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Effects of an integrated concept mapping and web-based problem-solving approach on students' learning achievements, perceptions and cognitive loads

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A B S T R A C T

Although students could effectively search for web data with proper keywords and select web pages related to the studied core issue, however summarizing or organizing the retrieved information remains a difficult task for them. Concept mapping is known to be an effective knowledge construction tool for helping learners organize important concepts related to a core issue. To address the problem, an integrated concept mapping and web-based problem-solving environment, CM-Quest, has been developed; moreover, an experiment has been conducted to evaluate the effectiveness of the approach on students' learning performance, learning satisfaction and cognitive load in an elementary school social studies course. The results show that the concept map-integrated approach can significantly enhance the students' web-based problem-solving performance, although the students showed lower degrees of technology acceptance and learning satisfaction in comparison with the conventional web-based problem-solving approach. Moreover, it is found that the students in the concept mapping group revealed higher cognitive loads than those in the control group, which could be the factor contributing to the lower technology acceptance degree and learning satisfaction. As a consequence, it is concluded that the integrated concept mapping and web-based problem-solving approach is helpful to students in guiding them to learn in a more effective way. On the other hand, it remains an open issue to find a suitable way of integrating concept maps into the learning process without introducing too much extra cognitive load so as to promote students' acceptance degree of using technology for better learning.

1. Introduction

The rapid advancement of information and network technologies not only changes the way in which people access and derive information, but also speeds up the accumulation of knowledge resources. Consequently, how to foster students' ability of efficiently seeking information on the Internet and utilizing the information in solving problems has become a widely-discussed issue (Markham & Lenz, 2002; Visser, 2003). In the past decade, various studies have been conducted to engage students in web-based information-seeking tasks for answering a series of questions related to a core issue (Bilal & Kirby, 2002; Sundin, 2008; Tu, Shih, & Tsai, 2008); this approach has been known as web-based problem solving (Kuo, Hwang, & Lee, 2012). Researchers have further indicated that students' web-based problem-solving performance is highly related to their learning outcomes and problem-solving skills, implying providing effective learning supports or information organizing strategies are very important in web-based problem-solving activities (Lefrancois, 1997; Tsai & Shen, 2009).

On the other hand, educators have found that most students possess basic skills of operating computers to search for data on the web, yet lack effective strategies for extracting usable information from the searched data (MacGregor & Lou, 2005). Some researchers have attempted to improve students' web-based problem-solving performance by providing additional instruction on information-seeking and

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extracting (Chen, Teng, Lee, & Kinshuk, 2011; Tsai, Liang, Hou, & Tsai, 2012; Zhang & Quintana, 2012). It was found that although the students could effectively search for web data with proper keywords and select web pages related to the core issue, however summarizing or organizing the retrieved information remains a difficult task for them (Hwang & Kuo, 2011). Therefore, it is necessary to provide scaffolding or effective tools to assist students in summarizing or organizing the information retrieved from the web.

Concept mapping is known to be an effective knowledge construction tool for helping learners organize important concepts related to a core issue and the relationships between the concepts (Boyle & Weishaar, 1997; Gould, 1987; McCagg & Dansereau, 1991; Reese, 1988). It provides a visualized approach to organize concepts by representing concepts as nodes and the relationships between concepts as links, which could be an effective approach for assisting students in overcoming the difficulty of extracting and organizing web content (Novak & Gowin, 1985). Thus, in this study, a fill-in-the-blank concept mapping strategy is proposed for developing web-based problem-solving systems. Moreover, an experiment has been conducted in an elementary school social studies course to evaluate the effectiveness of the proposed approach by answering the following research questions:

(1) Do students who learn with the integrated concept mapping and web-based problem-solving learning approach have significantly better learning performance than students without the concept mapping strategy?
(2) Do students who learn with the integrated concept mapping and web-based problem-solving learning approach have significantly better acceptance and satisfaction with the developed learning system than students without the concept mapping strategy?
(3) Do students learning in these two different approaches have significantly different cognitive loads?

2. Literature review

2.1. Web-based problem solving

The World Wide Web nowadays provides many benefits, such as immediacy of information, diversity of data contents, and promptness and convenience of data accessing. When facing problems to be solved, people mostly choose the Internet as a convenient and efficient channel for acquiring referential information or solutions (Chandra & Watters, 2012; Dimopoulos & Asimakopoulos, 2010). Therefore, educators have emphasized the importance of fostering students' abilities of searching for and utilizing information on the web for problem solving (Chandra, & Watters, 2012; Merrill & Gibert, 2008). To complete a web-based problem-solving task, students need to comprehend the questions or issues raised by the teacher, determine the keywords for information searching, select the searched web pages, extract and organize the selected information, and summarize their findings (Chen, 2010; Kim & Hannafin, 2011; de Vries, van der Meij, & Lazonder, 2008).

In the past decade, researchers have reported various web-based problem-solving activities conducted in different courses, such as computer science (Huang et al., 2012), natural science (Hwang, Wu, & Chen, 2012), social studies (Hwang & Kuo, 2011), and mathematics (Rae & Samuels, 2011). Most of the studies have identified the potential of applying web-based problem-solving activities in fostering students' information-searching skills and problem-solving abilities. For instance, Yu, She, and Lee (2010) investigated the effects of different problem-solving learning modes (i.e., web-based problem-solving and traditional problem-solving approaches) on students' biology learning performance. The experimental results demonstrated that web-based problem-solving learning strategies could effectively enhance students' problem-solving ability, and such effect was long-lasting.

