行政院國家科學委員會補助專題研究計畫成果報告

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※**知識建構：以網路相互支援設計科學活動為基礎**(2/3)※
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計畫類別：□個別型計畫　　o 整合型計畫

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執行期間：　88 年　8 月　1 日至　89 年　7 月　31 日

計畫主持人：袁賢銘

共同主持人：蔡今中

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□國際合作研究計畫國外研究報告書一份

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中　華　民　國　89　**年**　8　**月**　28　**日**

行政院國家科學委員會專題研究計畫成果報告

知識建構：以網路相互支援設計科學活動為基礎(2/3)

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主持人：袁賢銘　國立交通大學資訊科學系

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中文摘要

本論文描述一個應用於中學科學教育為主的全球資訊網化的概念構圖測驗系統的發展與應用經驗。共有 38 位中學生參與本研究。結果發現學生的成就與紙筆測驗成績並無顯著相關，但大多數學生對本系統的看法保持正面的態度。以學習動機與策略、測驗焦慮、系統滿意度問卷的分析結果顯示高批判思考型、自律、與測驗焦慮者未來較願意再使用本系統。

Science students' performance and use on a www-based concept map testing system, with relations to motivation and learning strategies

Abstract

This study described an attempt on developing a www-based concept map testing system for science students. Thirty-eight Taiwanese high school students involved in this study. It was found that students' performance on the system was not significantly related to their achievement measured by so-called traditional standard tests. Their views about the use of the system, in general, were positive. An analysis on students' future use of the system and their motivation and learning strategies revealed that students with more "critical thinking" metacognitive activities and "effort regulation" management strategy tended to show more willingness of using the on-line concept map testing system. Moreover, students with higher test anxiety showed more preferences to be tested through the system.

Science students' performance and use on a www-based concept map testing system, with relations to motivation and learning strategies

Introduction

In the recent fifteen years, concept maps have been widely applied to the instruction of various disciplines, especially in science (Novak & Gowin, 1984; Novak, 1990a). Relevant research of different-aged and culturally diverse learners has consistently shown the positive impacts of concept mapping on students' meaningful learning (Elhelou, 1997; Horton et al., 1993; Novak, 1990b; Novak, 1998; Wandersee, Mintzes, & Novak, 1994). The traditional way of constructing concept maps employs a "paper and pencil" approach. However, Chang, Chen and Sung (in press) have identified some weaknesses of constructing concept maps by paper and pencil. For example, "paper and pencil" concept mapping is inconvenient for interactions and feedback between learners and instructors, and its construction is complex and difficult for learners, especially for novice students. Chiu, Huang and Chang (2000) also point out some limitations of "paper and pencil" concept mapping. They caution that students often need to spend considerable amounts of time and effort revising and maintaining concept maps, and consequently they may not focus on the body of knowledge. Also, teachers must spend significant time and effort evaluating students' concept maps. Due to some features of computers (for example, the hypertext structure and the interactivity between user and existing content), many educators believed that computer technology could be viewed as a potential way of overcoming these limitations. Some computer-assisted concept mapping systems, therefore, were proposed (Fisher, 1990; Reader & Hammond, 1994; Chang, Chen & Sung, in press). With the rapid development of internet technology, on-line web learning has become a growing interest among educators (Barrett & Lally, 1999; Owston, 1997; Stamatis, Kefalas & Kargidis, 1999; Vescoukis & Retalis, 1999). Internet-based concept mapping systems have also been developed by educators (Chiu, Huang & Chang, 2000).

Concept mapping is not only used as a learning or metacognitive tool, but also can be used as an evaluation tool (Novak, 1995; Novak & Gowin, 1984). Novak (1995) has once claimed that "perhaps in time even national achievement exams will utilize concept mapping as a powerful evaluation tool" (p. 244). This study mainly described a www-based concept map test system about high school physics. That is, this study views the use of concept maps

as an evaluation tool. The main purpose of this study is to investigate a group of Taiwanese high school students' performance and use of a networked concept map testing system. Also, students' intention of using the on-line testing system in the future may play an important role in learning, as motivational researchers have claimed that there is a direct link between persistency and adopting better cognitive strategies together toward achievement and future learning (Pintrich & Schrauben, 1992; Eccles & Wigfield, 1992). Although there were some computer-assisted concept map system developed by earlier studies, almost none of them explored the possible relationships between students' intention of future use and their motivation and learning strategies.

