METACOGNITIVE SKILLS DEVELOPMENT: A WEB-BASED APPROACH IN HIGHER EDUCATION

Chun-Yi SHEN & Hsiu-Chuan LIU
Department of Educational Technology
Tamkang University, Taipei County, Taiwan
dannyshen1202@gmail.com

ABSTRACT
Although there were studies that presented the applications of metacognitive skill training, the research on web-based metacognitive skills training are few. The purpose of this study is to design a web-based learning environment and further examine the effect of the web-based training. A pretest-posttest quasi-experimental design was used in this study. Fifty-three college students were assigned into experimental and control groups. After four-week training period, the results of paired-samples t-test showed that experimental group's posttest scores were significantly higher than the pretest scores in self-plan, self-monitor, and total score, while there was no significance in the control group. In addition, students in experimental group made significantly greater gains compared to control group in self-plan. Discussion and suggestions are also provided.
Keywords: metacognitive skill, web-based training, metacognition, higher education, self-plan, self-monitor, quasi-experimental design

INTRODUCTION

With the rapid development of information diffusion technologies, students can use the Internet, multimedia, and other digital instruments to acquire new knowledge with ease. However, in face of diverse e-learning environments, how they can choose useful information and monitor their self-learning process is an issue that educators should pay attention to. From a review of 179 papers on learning achievement, Wang, Haertel, and Walberg (1990) discovered that *metacognition* ranks first among the 200 some factors affecting schooling outcomes. They pointed out that metacognitive skills is the ability to associate important messages with prior knowledge, draw inferences, and monitor or assess personal performance demonstrated in the reading process. Gagné (1985) pointed out that metacognition is a high-level cognitive process and also the ultimate goal of instructions. The goals of instructions are to deliver knowledge and also develop students' abilities to plan, monitor and even reorganize learning strategies.

According to Bransford, Brown, and Cocking (2000) metacognition and self-modify are important elements for developing effective learning and training. As Flavell (1976) pointed out metacognitive skills can be developed through instruction and learning. Among these researchers, Turner (1989) indicated that the reason why students fail to become active and independent students is sometimes they lack metacognitive awareness and strategies. Azevedo (2005) argued that students' metacognitive skills can be nurtured through proper arrangement of instructions. Taraban, Rynearson, and Kerr (2000) explored the relationship between metacognitive skills and learning outcomes among university freshmen. They investigated the metacognitive strategies commonly used by the students and which strategies were helpful for their academic performance. Their findings revealed that metacognitive strategies for reading comprehension could improve college students' academic performance.

According to Wittrock (1986), instructions that can activate students' metacognitive processes are helpful for improving students' reading comprehension. Besides, learning transfer can be facilitated if students notice their use of cognitive processes or learn to control these processes. O'Donnell, Dansereau, Hall, and Rocklin (1987) designed a training program with mixed learning strategies to investigate students' learning outcomes. The training consisted of two sections, including training of basic strategies and training of supportive strategies, which is similar to the training of metacognitive strategies. Their findings showed that students receiving the training exhibited significantly better learning outcomes. Ross and Green (2006) investigated whether college students adjust their study strategies to meet the cognitive demands of testing (e.g. the metacognitive skills). The results suggested that the college students would adjusted their study strategies so that they would be in line with the cognitive processing demands of tests and that performance was mediated by the study strategies that were used. Therefore, teachers should demand cognitive processes in the tests or homework depending on the cognitive level of instructions. Gunter, Easters, and Schwab (2003) proposed that metacognition-based instructional methods can nurture students' ability to monitor their own cognitive processes. Metacognitive support can enhance effective learning. In addition, metacognitive skills training can help students to prepare for future learning even in environments without scaffolds (Wagster, Tan, Wu, Biswas, & Schewartz, 2007). Artino (2009) and Veenman, Elshout, and Busato (1994) mentioned that offering metacognitive support in a computer-based environment can increase students' learning effectiveness.

Governor (1999) identified several instructional strategies for designing metacognitive instructions in an online learning environment. These strategies include content map, again technology, interaction button, monitoring and online help, and learning process evaluation. According to Kirsh (2005), a good visual design in the e-learning environment can reduce the cognitive load on students and make their learning of metacognitive skills more effective. In an application of metacognitive skills to instructions, Wenger & Payne (1996) proposed a metacognitive instruction system consisting of seven steps. This system allowed teachers to make use of the monitoring function of metacognition to help students learn in an efficient and meaningful manner. For instance, a graphical browser allows students to be aware of missing information and take actions to make up the loss, which is also a process of metacognition. According to Azervedo (2005), scaffolding students' self-regulated learning and metacognition during learning in a computer-based learning environment can motivate students to learn from challenging tasks. Hsiao (1997) proposed that not only learning strategies (note-taking, reflective questions, and summarization) but also metacognitive strategies (concept map, advance organizer, and instructional map) should be considered in the design of online instructions. In addition, prompts and pop-up windows should be embedded to encourage use of cognitive strategies among students.

In recent years, some online courses, learning materials, and empirical studies on development of metacognitive skills have been proposed. Most of them were focused on metacognitive skills in science or language learning domains. However, design or application of a website for improving metacognitive skills is seldom discussed (Azevedo, 2005). Additionally, Schraw, Dunkle, Bendixen, & Roedel (1995) and Schraw & Nietfeld (1998) argued that metacognitive skills are domain-general skills rather than domain-specific ones. The purpose of this study is to examine the effect of the web-based training of students' metacognitive skills in higher education.