On the other hand, researchers have pointed out that students are likely to get lost when searching for information for solving problems on the web without proper learning supports (Ferreira & Sanos, 2009; Kauffman, Ge, Xie, & Chen, 2008; Hargittai, 2006; Li & Kirkup, 2007). Moreover, it might be difficult for many students to extract and organize the information retrieved from the web, especially for young children (Hargittai, 2006; Kuo et al., 2012; Marchionini, 1995). Thus, it is important to provide learning supports to help students extract and organize information when designing web-based learning activities.

2.2. Concept mapping

Concept mapping is a visualized knowledge organizing tool developed by Novak and Gowin (1985). In a concept map, the concepts are presented by nodes and the relationship between each pair of nodes is presented by a directional link denoting a meaningful proposition. In most concept maps, the concepts are usually arranged in the form of a hierarchy, where a higher level concept is placed near the root of the hierarchy (Novak & Gowin, 1985).

In the past decades, concept mapping has been widely applied by educators to various courses in different ways. For example, Kim and Olaciregui (2008) designed a learning activity which engaged students in accessing a concept map-based information display to review a science portfolio; Liu, Chen, and Chang (2010) employed concept maps as an aid for improving EFL (English as Foreign Language) students' English reading comprehension. Recently, Adesope and Nesbit (2013) used concept mapping as a guiding tool for narrative reading.

Most studies have shown the effectiveness of concept mapping in helping students organize and comprehend the target concepts. For example, Chiou (2008) employed concept mapping in a university accounting course and found that the approach was effective in helping the students improve their learning achievements. The study of Lim, Lee, and Grabowski (2009) further showed that engaging students in concept mapping was more helpful to them than using concept maps as an instructional tool. They also found that students with high self-regulated skills gained more benefits from learning with concept mapping strategies than those with low self-regulated skills.

Although concept mapping has been identified as an effective tool for enhancing students' learning performance and promoting knowledge retention, researchers have indicated that students might have difficulty in constructing concept maps at the beginning stage of learning, especially young children. They might feel frustrated and impatient when developing concept maps on their own, and hence their learning motivation could be affected (Chang, Sung, & Chen, 2002; Jonassen, Beissner, & Yacci, 1993; Katayama & Robinson, 2000). Therefore, several alternatives of applying concept mapping in learning activities have been proposed. For example, researchers have pointed out that using concept maps in error correction activities or fill-in-the-blank activities is superior to asking students to develop the entire concept map by themselves in terms of reducing cognitive load and enhancing learning performance (Chang, Sung, & Chen, 2001; Chang et al., 2002; Liu, 2011). Therefore, in this study, a fill-in-the-blank concept mapping strategy was integrated in the development of a web-based problem-solving environment to help students organize the information retrieved from the web.

3. Integrated concept mapping and web-based problem-solving environment

In this study, an integrated Concept Map and Web-based Problem-Solving learning Environment, CM-Quest, is developed. As shown in Fig. 1, CM-Quest consists of a web-based problem-solving module, a concept mapping module, an information-searching module, a content-analysis module, a search behavior-recording module, and a searching behavior-analyzing module. The concept mapping functionalities are integrated into the web-based problem-solving process. As suggested by Tsai, Hwang, Tsai, Hung, and Huang (2012), four progressive questions designed by teachers are used to guide students to conduct thematic research in the web-based problem-solving activities with CM-Quest. During the process of completing concept maps for the specific topics and relevant questions designed by teachers, learners are guided to select, extract, analyze and organize data retrieved from the web. The web-based problem-solving module presents and guides the students to collect data related to the given specific topic by invoking the information-searching module. The searched results are processed by the content-analysis module and presented to the students in a structured format; in the meantime, the information-searching behaviors are recorded by the search behavior-recording module and are analyzed by the searching behavior-analyzing module to generate statistical data that summarizes the information-searching behaviors of individual students.

On the other hand, the concept mapping module helps the students think about and organize the inter-concept relationships. Unlike traditional web-based problem-solving tasks that ask students to answer a series of questions, the students who learn with CM-Quest are asked to extract and organize the searched data in a concept map during the web-based problem-solving process. Both the students' online learning logs of information searching and concept map development are recorded for teachers or researchers to do further analysis.

After students log into CM-Quest, a list of selected topics relating to the curriculum is presented to them. According to the topic that the teacher wants the students to investigate, they are required to choose the corresponding social question set to conduct the web-based learning activity. For example, the topic could be related to the issues of biotechnology, ecology or environmental protection.

After selecting a topic to investigate, the students can view a series of designed questions related to the topic on the left-hand side of the screen, as shown in Fig. 2. Guided by the questions, the students search the web content by entering keywords in the web searching area. The search engine then returns the relevant webpage information in the web search and displayed area to respond to the search operations. Students can select potential web pages based on the captions and the corresponding brief intros to browse and further justify whether the contents of the pages are relevant to the questions.

When finding relevant web content, students can extract useful content from the web pages and copy it to the Question and Answer area for further summarization, as shown in Fig. 3.

In addition to using a single keyword, students can also use multiple keywords to search for relevant web pages, as shown in Fig. 4.

