this questionnaire after the learning activity.

Results

Learning achievement

Before the experiment, a test of basic science knowledge was conducted to understand the differences in science cognition among the three groups. The descriptive statistics of the pre-test are presented in Table 1.

Table 1. Pre-test results of the natural science

	Group	N	Mean	SD
(E1)	Experimental Group 1	28	83.29	7.12
(E2)	Experimental Group 2	31	92.61	5.18
(C)	Control Group	33	79.24	10.29

After the learning activity, the three groups of students took the post-test. The pre-test scores were regarded as the covariance for analysis of covariance to delete the effects of the pretest on the learning outcome. The homogeneity of the regression coefficient was tested, which revealed that interaction F between the covariance was 0.31 ($p > 0.05$). This confirms the hypothesis of homogeneity of the regression coefficient.

Table 2 shows the ANCOVA result on the post-test scores of the three groups. The means and standard deviations of the post-test scores were 7.23 and 1.05 for Experimental group 1, 6.61 and 1.50 for Experimental group 2, and 5.73 and 1.64 for the control group. It is found that the post-test scores of the three groups are significantly different, with $F = 7.80$ ($p < .01$). Moreover, the adjusted means of the three groups were 7.34, 6.37, and 5.91. The pairwise comparisons show that there is a significant difference between E1 and E2, and a significant difference between E1 and C. In other words, the students in Experimental group 1 had significantly better learning achievement than the students in both Experimental group 2 and in the control group.

Consequently, it is concluded that a concept map-based ubiquitous learning approach to reading printed science books with handheld devices is more helpful to the students in terms of learning achievement in a natural science course than traditional printed science book reading and the conventional mobile technology-supported approach, implying the benefit of leading in with the concept maps to assist students to learn via mobile devices.

Table2. ANCOVA result of learning achievement on the post-test scores of the three groups

	Group	N	Mean	S.D.	Adjusted Mean	F(2, 88)	Pairwise comparisons
(E1)	Experimental Group 1	28	7.23	1.05	7.34	7.80^{**}	
(E2)	Experimental Group 2	31	6.61	1.50	6.37		(E1)>(E2)
(C)	Control Group	33	5.73	1.64	5.91		(E1)>(C)
	Total number of students	92	6.50	1.56			

$^{**}p < .01$

Cognitive load

Table 3 presents the analysis result of the students' cognitive load. The means and standard deviations are 3.55 and 1.36 for the control group, 3.86 and 1.38 for Experimental group 1, and 4.35 and 1.94 for Experimental group 2. Although both the experimental groups revealed slightly higher mean scores than the control group, the ANOVA result (F = 2.08 and $p > .05$) showed no significant difference between the three groups, implying that the three groups of students experienced equivalent levels of cognitive load during the learning activity. Moreover, the average cognitive loads of the three groups were not high, implying that printed science books provide an easy and relaxed way for students to read. In addition, it is interesting to find that Experimental group 1 had lower average cognitive load than Experimental group 2, showing that the lead in of the concept maps could have eased the cognitive load of the students in terms of using the mobile devices to access the supplementary digital materials.

Table 3. ANOVA result of cognitive load on the three groups

	Group	N	Mean	S.D.	F(2, 89)
(E1)	Experimental Group 1	28	3.86	1.38	2.08
(E2)	Experimental Group 2	31	4.35	1.94	
(C)	Control Group	33	3.55	1.36	

Acceptance of using the mobile technology to support printed science book reading

Table 4 presents an analysis of the students' degree of acceptance of using the mobile technology to support printed science book reading. The means and standard deviations of the usefulness subscale are 5.95 and 0.97 for Experimental group 1 and 6.24 and 1.12 for Experimental group 2, showing that most students felt that the proposed system was useful. From the interview, it was found that the students in both experimental groups showed positive attitudes toward reading the supplementary materials on the smartphones. Some of the students in Experimental group 1 further revealed that they were highly appreciative of the concept maps helping them understand the relationships between the learning items in the books.

In terms of ease of use, the means and standard deviations are 5.48 and 1.18 for Experimental group 1, and 6.04 and 1.18 for Experimental group 2; that is, most students felt that the ubiquitous learning system was easy to use. Moreover, the scores of the two groups were not significantly different, implying that the students in Experimental group 1 did not feel that it was difficult to receive the learning supports although they needed to read the concept maps via the handheld devices.