Instructional Strategies to Improve Metacognitive Skills

Based on previous studies (Puntambekar, Stylianou, & Hubscher, 2003; Valcke, Wever, Zhu, & Deed, 2009), the authors integrated the instructional strategies for web-based metacognitive skills training into four main categories, including advance organizer, concept map, scaffolding, and problem-solving strategies. The concept of advance organizer originates from Meaningful Learning Theory (Ausubel, Stager, & Gaite, 1969), which proposes that when learning new knowledge, students will first associate new knowledge with existing superordinate concepts and attempt to incorporate the new knowledge into their cognitive structure to make the new knowledge a part of their acquired knowledge. Hence, superordinate concepts have the function of assimilating new concepts. Students can learn more effectively if the main concepts of the new knowledge to be acquired can be extracted first and then integrated with their prerequisite knowledge. This process of integrating new knowledge with existing knowledge is called advance organizer.

Meaningful learning takes place only when students' prerequisite knowledge is related to the learning. In other words, students have meaningful learning only if the instructions comply with their competencies and experiences. For teachers, investigating students' prerequisite knowledge first and designing materials and offering instructions based on students' prerequisite knowledge later are important tasks. The difference between meaningful learning and rote learning lies in the fact that rote learning only provides students with isolated messages and does not relate them to the concepts already existing in one's cognitive structure. Hence, messages offered through rote learning will be easily forgotten and cannot be deeply rooted in students' cognitive system. In fact, students are already equipped with the ability to associate new messages with existing concepts. When they receive new messages, their cognitive structure provides a ground for new messages to be rooted. The cognitive structure accumulates new messages based on previously acquired messages. The amount of new messages that it can acquire depends on how much it has. In addition, Chiquito (1995) suggested that instructors should use advance organizers in practical instructions. Instructors should understand students' prerequisite knowledge first and use it as a basis to present new learning materials in a systematic and clear manner, which can help students integrate the new learning materials with their prerequisite knowledge and be prepared for introduction of new knowledge.

A concept map is an effective metacognitive strategy or teaching instrument, mainly because connecting concepts in a hierarchical structure facilitates understanding, clarification, and rectification of concepts (Edmondson & Smith, 1996). Doomekamp (2001) stated that students' metacognitive skills can be developed using tools that can effectively visualize the problem-solving process, such as concept maps. Kinchin and Hay (2005) mentioned that through drawing concept maps, students can organize, reorganize, and assimilate conceptual knowledge they learn, and their learning will become meaningful if new concepts are connected to existing ones.

Clariana and Wallace (2007) proposed that concept maps can be used as a metacognitive strategy or a heuristic instructional instrument. By drawing concept maps, students can identify and contemplate the relationship between concepts and further form a hierarchical framework of these concepts. Therefore, concept maps have been viewed as one of the effective metacognitive tools for promoting meaningful learning. Garrett, Alman, Gardner, and Born (2007) indicated that visualizing lecture information and interpreting diagrams are important metacognitive skills in learning transfer and can be a basis for developing more effective guidelines on evaluating metacognitive skills.

Scaffolding can increase students' metacognitive knowledge and skills. Providing learning strategies, procedural questions, and structured designs of activities which encompass underlining, note-taking, prompts, inquiries, exercises, checklists or making to-do lists, can scaffold students' self-awareness and self-modify system (Brophy, 1992; Hertzog & Hultsch, 2000; Kirsh, 2005; Schoenfeld, 1992). Azevedo (2005) argued that effective scaffolds should be able to (a) change students' mental models, (b) allow students to acquire declarative knowledge between the pretest and the pretest, and (c) record students' self-regulated learning processes. The scaffolds that support self-regulated learning include planning (setting up sub-goals and activate prior knowledge); monitoring (personal cognitive system, current understanding, the hypermedia system and its content, and motivation of learning tasks), effective and ineffective learning strategies, and methods for solving task difficulties and demand problems. Schoenfeld (1992) suggested that prompting students with procedural questions may help foster greater self-awareness and metacognitive skills. Whipp and Chiarelli (2004) also suggested that proper self-monitor and tracking are important characteristics of computer-based learning.

Kirsh (2005) argued that metacognitive tools provide students with some strategies that can make them more active information processors or allow them to monitor and control their learning activities. He mentioned two effective metacognitive training methods that can improve students' time management using external resources. First, designers can add reminders, questions and exercises, checklists, and a host of other artifacts to improve students' tracking of their time and progress. Second, designers can add external aids for students to scan all the questions in advance, select the easiest and most valuable ones to do first, and do questions that may be more time-consuming after they have completed all the prioritized questions.

Metacognitive processes such as self-modify and self-monitor require one's abilities to develop ideas, affections, and improve problem-solving (Treffinger, Selby, & Isaksen, 2008). The findings suggested that students' performance in solving academic problems can be effectively improved after receiving metacognitive instructions. It has also been empirically confirmed that integrating metacognitive skills to problem-solving instructions is feasible and effective (Mevarech & Mramarski, 2003). Besides, individuals with better problem-solving abilities were characterized by better metacognitive performance (Pan, 1993). Kramarski and Mevarech (2003) used the metacognitive training method called IMPROVE to develop students' abilities to raise metacognitive questions, including questions about the nature of a problem, strategies for solving the problem, construction of prior knowledge, and correlation between the prior knowledge and new knowledge. Their participants exhibited significantly better mathematics reasoning and reading comprehension skills after receiving the training.