To help students extract and organize the searched information, a concept mapping module is provided in CM-Quest. Fig. 5 shows the interface of the concept mapping module. When students click and choose the concept mapping function after answering the questions, CM-Quest displays an incomplete concept map in which some of the concepts and relationships are blanked out. The concept map is in fact generated by collecting the question statements in the learning sheet provided by the teacher. For example, the statement "what is the relationship between Finneon and biotechnology?" will become a proposition "Finneon-( )-biotechnology" to be completed in the concept map; "Which disease curing method can biotechnology be applied in addition to producing disease-prevention-related drugs or vaccines?" will become another form of incomplete proposition "Biotechnology-be applied to-( )" and two completed propositions "Biotechnology-be applied to producing disease-prevention-related drug" and "Biotechnology-be applied to producing vaccines". Through filling in the

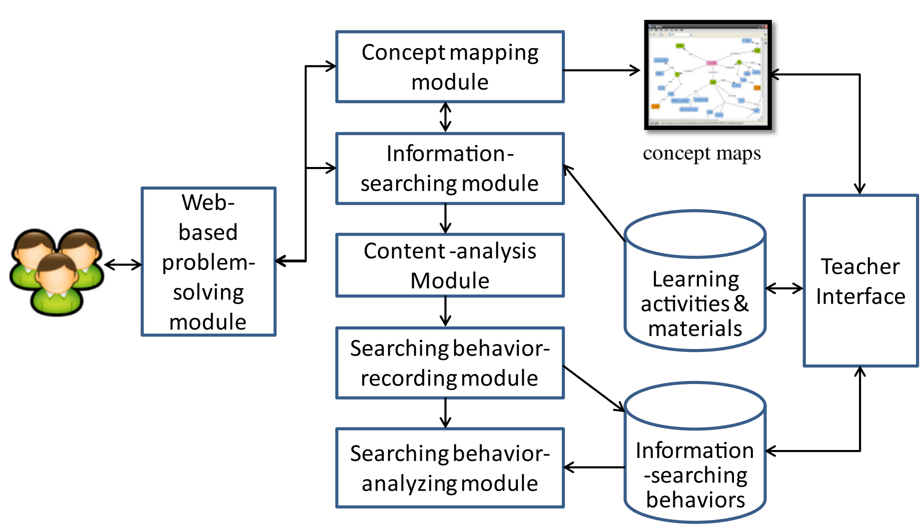

Fig. 1. The system structure of CM-Quest.

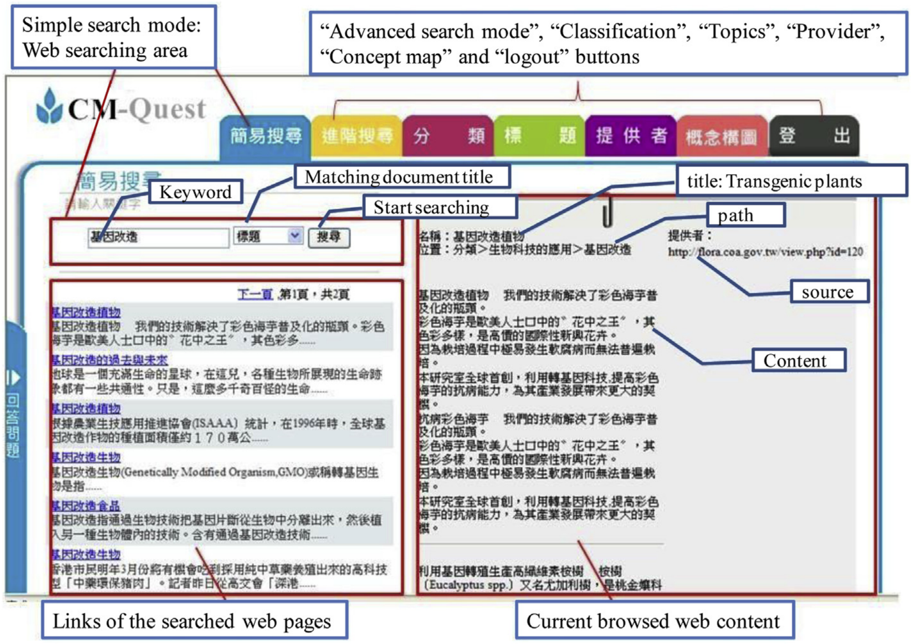

Fig. 2. Question presentation screen of CM-Quest.

concepts or relationships, students can review what they have collected and learned, and consolidate essential concepts and relationships among concepts from the acquired knowledge.

4. Method

To evaluate the effectiveness of the proposed approach, an experiment was conducted in a social studies course of an elementary school in southern Taiwan. One of the objectives of the selected course was to help students understand the knowledge and conceptions of the living environment and biotechnology, such as biotechnology and environmental protection, via using Internet resources.

4.1. Participants

The study adopted a quasi-experimental design, in which 66 sixth graders from two classes were assigned to an experimental group and a control group. The experimental group with 31 students adopted the integrated concept mapping and web-based problem-

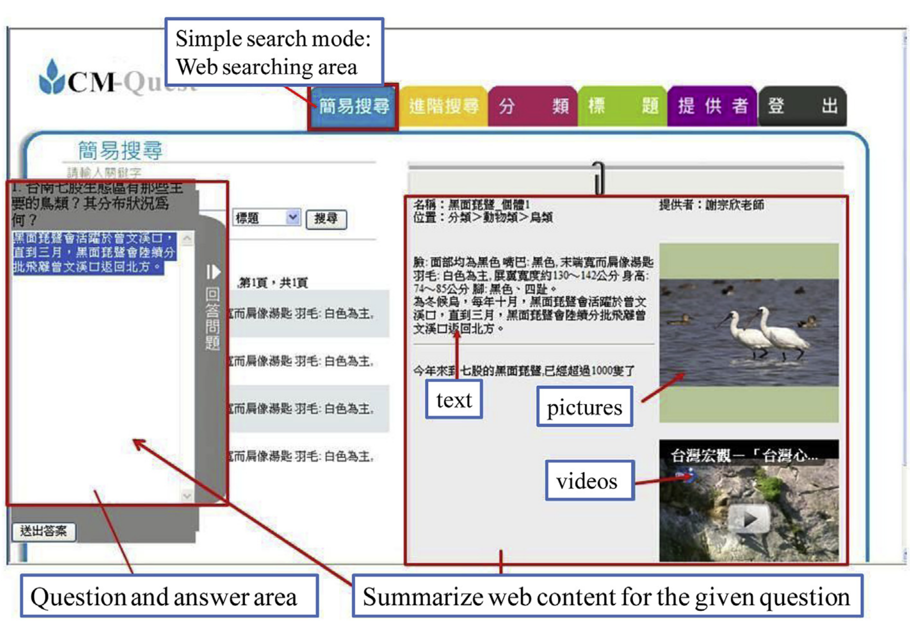

Fig. 3. A student’s summarized relevant web content in the Question and Answer area.