In terms of “attitude and intention of future use,” the means and standard deviations are 5.90 and 0.88 for Experimental group 1, and 6.19 and 0.99 for Experimental group 2. It was found that the *t*-test result shows no significant difference between the two groups, implying that the students in both experimental groups revealed similar degrees of acceptance of the ubiquitous learning system. Furthermore, from the interview, it is interesting to find that most of the students felt that the use of the QR-codes was convenient, efficient and interesting, although there were alternative ways of accessing the digital materials, such as selecting the items on the menu or searching for the data with keywords. This implies that the provision of a user-friendly interface is able to promote the willingness of students to use the learning system.

Table 4. t-test result of technology acceptance of the experimental groups

Scale		Group	N	Mean	S.D.	*t*
Usefulness	(E1)	Experimental Group 1	28	5.95	0.97	1.06
	(E2)	Experimental Group 2	31	6.24	1.12	
Ease of Use	(E1)	Experimental Group 1	28	5.48	1.18	1.82
	(E2)	Experimental Group 2	31	6.04	1.18	
Attitude	(E1)	Experimental Group 1	28	5.90	0.88	1.18
	(E2)	Experimental Group 2	31	6.19	0.99	

Discussion

To achieve the aim of assisting children in printed science book reading, a concept map-based ubiquitous learning approach was proposed in this study. The experimental results showed that the proposed approach had significantly better effectiveness in improving students' learning achievements than the conventional ubiquitous learning approach and the traditional printed science book reading approach. In addition, the experimental results showed no significant difference between Experimental group 2 and the Control group; that is, the effect of accessing digital supplementary materials was equivalent to that of the teacher's instruction. Such a finding conforms to what has been reported by previous studies (Chen et al., 2011). Meanwhile, the analysis of the questionnaire results showed that the proposed learning approach did not increase the students’ cognitive burden; moreover, it can be seen from Table 4 that most of the students held positive views regarding “ease of use,” “usefulness” and "attitude and intention of future use" regarding the ubiquitous reading-supported system.

To sum up, the proposed approach is helpful to students in terms of learning achievement, cognitive load and technology acceptance. Consequently, to effectively support printed science book reading, the provision of both concept maps and digital supplementary materials is required. Such an approach can also be applied to the printed book reading of other subjects, such as mathematics, language, social science, and natural science, in which concept maps could be helpful to readers in organizing the concepts in the book content, and hence their reading comprehension can be improved.

Conclusions

This study investigates the effects of a concept map-based ubiquitous learning approach to reading printed science books with handheld devices on students’ learning achievement, cognitive load, and technology acceptance. A learning activity has been conducted to compare the learning performance of students who read printed science books with mobile device-supported concept maps and supplemental learning materials, those who read printed science books with access to digital supplemental learning materials only, and those who read printed science books with traditional instruction. A quasi-experiment has been conducted in an elementary school to evaluate the effectiveness of the proposed approach. The experimental results show that the concept map-oriented ubiquitous learning approach is significantly more helpful to the students in reading printed books than traditional book reading and the conventional ubiquitous learning approach in terms of learning achievements; moreover, the students had a high level of acceptance of such a mobile technology-assisted learning system in terms of “ease of use”, “usefulness” and "attitude and intention of future use."

In sum, the experimental results show the importance of providing learning supports for printed science book reading. Therefore, one of the salient contributions of this study is to highlight the importance of providing concept maps and supplementary materials for printed science book reading. Another contribution is to demonstrate how the proposed approach can be used in a specific learning activity and to show its potential in terms of its effectiveness in improving the learning achievements and technology-acceptance degrees of the students.

Although the experimental results have shown the benefits of using CMULS, there are some limitations in the present study. For example, although mobile devices such as smartphones are becoming increasingly popular, not all students have access to such a learning device at present. Fortunately, researchers have predicted that mobile devices will become a common learning device in the near future (Norris, Hossain, & Soloway, 2011), implying that the proposed approach has the potential to become a widely-used learning model. Another limitation of this study is that the QR codes on the book are fixed. Even though concept maps as well as supplementary learning materials are offered, students may still experience difficulty reading the book. That is, adaptive learning materials for individual students to complement the printed content are needed. Therefore, one of our future works is to extend this study to offer adaptive learning resources for students.

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 101-2511-S-011 -005 -MY3.

References

Ackerman, R., & Goldsmith, M. (2008). Learning directly from screen? Oh-no, I must print it! Metacognitive analysis of digitally presented text learning. In Y. Eshet, A. Caspi, & N. Geri (Eds.), *Proceedings of the Chais Conference on Instructional Technologies Research 2008: Learning in the Technological Era* (pp. 1-7). Raanana, Israel: The Open University of Israel.