RESEARCH METHOD

Participants

A pretest-posttest quasi-experimental design was used in this study. Participants in this study were fifty-three college students from two classes in a private large-scale university in northern Taiwan. One class with twenty-nine students was assigned to the experimental group, and another class with twenty-four students was assigned to the control group. The experimental group has six males and twenty-three females aged from 20 to 22 years old, while the control group has five males and nineteen females aged from 19 to 22 years old.

Design of Web-Based Training

The website developed by the authors had four sections, which were (a) self-plan, (b) self-monitor, (c) self-modify, and (d) self-evaluate. Table 1 shows the learning objectives of the four sections.

Table 1. Learning objectives of the four sections

Section	Learning Objective
Self-plan	1. Understand the concept of self-plan 2. Make learning plans
Self-monitor	1. Understand the concept of self- monitor 2. Identify the concepts learners do not understand 3. Find the difficulties of learners' learning
Self-modify	1. Understand the concept of self- modify 2. Find the reasons of learners' learning difficulties

	3. Modify learning strategies based on the findings
Self-evaluate	1. Understand the concept of self-evaluate 2. Find the differences among learners' performance 3. Evaluate learners' performance

According to the previous studies, advance organizers are effective metacognitive tools that can help students gain more structured understanding of new knowledge based on their prior experiences. The case study method which has also been proven effective for metacognitive instructions was adopted in the design of our website. It was integrated into instructions of each section, along with the multimedia content.

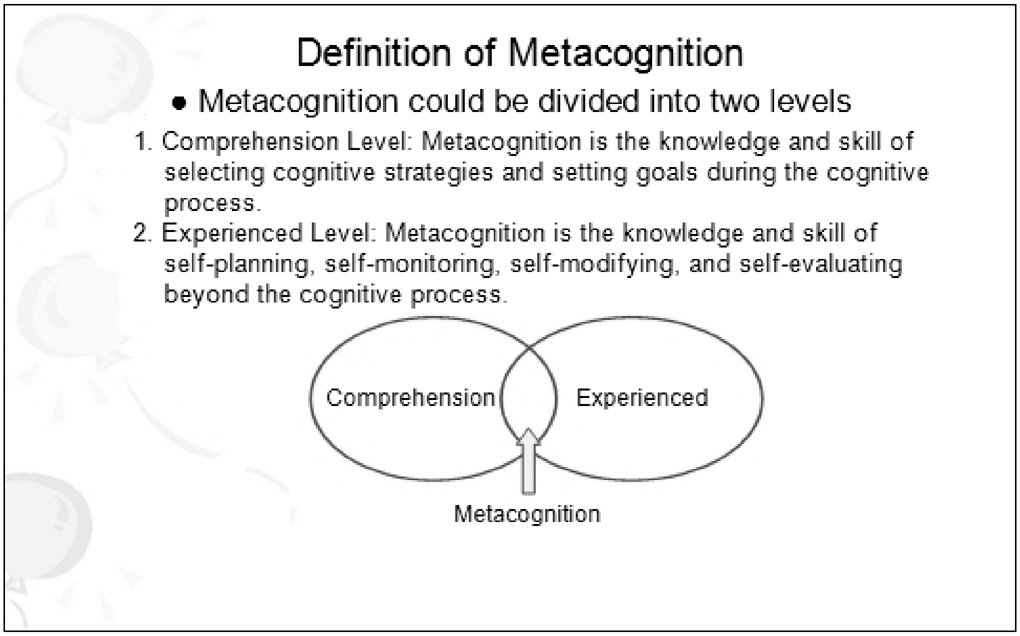

Figure 1. Sample screen of advance organizer of self-plan section

Therefore, each section started with the advance organizers, and the themes of the instructions surrounded issues about metacognition, including definition of metacognition, displaying components of metacognitive skills using hierarchical graphics, explanation of each component, and presentation of the learning goals for each section. After advance organizer, students were asked to read and watch a video-based case study followed by an exercise. Table 2 shows the design of the learning activities.

Table 2. Design of the learning activities

Section	advance organizer	case study with multimedia demonstration	exercise
Self-plan	1.definition 2.concept map 3.multimedia explanation 4.learning objectives	1.Case: There is a college student with poor time management skill. The learners are asked to use the technique of concept map to help the student. 2.Multimedia demonstration of drawing concept map using software	Please use the hierarchical concept map to make a study plan for your first job after graduation
Self-monitor	1. definition 2.concept map 3.multimedia explanation 4.learning objectives	1.Case: In order to understand a reading, the learners are asked to use the techniques of summary and note-taking to monitor the process of comprehension. 2.Multimedia demonstration of making highlights, making summary, giving a title, and using the checklist of self-monitor	Please write the questions of comprehensive based on the previous reading as a teacher
Self-modify	1. definition	1.Case: In order to improve a student's	Please use the question form of

	2.concept map 3.multimedia explanation 4.learning objectives	performance, learners are asked to use the question form of self-modify to change her thinking strategies. 2.Multimedia demonstration of using the question form of self-modify and creative problem-solving model to find the reasons and make modifications.	self-modify and creative problem-solving model to help a college student who chose the wrong major
Self-evaluate	1. definition 2.concept map 3.multimedia explanation 4.learning objectives	1.Case: In order to help a college student to evaluate his communication skill in workplace, learners are asked to use the checklist of self- evaluate. 2.Multimedia demonstration of using the checklist of self- evaluate.	Please use the checklist of self-evaluate to evaluate your attraction among your friends.

For instance, the first section began with demonstration of a concept map titled *A day of an undergraduate, Chih-chun* (Figure 2).