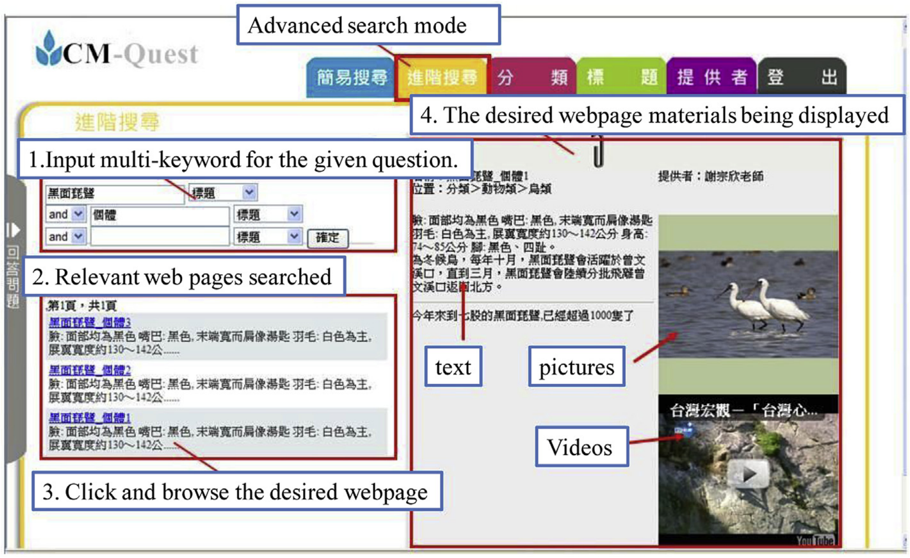

Fig. 4. Multi-keyword input for search via the advanced search mode.

solving learning approach, while the control group with 35 students learned with the conventional web-based problem-solving approach.

4.2. Instruments

The pre-test and post-test were developed by three experienced teachers who had taught the social studies course for more than six years. The pre-test aimed to evaluate the students' basic knowledge of the learning unit "knowing biotech", and was composed of ten yes-or-no items, fifteen multiple-choice items, and ten fill-in-the-blank items, with a perfect score of 100. The post-test had fifteen multiple-choice items and fifteen fill-in-the-blank items for evaluating the students' knowledge and concepts of the learning units of "Biotechnology", "Ecology" and "Environmental protection", also with a perfect score of 100.

The Questionnaire of learning perceptions was developed based on the scale proposed by Hwang, Wu, Tseng, and Huang (2011). The questionnaire consisted of three dimensions with a total of 18 items, including 5 items for "perceived ease-of-use", 6 items for "perceived usefulness" and 17 items for "learning satisfaction". The questionnaire items were scored on a Likert-type seven-point scale, where 7, 6, 5, 4, 3, 2 and 1 represented "strongly agree", "agree", "somewhat agree", "neutral", "somewhat disagree", "disagree" and "strongly disagree",

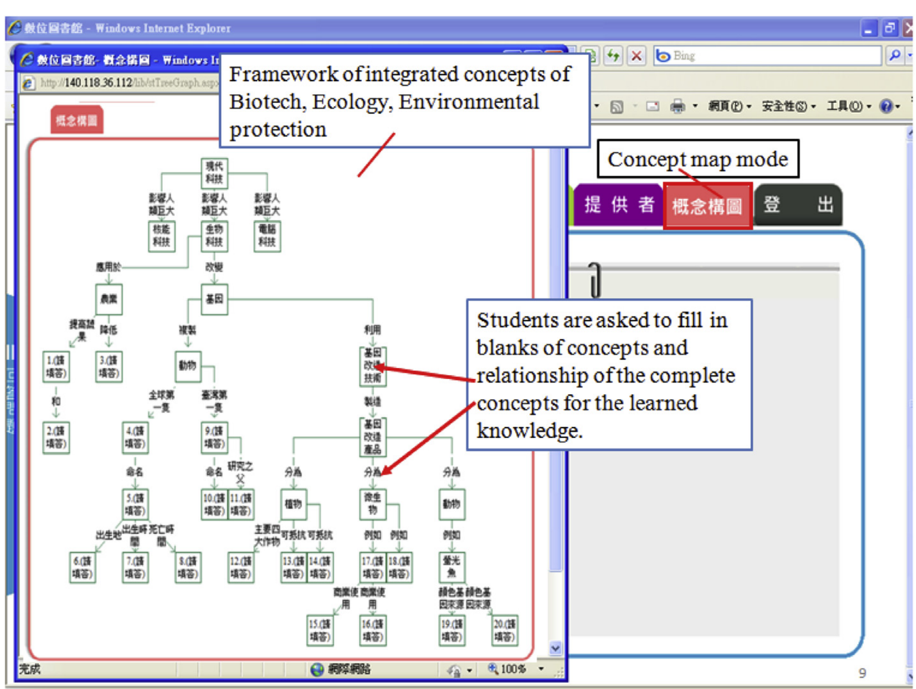

Fig. 5. The concept mapping module of CM-Quest.

respectively. The questionnaire items were discussed and revised by one professor and two elementary school teachers who had more than 10 years' experience of teaching social studies. The Cronbach's α values of the three dimensions were 0.88, 0.94 and 0.94, implying high reliability of the questionnaire.