Akinsanya, C., & Williams, M. (2004). Concept mapping for meaningful learning. *Nurse Education Today, 24*(1), 41-46.

Allor, J. H., & McCathren, R. B. (2003). Developing emergent literacy skills through storybook reading. *Intervention in School and Clinic, 39*(2), 72-79.

Bederson, B. B., Quinn, A., & Druin, A. (2009). Designing the reading experience for scanned multi-lingual picture books on mobile phones. In Heath, F., Rice-Lively, M. L., & Furuta, R. (Eds.), *Proceedings of the 9th ACM/IEEE-CS joint conference on Digital libraries* (pp. 305-308): New York, NY: ACM Press.

Chan, T., Roschelle, J., Hsi, S., Kinshuk, Sharples, M., Brown, T., ... Hoppe, U. (2006). One-to-one technology-enhanced learning: An opportunity for global research collaboration. *Research and Practice in Technology Enhanced Learning, 1*(1), 3-29.

Chang, K. E., Lan, Y. J., Chang, C. M., & Sung, Y. T. (2010). Mobile device-supported strategy for Chinese reading comprehension. *Innovations in Education and Teaching International, 47*(1), 69-84.

Chang, K. E., Sung, Y. T., Chang, R. B., & Lin, S. C. (2005). A new assessment for computer-based concept mapping. *Educational Technology & Society, 8*(3), 138-148.

Chao, P. Y., & Chen, G. D. (2009). Augmenting paper-based learning with mobile phones. *Interacting with Computers, 21*(3), 173-185.

Chen, N.-S., Teng, D. C.-E., Lee, C.-H., & Kinshuk. (2011). Augmenting paper-based reading activity with direct access to digital materials and scaffolded questioning. *Computers & Education, 57*(2), 1705-1715.

Chiou, C. K., Tseng, J. C. R., Hwang, G. J., & Heller, S. (2010). An adaptive navigation support system for conducting context-aware ubiquitous learning in museums. *Computers & Education, 55*(2), 834-845.

Chu, H. C., Hwang, G. J., & Tsai, C. C. (2010). A knowledge engineering approach to developing mindtools for context-aware ubiquitous learning. *Computers & Education, 54*(1), 289-297.

Chu, H. C., Hwang, G. J., & Tseng, J. C. R. (2010). An innovative approach for developing and employing electronic libraries to support context-aware ubiquitous learning. *Electronic Library, 28*(6), 873-890.

Cole, J., & Degen, B. (1990). *The magic school bus, lost in the solar system*. New York, NY: Scholastic Inc.

Coulby, C., Hennessey, S., Davies, N., & Fuller, R. (2011). The use of mobile technology for work-based assessment: The student experience. *British Journal of Educational Technology, 42*(2), 251-265.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *Mis Quarterly, 13*(3), 319-340.

Dünser, A., & Hornecker, E. (2007). An observational study of children interacting with an augmented story book. In K. Hui et al. (Eds.), *Proceedings of the 2nd International Conference on Technologies for E-learning and Digital Entertainment* (pp. 305-315). doi: 10.1007/978-3-540-73011-8_31

Erdogan, Y. (2009). Paper-based and computer-based concept mappings: The effects on computer achievement, computer anxiety and computer attitude. *British Journal of Educational Technology, 40*, 821-836.

Fletcher, K. L., & Reese, E. (2005). Picture book reading with young children: A conceptual framework. *Developmental Review, 25*(1), 64-103.

Ganea, P. A., Pickard, M. B., & DeLoache, J. S. (2008). Transfer between picture books and the real world by very young children. *Journal of Cognition and Development, 9*(1), 46-66.

Garza, T. J. (1991). Evaluating the use of captioned video materials in advanced foreign language learning. *Foreign Language Annals, 24*(3), 239-258.

Hoven, D. (1999). A model for listening and viewing comprehension in multimedia environments. *Language Learning & Technology, 3* (1), 88-103.

Hung, P. H., Hwang, G. J., Su, I. H., & Lin, I. H. (2012). A concept-map integrated dynamic assessment system for improving ecology observation competences in mobile learning activities. *Turkish Online Journal of Educational Technology, 11*(1), 10-19.

Hwang, G. J. (2003). A concept map model for developing intelligent tutoring systems. *Computers & Education, 40*(3), 217 - 235.

Hwang, G. J., & Chang, H. F. (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education, 56*(4), 1023-1031.

Hwang, G. J., Chu, H. C., Lin, Y. S., & Tsai, C. C. (2011). A knowledge acquisition approach to developing Mindtools for organizing and sharing differentiating knowledge in a ubiquitous learning environment. *Computers & Education, 57*(1), 1368-1377.