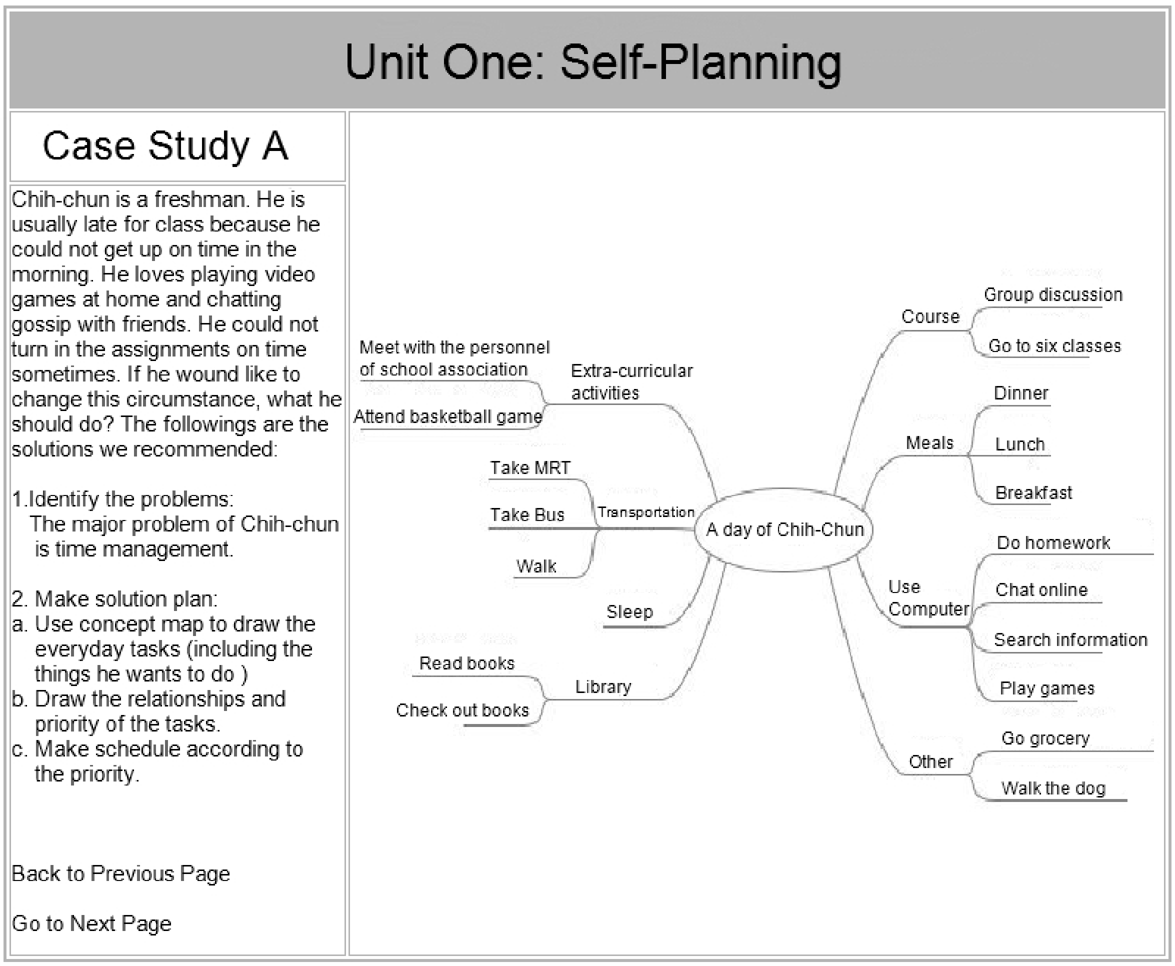

Figure 2. Sample screen of case study of self-plan section

In the exercise, students were prompted to use concept map tools to draw a time allocation table for themselves (see figure 3). This exercise was intended to guide students to organize their reflective processes and display their understanding of the learning content.