In addition, this study adopted the cognitive load scale proposed by Hwang, Wu, Zhuang, and Huang (2013), which was revised from the scale proposed by Sweller, Van Merrienboer, and Paas (1998). The cognitive load scale investigated two aspects through 4 items: two items of "mental effort" and two items of "mental load" with a seven-point Likert-type rating scheme. Mental load is related to students' knowledge levels for comprehending the learning materials, while mental effort refers to how the learning materials are organized and presented in relation to how much effort students are required to comprehend the whole learning content. Higher ratings imply that the students had higher cognitive loads during the learning process. The Cronbach's α value of the cognitive load measure was 0.81, revealing high reliability of the scale.

4.3. Experimental procedure

Fig. 6 shows the experimental procedure of this study. Before the learning activity, the students had an 80-min lesson on the subject unit. Following that, they took the pre-test to evaluate whether the prior knowledge of the two groups could be perceived as equivalent. The teacher then gave a 40-min orientation of the learning activity to both groups of students, including the learning tasks and the interface of CM-Quest.

During the learning activities, the students in both groups employed CM-Quest to complete the learning tasks; that is, they were asked to search for information on the web to answer a series of questions related to the target issues. The major difference between the two groups was the form of answering the questions. For the control group, the students were guided to summarize what they had found in a clipboard first, and then filling in the answers to the corresponding answer areas. On the other hand, the students in the experimental group entered the searched information to the corresponding locations of an incomplete concept map, which aimed to guide them to organize what they found on the web before answering the series of questions. That is, the students in the experimental group were guided to follow the procedure of identifying the questions, searching for data, completing the concept maps, and answering the questions, while those in the control group summarized the searched data on a clipboard before submitting the answers. In the fill-in-blank concept mapping practice of this study, a total of thirty-three concepts were taken into account based on the content of the selected subject unit. Thirteen concepts and inter-concept relationships were provided as prompts for helping students organize the derived knowledge. Such kind of educational setting was designed based on the cognitive mechanism proposed by Mayer (2009) for organizing rich information. This stage lasted 240 min. All of the students needed to answer two question sets prepared by the teacher, as shown in the appendix.

After the learning experiment, the teacher provided a summative feedback to the students in both groups for helping them correct possible misconceptions. Following that, the students took part in the post-test and the post-questionnaires, including the cognitive load scale and survey of perceived ease-of-use, perceived usefulness and satisfaction with the web-based problem-solving learning approach.

5. Results and discussion

5.1. Analysis of learning performance

An Independent Sample t-test demonstrated that the pre-test scores of the two groups did not reach a significant level ($t = -0.88$, $p > 0.05$), indicating that the prior society studies knowledge of the two groups is equivalent before the learning activity. In addition, the analysis of homogeneity of within-class regression coefficient showed that the two groups had no difference with $F = 2.99$ ($p > 0.05$), implying that the homogeneity test was passed. Following that, Analysis of covariance (ANCOVA) was employed to analyze the post-test scores of the two groups by excluding the effect of the pre-test scores. Table 1 shows the ANCOVA result. The adjusted means of the experimental group and the control group are 92.70 and 87.33, respectively; moreover, the post-test scores of the two groups reached a significant level with $F = 10.13$ ($p < 0.01$) with $\eta^2 = 0.25$, showing a large effect size (Cohen, 1988).

Consequently, it is concluded that the students who learned with the integrated concept mapping and web-based problem-solving approach had significantly better learning performance than those who learned with the conventional web-based problem-solving approach.

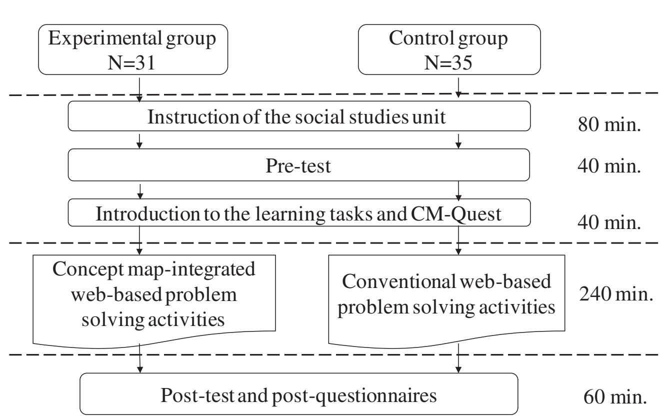

Fig. 6. Experimental procedure of the study.

Table 1
ANCOVA of the post-test for the two groups' learning performance.

Variance	Group	N	Mean	SD	Adjusted mean	SE	F	η^2
Learning performance	Experimental	31	92.16	7.92	92.70	1.22	10.13**	0.25
	Control	35	87.83	8.48	87.33	1.15		

$^{**}p < 0.01$.

5.2. Analysis of perceptions of the web-based learning system

Table 2 shows the t-test results of the "perceived ease-of-use", "perceived usefulness" and "learning satisfaction" ratings of the two groups. It is found that the ratings of the experimental group were significantly lower than those of the control group in terms of perceived ease-of-use, perceived usefulness and learning satisfaction with $t = -6.23$ ($p < 0.001$), $t = -7.16$ ($p < 0.001$) and $t = -6.25$ ($p < 0.001$), respectively. The η^2 values of the three dimensions were 0.37, 0.45 and 0.38 respectively, showing a large effect size (Cohen, 1988). That is, the students who learned with the conventional web-based problem-solving approach showed better acceptance and satisfaction than those who learned with the integrated concept mapping approach.