Theoretical Perspectives

Concept map is based on a learning principle that meaningful learning occurs when learners could construct their knowledge hierarchically and explore the possible linkages between concepts (Novak & Gowin, 1984). Therefore, concept maps present the hierarchical structure of students' ideas, with emphasis on the relations between concepts. Using computers as a tool of implementing tests is often advocated by researchers in educational technology (e.g., Alessi & Trollip, 1991). The internet technology allows teachers to administer tests on-line and then record all of students' test outcomes. Students as well as teachers could take, implement or score the test without the constraints of time and location. The networked technology could also provide timely feedback to the respondents either from the pre-designed content or from the instructor. The perspectives of this study integrate the use of concept map with web-based testing. Many educators and researchers believe that with the assistance of computers or even internet, students can easily construct, modify and present their concept maps, and teachers can more efficiently evaluate students' concept maps (Chiu, Huang & Chang, 2000; Reader & Hammond, 1994).

This paper, here, reviews three major versions of computer-assisted concept mapping systems used by educators. The first version is called as "free construction" in which students allow to freely draw their concept maps in the computer-assisted environments. This version is the same as the "mapping by self" version used by Chang, Chen and Sung (in press). The second and third versions are viewed as "partial framework" concept mapping. The second version, called "recall" partial framework, leaves some blanks (concepts or relation links) of concept maps to be filled in. In the system, the student freely types in his/her answers without any possible answers of the concept map blanks provided. The third

version, called “recognition” partial framework, also leaves some blanks (concepts or relation links) of concept maps to be filled in. The system has shown some known concept nodes and relation links to be selected to fill in the concept map blanks. The student chooses his/her answers among the known concept nodes and relation links. It should be noted that what Chang, Chen and Sung (in press) use as the “partial framework” concept mapping is the “recognition” partial framework defined in this paper. Figure 1 shows the features of these three versions.

(Insert Figure 1 and Table 1 here)

Table 1 further presents a comparison of the advantages and possible limitations among these three versions. Students’ answers in the “recognition” partial framework version are easy to score. In the “recall” framework version, if educators have collected abundant students’ possible answers and then store them into the system, the system itself may evaluate students’ answers. In the versions of “recognition” and “recall,” the partial framework can serve as a scaffold or anchored conceptions for students’ meaningful learning (Chang, Chen & Sung, in press). The “free construction” version may assess students’ relatively higher-order thinking. It allows more flexibility about student knowledge structures. However, students taking the “free construction” version may require more experiences about constructing concept maps and using computers. Also, students’ concept maps developed in the “free construction” version may not be easy to score. Clearly, the “recognition” partial framework version may allow lower flexibility about students’ ideational organization. Students in the “recall” partial framework version are asked to freely type in their answers into the concept map blanks; therefore, students’ typing speed may cause some problems when answering the questions, especially for typing some complicated non-English languages (e.g., Chinese).

The concept mapping system used in this study employed the “recall” partial framework (please refer to Figure 2, Figure 3 and Figure 4 presented later). The partial framework version (either in the format of “recall” or “recognition”), as suggested by the findings derived from Chang, Chen and Sung’s (in press) study, can serve as a scaffold or “anchored” conceptions, and it can demonstrate more potential than “free construction” version in helping students learn science. The partial framework version allows teachers to easily evaluate the concept maps. More importantly, Taiwanese students in general do not have relevant knowledge and skills about concept maps and the use of computer network; therefore, they may not be ready to use “free construction” version at this stage. However, the “recall” partial framework version allows more freedom of students’ answers than the “recognition” version.

This study further approached another important research question, motivation in using on-line concept map testing system. The social cognitive model of motivation (Pintrich, 1988; Pintrich & DeGroot, 1990) proposes that a highly motivated student with appropriate learning strategies, if invests enough effort, then academic achievement can be expected. Therefore, this study further explores the possible relationships between students' motivation, learning strategies, and their future intention of using the Www-based COncept Map Test (WCOMT) system. This study completed by Ross and Schulz (1999) also revealed that computer-assisted instruction did not accommodate learners of various learning styles. This study tried to address a similar issue.

In the social cognitive model of motivation, there are two factors influencing academic achievement and future learning, that is, motivation and learning strategies (Pintrich & Schrauben, 1992; Anderman & Maehr, 1994). Learning motivation can be further categorized into the following components: value (how the learning may fit personal goal), expectancy (individual's perception of possible learning success), and affect (individual's feeling in learning and particular addresses test anxiety). The learning strategies are differentiated as cognitive, metacognitive, and management strategies (Pintrich & Schrauben, 1992). Cognitive strategies contain three basic strategies, repetitive learning, elaboration, and organization. The metacognitive strategies are critical thinking, planing, monitoring, and self-regulating and the management strategies designate as students' management of time and study environment, effort regulation, peer learning, and help seeking. It is expected that students' motivation and learning orientations are related to their perceptions or preferences of a new way of learning and testing. Therefore, this study examined possible linkages between students' willingness about the future use of WCOMT and their motivation and learning strategies.