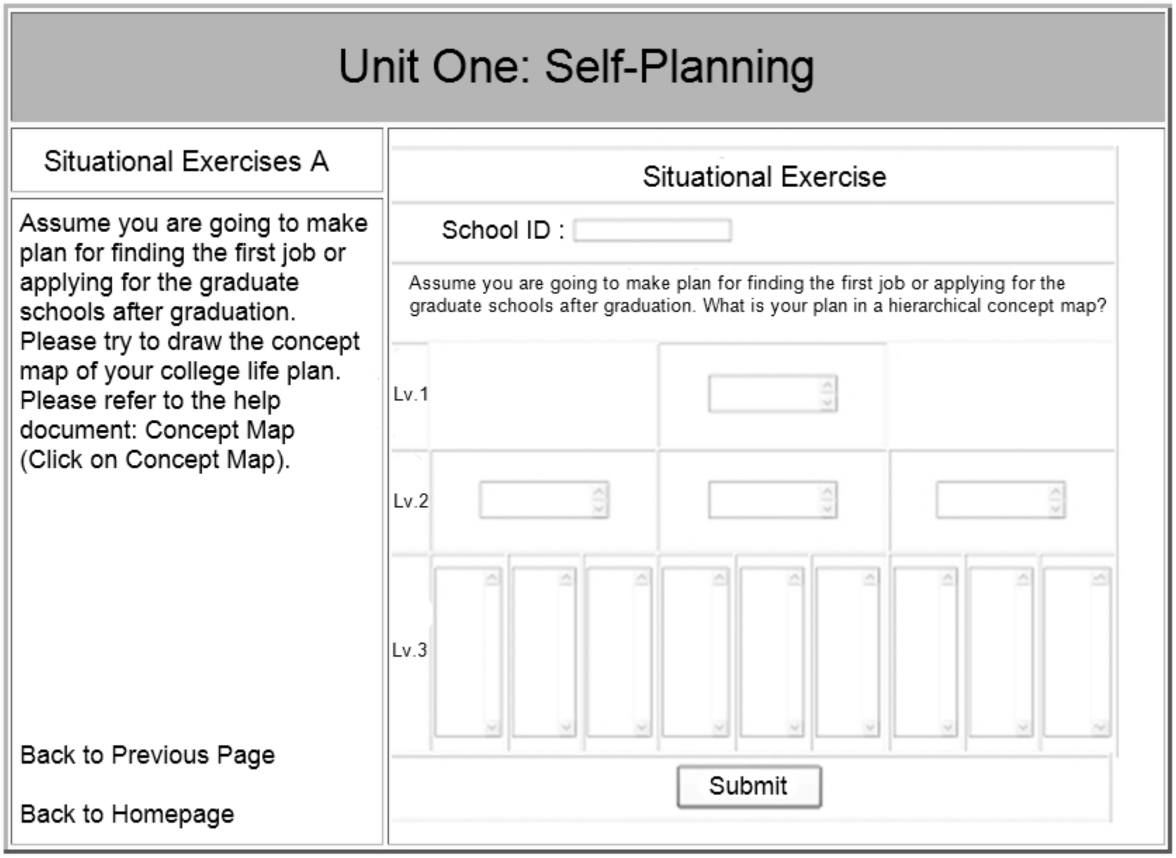

Figure 3. Sample screen of exercise of self-plan section

In the second section, the students were asked to read a descriptive article about how to use comprehension-monitoring skills in learning and design a short-essay test of comprehension of the previous article as exercise. The third section involved application of problem-solving strategies. Students were required to follow the six problem-solving steps in Creative Problem-Solving Model to solve given problems. The fourth section presented a case of assessing one's interpersonal communication skills. Application of metacognitive scaffolding tools, including summarization and self-evaluate, were embedded in each section. This design was intended to identify a correction direction for learning metacognitive skills and key features of metacognitive skills to increase students' active participation in the learning processes.

Instruments

The Metacognitive Skills Evaluation Questionnaire (MSEQ) used in this study was developed based on Metacognition Rating Scale for General Biology (MRSGB). The Metacognition Rating Scale for General Biology developed by Wang, Wang, and Wang (2004) consisted of four subscales, including self-plan, self-monitor, self-modify, and self-evaluate. The scale was tested through a series of tests, including expert validity test and construct validity test, before it was used in the formal test. MSEQ contains 6-point Likert scale with 45 items divided into four dimensions: self-plan (e.g. *When I am learning, I usually set the goals first, and then decide what should be learned, and learn to what extent*), self-monitor (e.g. *When I am learning, I usually know whether there is any thing I do not understand yet.*), self-modify (e.g. *I can usually find a better way of learning to improve my learning.*), and self-evaluate (e.g. *When I know my answer is wrong, I usually try to find out the reason.*). The overall Cronbach's alpha of MSEQ was .92. Table 1 presents the content and the Cronbach's alpha for each dimension of MSEQ.

Table 1. The Construct of MSEQ

Dimension	Definition	alpha
Self-plan (12 items)	Students discover or realize the key points in the learning materials, set learning goals for themselves, and understand when and how to use learning strategies in the cognitive processes.	.80
Self-monitor (14 items)	Students are able to identify which concepts they understand and which they do not or the difficulties they have encountered in learning.	.82
Self-modify (9 items)	Students are able to identify their learning problems, such as inefficiency of their learning methods or low learning performance, and causes of the problems, and then use better learning methods to improve their learning.	.83
Self-evaluate (10 items)	Students can evaluate their learning performance in an objective manner and understand the difference between them and others.	.84

Procedure

From the beginning of the semester, students from two classes were assigned into the experimental group and the control group. Before implementation of online instructions, students in both groups were given the MSEQ as pretests. The questionnaire was conducted online. Later, students in the experimental group were given web-based metacognitive skills training in a computer lab once a week. On the other hand, students in the control group were not given any metacognitive skills training. To avoid waste of time due to participants' unfamiliarity with the interface or the functions of the website, participants were given instructions on how to operate the website before the experiment. Each section consisted of introduction, learning by case, exercises by case, and test and was expected to be completed in one hour. The websites had four sections (one section for each dimension), while the materials were accessible by students after class from their home. After the fourth section ended, students in both groups were asked to answer the MSEQ again as the posttest. For analysis, paired-samples t-test and analysis of covariance (ANCOVA) with the pretest as the covariate were used in this study. The data were analyzed by dimensions, to obtain analysis of specific changes in each dimension that occurred as the effect of metacognitive skills web-based training.

Findings

The results of paired-samples t-test showed that experimental group's posttest scores were significantly higher than the pretest scores in self-plan (t=4.257, p<.001), self-monitor (t=3.364, p<.01), and total score (t=3.753, p<.001), while there was no significance in the control group. Table 2 showed the means, standard deviation, t value, and Significance of each dimensions of the two groups.