5.3. Analysis of cognitive load

Cognitive load refers to the load that is relevant to the executive control of working memory (Sweller, 1994). Scholars have indicated that, during learning activities, the amount of information and interactions that must be processed simultaneously can either under-load, or overload the finite amount of working memory one possesses (Paas, Renkle, & Sweller, 2004).

As listed in Table 3, the experimental group students' mental effort and mental load were significantly higher than the control group students with $t = 3.61$ ($p < 0.01$) and $t = 5.09$ ($p < 0.001$). Moreover, the overall cognitive load of the experimental group was significantly higher than that of the control group with $t = 5.41$ ($p < 0.001$). The corresponding η^2 values of the mental effort, mental load and overall cognitive load were 0.17, 0.29 and 0.31, respectively, showing large effect sizes (Cohen, 1988). That is, the students who learned with the concept mapping strategy had higher cognitive load than those who learned with the conventional approach.

Researchers have indicated that mental effort is account for when learners are asked to engage in higher-order thinking and challenging tasks (Sweller et al., 1998). On the other hand, mental load refers to the interaction among the task, subject characteristics and learning materials. It is related to the number of different types of information that learners need to deal with for comprehending new knowledge; that is, it represents the complexity of the instructional materials presented to the learners and the amount of information the learners' working memory needs to simultaneously handle (Hwang & Chang, 2011; Sweller et al., 1998). Therefore, the results imply that integrated concept mapping and web-based problem-solving approach not only engaged the students' in higher-order thinking and challenging tasks, but also increased the complexity of the learning content. This could be the reason why the students in the experimental group students showed significantly lower acceptance and learning satisfaction than those in the control group.

In the meantime, from the post-test results, it was found that the experimental groups showed significantly better learning performance than the control group, implying that the challenges of the learning tasks and the increased complexity of the learning materials were at an appropriate level within the zone of proximal development proposed by Vygotsky (1978). This finding complies with what have been reported by Hwang and Chang (2011) and Sweller et al. (1998) that cognitive load can inspire students to learn as it also increases their mental pressure in the meantime.

6. Conclusions and suggestions

In this study, an integrated concept mapping and web-based problem-solving approach was developed and an experiment was conducted to evaluate the effectiveness of the approach. The results are quite different from those of previous studies that reported positive or negative effects of concept mapping on the students' learning performance or learning motivations. It was found in this study that the students who learned with the integrated concept mapping and web-based problem-solving approach showed significantly better learning performance than those who learned with the conventional web-based problem-solving approach. Although the learning achievement test was not designed by directly transforming the concept map relationships into the test items, some of the items require the students to think from the global view of the acquired knowledge, and some require them to summarize what they had found from several related concepts. This could be the reason why concept mapping was helpful to the students in improving their learning achievement. That is, concept maps played the role of helping the students organize the searched information and their prior knowledge during the learning activity, which could further help them clarify possible misconceptions and comprehending the derived knowledge from a global view, as indicated by several researchers (Freeman & Jessup, 2004; Mayer, 2009; Walker & King, 2002). In the meantime, the experimental results also revealed that the students who learned with the concept mapping approach showed a significantly lower acceptance degree and satisfaction of

Table 2
Independent sample t-test of acceptance and learning satisfaction between the two groups.

	Group	N	Mean	SD	t	η^2
Perceived ease-of-use	Experimental	31	4.83	1.09	−6.23***	0.37
	Control	35	6.22	0.62		
Perceived usefulness	Experimental	31	5.10	0.85	−7.16***	0.45
	Control	35	6.37	0.53		
Learning satisfaction	Experimental	31	4.90	0.95	−6.25***	0.38
	Control	35	6.29	0.50		

$^{***}p < 0.001$.

Table 3
Independent Sample *t*-test of the cognitive loads between the two groups.

	Group	*N*	Mean	SD	*t*	η^2
Mental effort	Experimental	31	3.83	3.00	3.61**	0.17
	Control	35	2.49	3.02		
Mental load	Experimental	31	3.03	2.52	5.09***	0.29
	Control	35	1.66	1.86		
Cognitive load	Experimental	31	3.43	4.24	5.41***	0.31
	Control	35	2.07	3.92		

**$p < 0.01$, ***$p < 0.001$.

learning with the developed CM-Quest. That is, they gained the benefits from the concept mapping approach but showed negative perceptions of its use.

Such findings are quite different from those of previous studies that reported purely positive or negative effects of using concept mapping on students' learning performance and perceptions (Chiou, 2008; Huang et al., 2012; Kim & Olaciregui, 2008). For example, the learning activity conducted by Hwang, Wu, and Ke (2011) on an elementary school natural science course showed that concept mapping had improved the students' learning performance; in the meantime, they also reported that the students highly accepted the concept mapping approach in terms of perceived usefulness. On the other hand, the experiment conducted by Charsky and Ressler (2011) revealed that the students did not appreciate the concept mapping strategy, and hence their learning performance and learning motivations were significantly worse than those who did not learn with concept mapping in a digital game-based learning activity.

Some interesting results were also found in analyzing the cognitive loads of the two groups. When learning with the integrated concept mapping and web-based problem-solving approach, the higher mental effort and mental load revealed that the experimental group students were situated in a learning environment with more challenging tasks and more complex learning content; on the other hand, for those who learned with the conventional web-based problem-solving approach, there were less challenges and complexity in their learning tasks and materials (Hwang, Yang, & Wang, 2013).