One may question that the exploration about the relationships between student willingness to be tested by WCOMT and other variables (e.g., learning strategies) may not be critical, as students do not usually get the choice about the way being tested. However, in the paradigm of constructivism (Brooks & Brooks, 1993, Tsai, 1998a, 2000a), teachers need to be reflective, to utilize multiple ways of evaluation and to create student-centered learning environments for students. The exploration about the interplay between students' willingness of using WCOMT and their learning strategies may give teachers and educators some clues that WCOMT may be a better fit for which group of learners. Consequently, teachers may provide student-centered ways of instruction and evaluation.

In sum, the purpose of this study is to investigate a group of Taiwanese high school

students' performance and use of an on-line concept map testing system. To state more specifically, this study was conducted to explore the following three research questions:

1. What is the relationship between students' performance on the WCOMT and their scores as determined by traditional standard test?
2. What are the students' views of using WCOMT and their intention of using it as an assessment tool in the future?
3. What are the relationships between students' intention of using WCOMT and their motivation and learning orientations?

Method

Subjects

The subjects of this study came from 38 Taiwanese high school eleventh graders (17-year-olds) and 13 of them are female. They, enrolled in a program of civil engineering of a vocational high school, were about average achievers when comparing to the same-aged learners.

Research Procedures

All of the subjects were asked to finish a www-based concept map testing (WCOMT) in physics after receiving instruction of relevant physics topics and about concept maps. The day after taking the WCOMT, questionnaire about their views and intention of using the system, as well as that about their motivation and learning strategies were administered. Moreover, students' most recent scores (nearest to the implementation of the WCOMT) on a school-wide standard test in physics were used as an indicator of their physics achievement measured by so-called traditional testing. The standard test covered the topics of static equilibrium, Newton's laws of motion, and friction for high school physics.

On-line concept map testing system (WCOMT system)

As described earlier, the WCOMT employed the version of "recall" partial framework concept mapping. Consequently, the test system could be viewed as a series of fill-in questions presented in a concept map format. Figure 2 and Figure 3 show two examples that are sample items in its simplistic form.

(Insert Figure 2, Figure 3 and Figure 4 about here)

Students were asked to fill in the blank on-line. The blank may be a concept or a relation keyword between two concepts. In many cases, the testing system includes typical concept maps, showing hierarchical levels of concepts, and leaves more than one blank to be

filled in, as that illustrated in Figure 4. Again, it should be noted that the WCOMT is somewhat different from the "recognition" partial framework developed by Chang, Chen and Sung (in press). Chang et al.'s "recognition" partial framework version has shown some known concept nodes and relation links to be selected to fill in the concept map blanks. However, the WCOMT system asks students to type in their answers directly without providing any possible answers for the concept map blanks. We believe that this modification could explore students' ideas in a more proper manner, as it allows more freedom for respondents to express their ideas.

The test items used in this study covered similar topics as those used in the standard test (e.g., static equilibrium, Newton's laws of motion, and friction). The system would show one concept map (but often more than one fill-in blanks) per screen. After one student finished the whole testing items, he or she should submit his or her answers through internet and then he or she could view the reference answers on-line. The WCOMT system is available on http://totem.cte.nctu.edu.tw/vc/ in Chinese.

Measurements

1. Scoring of concept maps

The concept map blanks in the WCOMT were scored with unequal weights, ranging from 1 to 3 points. Usually, the concept in a higher hierarchy or the keyword between two concepts was given more weight. For example, correctly answering the first item in Figure 2 would be granted one point, while the item in Figure 3 three points. This way of scoring concurs with the rationale of concept mapping that concepts in a higher hierarchy and relation links are relatively more important than others (Novak & Gowin, 1984). The concept map items in the WCOMT system used in this study included 28 blanks (14 one-point blanks, 6 two-point blanks, and 8 three-point blanks). Students took about 50 minutes to complete them.

One high school science teacher and one university professor determined the score of each concept map blank. The agreement between these two experts for rating the scores was .82. The score of the blank with disagreement was determined after discussion.

Some educators may argue not to narrow concept maps into a quantifiable fashion or with schematizing formal relations as the primary goal. However, regular school system may request teachers to provide grades at least in final (summative evaluation), no matter which assessment format they take, traditional, concept maps, or any alternative assessment. Therefore, we believe that in a certain point of instruction, teachers have to quantify students' qualitative understanding status. It is also very common that for practical and research

purposes, educators try to represent students' qualitative ideas or knowledge structures in quantitative terms. For instance, Anderson and Demetrius (1993) and Tsai (1998b, 1999, 2000b) have developed a "flow map" method to quantitatively represent student knowledge organization through analyzing student interview recall data. Hence, this study tried to represent students' performance on WCOMT system in a quantitative way.