Table 2. Results of Descriptive Statistics and Pair-Samples T Test

Dimension	Experimental group (n=29)					Control group (n=24)				
	Pre	Post	Change	t	p	Pre	Post	Change	t	p
Self-plan	3.161	3.509	0.348	4.257	<.001	3.170	3.174	0.003	0.026	0.980
SD	0.575	0.587				0.660	0.595			
Self-monitor	3.180	3.406	0.227	3.364	<.01	3.307	3.455	0.149	1.120	0.274
SD	0.569	0.616				0.670	0.477			
Self-modify	3.621	3.778	0.157	1.779	0.086	3.569	3.704	0.134	1.301	0.206
SD	0.617	0.660				0.585	0.578			
self-evaluate	3.559	3.617	0.059	0.717	0.479	3.567	3.650	0.083	0.625	0.521
SD	0.638	0.645				0.600	0.713			
Total score	3.380	3.578	0.198	3.753	<.001	3.403	3.496	0.092	0.952	0.351
SD	0.516	0.577				0.548	0.503			

To examine the effect of web-based metacognitive skill training, ANCOVA was used after pair-samples t test. The results of ANCOVA showed that students in experimental group made significantly greater gains compared to control group in self-plan (F (1, 50) = 6.4920, p < 0.05). However, there is no significant differences in self-monitor (F (1, 50) = 0.033, p = 0.856), self-modify (F (1, 50) = 0.089, p =0.767), self-evaluate (F (1, 50) = 0.037, p = 0.849), and total score (F (1, 50) = 0.976, p = 0.328).

DISCUSSION AND CONCLUSION

Although, the results of ANCOVA revealed that students in the experimental group had improved their self-plan skills only after receiving web-based training compared to the control group, we were excited to find that there were significant differences between pretest and posttest in self-plan, self-monitor, and total score in experimental groups while there was no significant difference in control group. In addition, though there was no significant difference between pretests and posttests in self-modify and self-evaluate in the experimental group, the scores of posttests were higher than the pretests. Moreover, the pretest-posttest differences in self-modify between two groups was not significant but close to the level of significance (p=.086). This analysis explained that the web-based metacognitive skill training indeed helped students enhance their self-plan and self-monitor skills but could not significantly improve their self-modify and self-evaluate skills. From the results above, we made the following inferences.

First, visualizing strategies, such as concept map and hierarchical mapping, were properly applied in the learning section of self-plan, so participants in the experimental group could exhibit a significant improvement in this metacognitive component. Compared with other sections, this section had three distinct characteristics:

1. Structured—the structure of the knowledge to be delivered was analyzed in advance, and information was displayed with the aid of multimedia to enhance students' comprehension and memory of the learning materials.
2. Procedural—Concept maps and hierarchical maps were utilized to display how to use metacognitive strategies step by step. These metacognitive tools could effectively make up the gap between imagination and comprehension.
3. Visualized—complicated concepts could be clearly expressed through use of visualizing tools. In other words, visualization of ideas could effectively increase the retention of the ideas in students' memory.

Moreover, the learning materials provided in our website were not completely conformed to the principles for designing metacognitive instructions, thus resulting in insignificant improvement of the students' metacognitive skills in some aspects. The inconformity existed in the following aspects,

First, training of comprehension monitoring was insufficient. According to Kirsh (2005), though metacognitive tools could help students monitor their learning activities, learning activities should be designed to be more structured and tangible. For instance, in the training of metacognitive skills for reading comprehension, students should be asked to summarize the article, explain key ideas, construct the context, and analyze the core meaning of the article after reading it. In our self-monitor section, we also asked students to read an article and offered metacognitive tools, such as highlighting, making topic sentences, and summarization. However, we did not let students interpret the key ideas and engage in more in-depth reflective activities, such as drawing a concept map about the ideas they have comprehended, which could allow them to have a better control over their comprehension of the article. Therefore, for better effectiveness in learning self-monitor, we suggest that computer graphics can be more sufficiently exploited in the design of an e-learning website to provide more in-depth reflective training.

Second, social functions were not sufficiently embedded in our website. According to Osman and Hannafin (1992), transfer of metacognitive skills relies on application of social interactions. Manning and Payne (1996) have also mentioned that interactive teaching processes help students improve their self-regulated abilities through free dialogues. We did not let students discuss the learning content with peers or instructors directly. Therefore, we suggest that dialogues and interactions between students or between students and instructors should be considered and emphasized in the design of an e-learning website.

Third, the instructional design regarding self-awareness was insufficient. Based on the self-modify processes (self-observation, self-judgment, and self-reaction) proposed by Schunk (1998) further argued that an individual should be able to observe and understand his or her performance, judge the performance according to personal criteria, and respond to the judgment. After accomplishing one task, one will evaluate his or her performance and then acclaim or criticize the performance on his or her mind. Below is a brief explanation of the three self-modify processes:

The learning activities involved in the self-evaluate section were intended to guide students to develop self-evaluate skills necessary for a job interview. These skills included how to determine if one has correct understanding of the interviewer's requirement of interpersonal communication skills and how to set up objective criteria for assessing his or her own attractiveness. Due to the limitation of time allowed for each section, we were unable to integrate training on self-judgment of performance and improvement of self-reaction into the instructions. Therefore, for better effectiveness of self-evaluate, we suggest that cognitive processes including self-observation, self-judgment, and self-reaction should be emphasized in the design of a web-based training.