Therefore, it is inferred that the lower acceptance and learning satisfaction responded by the experimental group was due to the higher cognitive loads caused by the challenges and complexity of concept mapping. In the meantime, the better learning performance achieved by the experimental group revealed the effectiveness of concept mapping in helping the students organize what they had found on the web for problem solving, although the students showed lower acceptance and learning satisfaction to the approach. Such a phenomenon reflects the fact that most students might not have the ability to judge what is good to them; this also implies the necessity of providing learning supports in helping students deal with complex web-based learning tasks, as indicated by Bilal and Kirby (2002) and Kuo et al. (2012).

To sum up, there are two contributions of this study. First, it is found that the integrated concept mapping approach can benefit the students in terms of improving their learning performance of web-based problem-solving activities. Second, it is found that gaining benefits from the concept mapping approach does not necessarily imply that the students appreciate or accept its use. From the findings in this study, it is concluded that concept mapping appears to be a difficult-to-accept learning support for most students although it could be useful to them. Consequently, it remains a challenging issue of how to better design an integrated concept mapping learning system to improve both the learning performance and the acceptance of using technology for better learning.

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Appendix. Illustrative examples of web-based problem-solving question sets

Question set 1: Biotechnology
Q1 In the military field, what are weapons manufactured by virtue of gene recombination technology or gene engineering called? Please enumerate two examples.
Q2 Biotechnology can be applied to which method of disease curing besides producing disease-prevention-related drugs or vaccines? Which diseases can be cured by such a method? Enumerate two examples.
Q3 (a) By virtue of biotechnology, pig manure and urine from pig farms can be converted into what for people to utilize?
(b) Taiwan University has successfully developed a double transgenic pig, which is also known as the "Enviropig". Please enumerate its differences from common pigs (at least two differences).
Q4 (a) When dealing with the problem of heavy oil polluted sea areas, biotechnology uses which substance to decompose heavy oil?
(b) Commonly used methods for treating household sewage can be classified into which categories as per degree of treatment? What is the name of the bio-treatment method used by grade-two treatment?
Q5 …
… …

Question set 2: Gene modification	
Q1	(a) Which four crops account for 99.9% of global gene-modified plants? After improvement, these crops have an enhancement in ability of resisting what? (b) Gene modification can change zebra fish into finneon because the color genes of which two creatures are implanted?
Q2	In terms of microorganisms, gene modification is used in gene amelioration engineering of which two bacteria? What are the two transgenic yeasts that have been approved for commercial use?
Q3	(a) Which animal was the first to be cloned in the world? Please indicate its name, birth place, year of birth and year of death. (b) Which animal was the first to be cloned in Taiwan? What is its name? Which scholar is responsible for this clone project?
Q4	Which benefits can biotechnology bring to agriculture? (Please enumerate two benefits at least)
Q5	…
…	…

References

Adesope, O. O., & Nesbit, J. C. (2013). Animated and static concept maps enhance learning from spoken narration. *Learning and Instruction, 27*, 1–10.

Bilal, D., & Kirby, J. (2002). Differences and similarities in information seeking: children and adults as web users. *Information Processing & Management, 38*(5), 649–670.

Boyle, J. R., & Weishaar, M. (1997). The effects of expert-generated versus student-generated cognitive organizers on the reading comprehension of students with mild disabilities. *Learning Disabilities Research & Practice, 12*, 228–235.

Chandra, V., & Watters, J. J. (2012). Re-thinking physics teaching with web-based learning. *Computers & Education, 58*(1), 631–640.

Chang, K. E., Sung, Y. T., & Chen, S. F. (2001). Learning through computer-based concept mapping with scaffolding aid. *Journal of Computer Assisted Learning, 17*(1), 21–33.

Chang, K. E., Sung, Y. T., & Chen, I. D. (2002). The effect of concept mapping to enhance text comprehension and summarization. *The Journal of Experimental Education, 71*(1), 5–23.

Charsky, D., & Ressler, W. (2011). "Games are made for fun": lessons on the effects of concept maps in the classroom use of computer games. *Computers & Education, 56*(3), 604–615.

Chen, C. H. (2010). Promoting college students' knowledge acquisition and ill-structured problem solving: Web-based integration and procedure prompts. *Computers & Education, 55*(1), 292–303.

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.-C. (2008). The effect of concept mapping on students' learning achievements and interests. *Innovations in Education and Teaching International, 45*(4), 375–387.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Dimopoulos, K., & Asimakopoulos, A. (2010). Science on the web: secondary school students' navigation patterns and preferred pages' characteristics. *Journal of Science Education and Technology, 19*(3), 246–265.

Ferreira, D. J., & Sanos, L. D. (2009). Scaffolding online discourse in collaborative ill-structured problem-solving for innovation. *Informatics in Education, 8*(2), 173–190.

Freeman, L. A., & Jessup, L. M. (2004). The power and benefits of concept mapping: measuring use, usefulness, ease of use, and satisfaction. *International Journal of Science Education, 26*(2), 151–169.

Gould, B. T. (1987). *Effect of prior knowledge and text structure instruction on the comprehension and memory for expository reading of intermediate and junior-high grade students*. Unpublished doctoral dissertation. USA: Boston University.

Hargittai, E. (2006). Hurdles to information seeking: explaining spelling and typographical mistakes in users' online search behavior. *Journal of the Association for Information Systems, 7*(1), 52–67.

Huang, H.-S., Chiou, C.-C., Chiang, H.-K., Lai, S.-H., Huang, C.-Y., & Chou, Y.-Y. (2012). Effects of multidimensional concept maps on fourth graders' learning in web-based computer course. *Computers & Education, 58*(3), 863–873.