Hwang, G. J., Chu, H. C., Shih, J. L., Huang, S. H., & Tsai, C. C. (2010). A decision-tree-oriented guidance mechanism for conducting nature science observation activities in a context-aware ubiquitous learning environment. *Educational Technology & Society, 13*(2), 53-64.

Hwang, G. J., Shi, Y. R., & Chu, H. C. (2011). A concept map approach to developing collaborative Mindtools for context-aware ubiquitous learning. *British Journal of Educational Technology*, 42(5), 778-789.

Hwang, G. J., Wu, P. H., & Ke, H. R. (2011). An interactive concept map approach to supporting mobile learning activities for natural science courses. *Computers & Education*, 57(4), 2272-2280.

Hwang, G. J., Tsai, C. C., Chu, H. C., Kinshuk, & Chen, C. Y. (2012). A context-aware ubiquitous learning approach to conducting scientific inquiry activities in a science park. *Australasian Journal of Educational Technology, 28*(5), 931-947.

Hwang, G. J., Tsai, C. C., & Yang, S. J. H. (2008). Criteria, strategies and research issues of context-aware ubiquitous learning. *Educational Technology & Society, 11*(2), 81-91.

Hwang, G. J., Wu, P. H., & Chen, C. C. (2012). An online game approach for improving students' learning performance in web-based problem-solving activities. *Computers & Education, 59*(4), 1246-1256.

Kim, P., & Olaciregui, C. (2008). The effects of a concept map-based information display in an electronic portfolio system on information processing and retention in a fifth-grade science class covering the Earth's atmosphere. *British Journal of Educational Technology, 39*, 700-714.

Kuo, F. R., Hwang, G. J., & Lee, C. C. (2012). A hybrid approach to promoting students' web-based problem solving competence and learning attitude. *Computers & Education*, *58*(1), 351-364.

Lim, K. Y., Lee, H. W., & Grabowski, B. (2009). Does concept-mapping strategy work for everyone? The levels of generativity and learners' self-regulated learning skills. *British Journal of Educational Technology, 40*(4), 606-618.

Liu, P. L., Chen, C. J., & Chang, Y. J. (2010). Effects of a computer-assisted concept mapping learning strategy on EFL college students' English reading comprehension. *Computers & Education, 54*(2), 436-445.

Liu, T. C., Peng, H. Y., Wu, W. H., & Lin, M. S. (2009). The effects of mobile natural-science learning based on the 5E learning cycle: A Case Study. *Educational Technology & Society*, *12*(4), 344-358.

Looi, C.-K., Seow, P., Zhang, B., So, H.-J., Chen, W., & Wong, L.-H. (2010). Leveraging mobile technology for sustainable seamless learning: A research agenda. *British Journal of Educational Technology*, 41(2), 154-169.

Looi, C.-K., Wong, L.-H., So, H.-J., Seow, P., Toh, Y., Chen, W., … Soloway, E. (2009) Anatomy of a mobilized lesson: Learning my way. *Computers and Education, 53*, 1120-1132.

Mantzicopoulos, P., & Patrick, H. (2010). "The Seesaw is a machine that goes up and down": Young children's narrative responses to science-related informational Text. *Early Education and Development, 21*(3), 412-444.

Mantzicopoulos, P., & Patrick, H. (2011). Reading picture books and learning science: Engaging young children with informational text. *Theory into Practice, 50*(4), 269-276.

McKenzie, J., & Darnell, D. (2003). *The eyeMagic book. A report into augmented reality storytelling in the context of a children's workshop.* Retrieved from http://www.mindspacesolutions.com/demos/eyeMagicWorkShopReport.pdf

Norris, C., Hossain, A., & Soloway, E. (2011). Using smartphones as essential tools for learning- A call to place schools on the right side of the 21st century. *Educational Technology*, 18-25. Retrieved from http://cecs5580.pbworks.com/w/file/fetch/50303907/ET%20article%20Norris%20Soloway.pdf

Novak, J. D. (2002). Meaningful learning: The essential factor for conceptual change in limited or appropriate propositional hierarchies (LIPHs) leading to empowerment of learners. *Science Education, 86*(4), 548-571.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn.* Cambridge, NY: Cambridge University Press.

Ogata, H., Matsuka, Y., El-Bishouty, M. M., & Yano, Y. (2009). LORAMS: linking physical objects and videos for capturing and sharing learning experiences towards ubiquitous learning. *International Journal of Mobile Learning and Organisation, 3*(4), 337-350.