IMPLICATIONS AND SUGGESTIONS

Based on the above findings, we proposed the following suggestions. First, materials about metacognitive skills should be properly utilized as an instructional aid. Our results suggested that integrating materials about meanings of metacognition and usage of metacognitive strategies into online instructions can effectively increase the effectiveness of the instructions. Proper integration of these materials can not only promote students' metacognitive skills but also provide metacognitive strategies that they can use for learning in other domains. Second, in a web-based environment, instructors should pay attention to students' metacognitive competence and improve their metacognitive competence. Internet provides an environment for self-learning, and metacognitive skills helps students construct knowledge and monitor, regulate, and assess their learning in the cognitive processes. In the promotion of web-based self-learning, instructors should understand that in order to enhance the effectiveness of self-learning, students must be prepared with the basic skills for self-learning, and metacognitive skills offers the core skills required by self-learning. Third, in the design of web-based training, instructors should follow the principles for designing metacognitive instructions and integrate metacognitive strategies to enhance students' self-learning abilities. Web-based training should be designed according to the principles for designing metacognitive instructions and with integration of metacognitive strategies, such as scaffolding, problem-solving, inquiry, summarization, concept map, and visualization, can enhance students' metacognitive skills, which is the basic competence required by self-learning. Hence, instructors are advised to refer to the principles in the design of e-learning materials and appropriately integrate metacognitive strategies to promote students' self-learning abilities.

For the future studies, the principles for designing online metacognitive instructions should be further investigated. In this paper, we reviewed previous literature to induce a series of instructional strategies for designing online metacognitive instructions and applied a portion of the principles to the design of our e-learning materials. However, subject to research objectives and scope, we did not further investigate applications of these principles. Therefore, future researchers can revisit these principles from either a qualitative or a quantitative perspective to explore when and how to use these principles, the advantages and limitations of each principle, and whether there is any exception to the application of these principles.

To increase students' performance in self-monitor, self-modify, and self-evaluate, more training on structural reflection, social interaction, and self-awareness should be involved in e-learning materials. Due to insufficient time, we were unable to reinforce students' learning in self-monitor, self-modify, and self-evaluate aspects. We suggested that future researchers integrate activities involving structural reflection, interactions between students or between students and instructors, and development of self-awareness into e-learning materials.

In addition, memory retention and learning transfer should be emphasized in the design of e-learning materials. Our results showed that effectiveness of metacognitive instructions may be affected by retention of meta-memory and learning transfer. In our website, although we used context-based tests to increase students' meta-memory, we did not evaluate the effect of learning transfer and allow students to review the learning content due to limitation of time. Hence, we suggested that future researchers allocate time for students to review the learning content, so that more memory can be retained. Besides, future researchers can also develop an online test with a set of criteria for evaluating transfer of learning from training materials.

Future studies on application of web-based metacognitive training should extend to other learning domains or cover a broader range of research subjects: We developed a website of metacognitive skills instructions for college students to investigate its effects on learning of metacognitive skills. Our findings confirmed that our application was effective in some aspects. Previous literature has pointed out that metacognitive skills has significant benefits for students in many areas of learning, including mathematics, reading, problem-solving, self-modify, crucial thinking, and creative thinking (Caverly & MacDonald, 2000). Instructors can use Internet as a metacognitive tool to effectively guide students to engage in learning self-analysis, self-judgment, and self-modify (Wijekumar & Jonassen, 2007). Therefore, we suggested that future researcher focus on other learning domains or widen the range of research subjects to explore the effects of integrating metacognitive instructions into e-learning on students' learning in other domains or on students in different age groups to produce more empirical results.

REFERENCES

Artino, A. R. (2009). Online learning: Are subjective perceptions of instructional context related to academic success? *The Internet and Higher Education, 12*(3-4), 117-125.

Ausubel, D.P. , Stager, M., & Gaite, A.J. (1969). Proactive effects in meaningful verbal learning and retention. *Journal of Educational Psychology, 60*(1), 59-64.

Azevedo, R. (2005). Computer Environments as metacognitive tools for enhancing learning. *Educational*