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., & Kuo, F. R. (2011). An information-summarising instruction strategy for improving the web-based problem solving abilities of students. *Australasian Journal of Educational Technology, 27*(2), 290–306.

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.

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., Wu, C. H., Tseng, J. C. R., & Huang, I. (2011). Development of a ubiquitous learning platform based on a real-time help-seeking mechanism. *British Journal of Educational Technology, 42*(6), 992–1002.

Hwang, G. J., Wu, P. H., Zhuang, Y. Y., & Huang, Y. M. (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.

Hwang, G. J., Yang, L. H., & Wang, S. Y. (2013). A concept map-embedded educational computer game for improving students' learning performance in natural science courses. *Computers & Education, 69*(1), 121–130.

Jonassen, D. H., Beissner, K., & Yacci, M. (1993). *Structural knowledge: Techniques for representing, conveying, and acquiring structural knowledge*. Hillsdale, NJ: Lawrence Erlbaum.

Katayama, A. D., & Robinson, D. H. (2000). Getting students "partially" involved in note-taking using graphic organizers. *The Journal of Experimental Education, 68*, 119–133.

Kauffman, D. F., Ge, X., Xie, K., & Chen, H. (2008). Prompting in web-based environments: supporting self-monitoring and problem solving skills in college students. *Journal of Educational Computing Research, 38*(2), 115–137.

Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): bridging research and theory with practice. *Computers & Education, 56*(2), 403–417.

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*(4), 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.

Lefrancois, G. (1997). *Psychology for teaching*. Waldsworth: Belmont. CA.

Li, N., & Kirkup, G. (2007). Gender and cultural differences in Internet use: a study of China and the UK. *Computers & Education, 48*, 301–317.

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. (2011). A study on the use of computerized concept mapping to assist ESL learners' writing. *Computers & Education, 57*(4), 2548–2558.

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.

McCagg, E. C., & Dansereau, D. F. (1991). A convergent paradigm for examining knowledge mapping as a learning strategy. *The Journal of Educational Research, 84*(6), 317–324.

MacGregor, S. K., & Lou, Y. (2005). Web-based learning: how task scaffolding and web site design support knowledge acquisition. *Journal of Research on Technology in Education, 37*(2), 161–175.

Marchionini, G. (1995). *Information seeking in electronic environments*. New York: Cambridge University Press.

Markham, T., & Lenz, B. (2002). Ready for the world. *Educational Leadership, 59*, 76–80.

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). New York: Cambridge University Press.

Merrill, M. D., & Gibert, C. G. (2008). Effective peer interaction in problem-centered instructional strategy. *Distance Education, 29*(2), 199–207.

Novak, J. D., & Gowin, D. B. (1985). *Learning how to learn*. New York: Cambridge University Press.
Paas, F., Renkle, A., & Sweller, J. (2004). Cognitive load theory: instructional implications of the interaction between information structures and cognitive architecture. *Instructional Science, 32*, 1–8.
Rae, A., & Samuels, P. (2011). Web-based personalised system of instruction: an effective approach for diverse cohorts with virtual learning environments? *Computers & Education, 57*(4), 2423–2431.
Reese, D. J. (1988). *Effects of training in expository text structure on reading comprehension*. Unpublished doctoral dissertation. USA: University of South Florid.
Sundin, O. (2008). Negotiations on information-seeking expertise: a study of web-based tutorials for information literacy. *Journal of Documentation, 64*(1), 24–44.
Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*(4), 295–312.
Sweller, J., Van Merrienboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), 251–296.
Tsai, P. S., Hwang, G. J., Tsai, C. C., Hung, C. M., & Huang, I. (2012). An electronic library-based learning environment for supporting web-based problem-solving activities. *Educational Technology & Society, 15*(4), 252–264.
Tsai, M. J., Liang, J. C., Hou, H. T., & Tsai, C. C. (2012). University students' online information searching strategies in different search contexts. *Australasian Journal of Educational Technology, 28*(5), 881–895.
Tsai, C. W., & Shen, P. D. (2009). Applying web-enabled self-regulated learning and problem-based learning with initiation to involve low-achieving students in learning. *Computers in Human Behavior, 25*(6), 1189–1194.
Tu, Y. W., Shih, M., & Tsai, C. C. (2008). Eighth graders' web searching strategies and outcomes: the role of task types, web experiences and epistemological beliefs. *Computers & Education, 51*(3), 1142–1153.
Visser, Y. L. (2003). *The effect of problem-based and lecture-based instructional strategies on learning problem solving performance, problem solving processes, and attitudes*. Unpublished doctoral dissertation. Florida: Florida State University.
de Vries, B., van der Meij, H., & Lazonder, A. W. (2008). Supporting reflective web searching in elementary schools. *Computers in Human Behavior, 24*(3), 649–665.
Vygotsky, L. (1978). *Mind in society: The development of higher psychological process*. Cambridge, MA: Harvard University Press.
Walker, J. M. T., & King, P. H. (2002). Concept mapping as a form of student assessment and instruction. In *Proceedings of 2002 American Society for Engineering Education annual conference and exposition proceedings*. Canada.
Yu, W. F., She, H. C., & Lee, Y. M. (2010). The effects of web-based/non-web-based problem-solving instruction and high/low achievement on students' problem-solving ability and biology achievement. *Innovations in Education and Teaching International, 47*(2), 187–199.
Zhang, M., & Quintana, C. (2012). Scaffolding strategies for supporting middle school students' online inquiry processes. *Computers & Education, 58*(1), 181–196.