O'Hara, K., & Sellen, A. (1997). A comparison of reading paper and online documents. In O'Hara, K., & Sellen, A. (Eds.), *Proceedings of the SIGCHI conference on Human factors in computing systems (CHI '97)* (pp. 335-342). New York, NY: ACM Press.

Ortiz, C., Stowe, R. M., & Arnold, D. H. (2001). Parental influence on child interest in shared picture book reading. *Early Childhood Research Quarterly, 16*(2), 263-281.

Ozcelik, E., & Acarturk, C. (2011). Reducing the spatial distance between printed and online information sources by means of mobile technology enhances learning: Using 2D barcodes. *Computers & Education, 57*(3), 2077-2085.

Panjaburee, P., Hwang, G. J., Triampo, W., & Shih, B. Y. (2010) A multi-expert approach for developing testing and diagnostic systems based on the concept effect model. *Computers & Education, 55,* 527-540.

Paris, A. H., & Paris, S. G. (2003). Assessing narrative comprehension in young children. *Reading Research Quarterly, 38*(1), 36-76.

Peng, H. Y., Chuang, P. Y., Hwang, G. J., Chu, H. C., Wu, T. T., & Huang, S. X. (2009). Ubiquitous performance-support system as Mindtool: A case study of instructional decision making and learning assistant. *Educational Technology & Society, 12*(1), 107-120.

Reader, W., & Hammond, N. (1994) Computer-based tools to support learning from hypertext: concept mapping tools and beyond. *Computers & Education, 12,* 99-106.

Rogers, Y., Price, S., Randell, C., Fraser, D. S., Weal, M., & Fitzpatrick, G. (2005). Ubi-learning integrates indoor and outdoor experiences. *Communications of the ACM, 48*(1), 55-59.

Roschelle, J., & Pea, R. (2002). A walk on the WILD side: How wireless handhelds may change computer-supported collaborative learning. *International Journal of Cognition and Technology, 1*(1), 145-168.

Segall, N., Doolen, T. L., & Porter, J. D. (2005). A usability comparison of PDA-based quizzes and paper-and-pencil quizzes. *Computers & Education, 45*(4), 417-432.

Shih, J. L., Chuang, C. W., & Hwang, G. J. (2010). An inquiry-based mobile learning approach to enhancing social science learning effectiveness. *Educational Technology & Society, 13*(4), 50-62.

Shin, J., Deno, S. L., Robinson, S. L., & Marston, D. (2000). Predicting classroom achievement from active responding on a computer-based groupware system. *Remedial and Special Education, 21*(1), 53-60.

Sweller, J., van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), 251-296.

Tare, M., Chiong, C., Ganea, P., & DeLoache, J. (2010). Less is more: How manipulative features affect children's learning from picture books. *Journal of Applied Developmental Psychology, 31*(5), 395-400.

Trundle, K. C., & Bell, R. L. (2010). The use of a computer simulation to promote conceptual change: A quasi-experimental study. *Computers & Education, 54*(4), 1078-1088.

Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. *Child Development, 69*(3), 848-872.

Whitehurst, G. J., Falco, F. L., Lonigan, C. J., Fischel, J. E., Debaryshe, B. D., Valdezmenchaca, M. C., & Caulfield, M. (1988). Accelerating language-development through picture book reading. *Developmental Psychology, 24*(4), 552-559.

Wong, L. H., Chin, C. K., Tan, C. L., & Liu, M. (2010). Students' personal and social meaning making in a Chinese idiom mobile learning environment. *Educational Technology & Society, 13*(4), 15-26.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of child psychology and psychiatry, and allied disciplines, 17*(2), 89-100.

Wu, P. H., Hwang, G. J., Milrad, M., Ke, H. R., & Huang, Y. M. (2012). An innovative concept map approach for improving students' learning performance with an instant feedback mechanism. *British Journal of Educational Technology, 43*(2), 217-232.

Yang, J. C., Huang, Y. T., Tsai, C. C., Chung, C. I., & Wu, Y. C. (2009). An automatic multimedia content summarization system for video recommendation. *Educational Technology & Society, 12* (1), 49-61.

Yang, S. J. H. (2006). Context aware ubiquitous learning environments for peer-to-peer collaborative learning. *Educational Technology & Society, 9*(1), 188-201.

Yeh, R. B., Liao, C., Klemmer, S. R., Guimbretière, F., Lee, B., Kakaradov, B., & Paepcke, A. (2006). ButterflyNet: A mobile capture and access system for field biology research. In R. Grinter et al. (Eds.), *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 571-580). New York, NY: ACM.