Psychologist, 40(4), 193-197.
Bransford, J., Brown, A., & Cocking, R. (2000). *How People Learn: Brain, Mind, and Experience & School*. Washington, DC: National Academy Press.
Brophy, J. (1992). Probing the subtleties of subject-matter teaching. *Educational Leadership*, 4-8.
Caverly, D. C. & MacDonald, L. (2000). Techtalk: Teaching writing online. *Journal of Developmental Education, 24*, 42-43.
Chiquito, A. (1995). Metacognitive learning techniques in the user interface: advance organizers and captioning. *Computers and Humanities, 28*, 211-223.
Clariana, R.B. & Wallace, P. (2007). A computer-based approach for deriving and measuring individual and team knowledge structure from essay questions. *Journal of Educational Computing Research, 37*(3), 211-227.
Doomekamp, B. G. (2001). Designing teaching materials for learning problem solving in technology education. *Research in Science and Technological Education*, *19*(1), 25-38.
Edmondson, K. M. & Smith, D. F. (1996). *Concept map to facilitate veterinary students' understanding of fluid and electrolyte disorders*. Paper presented at Annual Meeting of the American Education Research Association. New York, NY.
Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L.B. Resnick (Ed.). *The nature of intelligence* (pp.231-235). Hillsdale, NJ: Lawrence Erlbaum Associations.
Gagne', R. M.(1985). *The conditions of learning and theory of instruction*. New York: College Publishing.
Governor, D. (1999). Cognitive Styles and Metacognition in Web-based Instruction. Retrieved April 20, 2008, from http:// www.pcola.gulf.net/~dulci/thesis.html.
Gunter, M. A., Estes, T. H., & Schwab, J. (2003). Instruction: *A models approach* (4th ed). Boston: Allyn & Bacon.
Hertzog, C., & Hultsch, D. F. (2000). Metacognition in adulthood and old age (pp. 417-466). In T. Salthouse & F. I. M. Craik (Eds.) *Handbook of Aging and Cognition II*. Mahwah, NJ: Erlbaum.
Hollingworth, R. D., & McLoughlin, C. (2001). Developing science students' metacognitive problem solving skills online. *Australian Journal of Educational Technology*, *17*(1), 50-63.
Hsiao, Y. (1997). *The effects of cognitive styles and learning strategies in a hypermedia environment: A review of literature.* Retrieved from April 20, 2008, from http:// www.edb.utexas.edu/mmresearch/Students97/Hsiao/.
Kirsh, D. (2005). *Metacognition, Distributed Cognition and Visual Design, in Cognition, Education, and Communication Technology* (eds.). Mahwal, NJ: L. Erlbaum Associates.
Kinchin, I. & Hay, D. (2005). Using concepts maps to optimize the compostion of collaborative students groups: A pilot study. *Journal of Advanced Nursing*, *51*(2), 182-187.
Kramarski, B. & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: Effects of cooperative learning and metacognitive training. *American Educational Research Journal*, *40*(1), 281-282.
Manning, B. H. & Payne, B. D. (1996). *Self-Talk for Teachers and Students.* Needham Heights, MA: Allyn & Bacon.
Mevarech, Z. R., & Kramarski, B. (2003). The effects of metacognitive training versus worked-out examples on students mathematical reasoning. *British Journal of Educational Psychology*, *73*, 449-471.
O'Donnell, A. M., Dansereau, D. F., Hall, R. H., & Rocklin, T. R. (1987). Cognitive, social/affective, and metacognitive outcomes of scripted cooperative learning. *Journal of Educational Psychology, 79*(4), 431-437.
Osman, M. E., & Hannafin, M. J. (1992). Metacognition Research and Theory: Analysis and Implications for Instructional Design. *Educational Technology Research and Development*, *40*(2), 83-99.
Pan, H. M. (1993). A study of metacognitive behavior in mathematical problem solving of older elementary school students in Taiwan. Doctoral dissertation, Nothern Colorado University.
Puntambekar, S. ,Stylianou, A., & Hubscher, R. (2003). Improving navigation and learning in hypertext environments with navigable concept maps. *Human-Computer Interaction*, *18*, 395-428.
Ross, M. E., & Green, S. B. (2006). College students' study strategies as a function of testing: An investigation into metacognitive self-regulation. *Innovative Higher Education*, *30*(5).
Schoenfeld, A. H. (1992). Learning to think mathematically: problem solving, metacognition, and sense making in mathematics. In A. Grouws(Ed.). *Handbook of Research on Mathematics Teaching and Learning*. Macmillan Publishing Company, Maxwell Macmillan Canada.
Schraw, G., Dunkle, M.E., Bendixen, L.D., & Roedel, T.D. (1995). Does a general monitoring skill exist? *Journal of Educational Psychology, 87*(3), 433-444.
Schraw, G. & Nietfeld, J. (1998). A Further Test of the General Monitoring Skill Hypothesis. *Journal of Educational Psychology, 90*(2), 236-248.
Schunk, D. H. (1998). *Teaching elementary students to self-regulate practice of mathematical skills with modeling*. In D. H. Schunk & B. J. Zimmerman (eds.), Self-regulated learning: from teaching to

self-reflective. New York: Guilford Press.
Taraban, R., Rynerason, K., & Kerr, M. S. (2000). Metacognition and freshman academic performance. *Journal of Developmental Education, 24*(1), 12-24.
Treffinger, D.J., Selby, E.C. & Isaksen, S.G. (2008). Understanding individual problem-solving style: A key to learning and applying creative problem solving. *Learning and Individual Differences, 18*(4), 390-401.
Turner, G. Y.(1989). Promoting learning autonomy: helping students become independent learners. *Reading Horizons*, *29*(2), 110-116.
Valcke, M., Wever, B. D., Zhu, C., & Deed, C. (2009). Supporting active cognitive processing in collaborative groups: The potential of Bloom's taxonomy as a labeling tool. *The Internet and Higher Education, 12*(3-4), 165-172.
Veenman, M..J., Elshout, J.J., & Busato, V.V. (1994). Metacognitive mediation in learning with computer-based simulations. *Computers in Human Behavior, 10*(1), s 93-106.
Wang, M. C., Haertel, G. D., & Walberg, H. J. (1990). What influences learning? A content analysis of review literature. *Journal of Educational Research, 84*. 30-43.
Wang, T.H., Wang, W.L., & Wang, K.H. (2004). A case study of web-based instruction (WBI): The effectiveness of using frontpage feedback system (FFS) as metacognition strategy for freshmen biology teaching. *International Journal on E-Learning, 3*(2), 18-27.
Wagster, J., Tan, J., Wu, Y.,Biswas, G. & Schwartz, D. (2007). *Do Learning by Teaching Environments with Metacognitive Support Help Students Develop Better Learning Behaviors?* The twenty-ninth Annual Meeting of the Cognitive Science Society, Nashville, Tennessee.
Wenger, M. J., & Payne, D. G. (1996). Comprehension and retention of nonlinear text: considerations of working memory and material-appropriate processing. *American Journal of Psychology*, *10*9(1), 93-130.
Whipp, J. L. & Chiarelli, S. (2004). Self-regulation in a web-based course: A case study. *Educational Technology Research & Development*, *52*(4), 5-22.
Wijekumar, K.K. & Jonassen, D.H. (2007). The role of computer tools in experts' solving ill-structured problems. *Computers in Human Behavior, 2*(1), 664-704.
Wittrock, M. C. (1986). *Handbook of Research on Teaching (3rd)*. N.Y.: Simon & Schuster Macmillan.