2. Students' views and intention of using on-line concept map testing system

Students' views and intention of using WCOMT were gathered from a questionnaire. The questionnaire employed a 5-point Likert scale, exploring students' views about some related issues of using the WCOMT system (e.g., the speed of screen information through internet, the possible influences of typing speed when using the system). The questionnaire concluded with a question, exploring students' intention of using the system in the future. The students were also required to write qualitative comments to explain the orientation of their intention. One university professor and one high school science teacher further examined students' quantitative responses and qualitative descriptions. It was found that at least 90% of students' quantitative results were consistent with their qualitative descriptions.

3. Questionnaire exploring student motivation and learning strategies

The Motivated Strategies for Learning Questionnaire (MSLQ, Pintrich, Smith, Garcia, & McKeachie, 1992) was modified and adapted into Taiwan high school version (MSLQ-TaiwanH, Lin, 1999). In Taiwan version there are 81 items separated into two parts, motivation orientation and learning strategies, which are very similar to the factor structure of the original questionnaire. In modifying and adapting MSLQ into Taiwan version, data was obtained from a sample of 143 Taiwan high students.

The result of factor analyses showed that the motivation section includes 31 items grouped into 3 components concerning value, expectancy, and affect. The value component includes three subscales: students' intrinsic goal, extrinsic goal, and task value toward a course. The expectancy component concerns about students' belief to achieve successfully in a course and contains two subscales, control beliefs about learning and self-efficacy. The affect component contains only one subscale, test anxiety.

The first part of the learning strategy section consists of 31 items grouped into 5 factors regarding students' use of different cognitive and metacognitive strategies, i.e., rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation. The second part of the learning strategy section includes 19 items grouped into 4 factors that assess students'

management of different resources, e.g. time and study environment, effort regulation, peer learning, and help seeking.

Separated exploratory factor analyses were performed for motivation, cognitive strategies and resource management factors and found the percentages of total variance explained by several factor analyses were from 0.52 to 0.64. The reliabilities for 15 subscales were satisfied (Cronbach α for 15 factors = .64 ~ .84 and for total scale = .83).

Results and Discussion

The relationships between performance of WCOMT system and that of traditional test

Students' performance on the WCOMT was not related to their scores as measured by the traditional test; however, the relationship almost reached the significance level of 0.05 ($r = 0.27$, $p=0.095$). This indicates that concept map testing and traditional tests may have some shared ground in assessing students' understandings in physics concepts, but the consistency between these two assessment methods is not sufficiently high. We interpreted such result stemmed from the idea that students' score on WCOMT may be a better indicator of representing students' performance in relatively higher cognitive levels (e.g., knowledge integration), while traditional tests may assess students' memorization of scientific information. Some research in Taiwan has revealed that many higher science achievers identified by standard tests did not employ meaningful strategies in learning science, and they tended to rely on rote memorization (Tsai, 1998c).

One may question that the "recall" partial framework, as we used in the WCOMT system, may miss the generation of associated ideas, while the "free construction" may be a better version to assess student higher levels of thinking and knowledge integration. However, we believe that, when comparing to traditional exams, which often present the questions in multiple-choice format with a single correct answer, the WCOMT system may still evaluate students' performance in a higher level. As described earlier, the partial framework in WCOMT system can serve as a scaffold or anchored conceptions for students' meaningful learning. When students do not have relevant experiences about concept maps and computers, the "free construction" version may cause high test anxiety for students. Also, researchers may not have highly valid methods to score student concept maps constructed in the "free construction" version.

Students' views and intention of using WCOMT

Students' views of using WCOMT as surveyed by the questionnaire are summarized as follows. Students tended to complain that the speed of delivering information of WCOMT system was not quick enough (mean = 3.84, S.D. =1.20 on 1-5 Likert scale, responding to the item "The data transferring of this system through the Internet is too slow"). However, they did not think on-line testing would cause some problems of cheating (mean = 2.00, S.D. = 1.25, responding to the item "The on-line test will entice me to cheat in the test"). The reference answers provided by the WCOMT system (after taking the test) helped them understand the test content (mean = 3.50, S.D.= 1.08, responding to the item "the reference answers provided by the system are helpful after finishing the test"). The reference answers could be viewed as a timely feedback between learners and instructors, overcoming a weakness by traditional "paper and pencil" concept mapping.

Many of the students also agreed that they spent much time on responding to the questions due to their slow typing speed (mean = 3.45, S.D.=1.37, responding to the item "I spent a lot of time on answering the test items due to my slow typing speed"). Chang, Chen and Sung's (in press) "recognition" partial framework version, which provided some known nodes and relation keywords to be selected, may avoid the typing problem. Because typing Chinese characters is very complicated, in this perspective, Chang et al's system may be a trade-off. However, for language like English, we believe that the WCOMT system, which could be viewed as a "free recall" partial framework version, may be a better mode of assessing students' understanding.

Finally, students' intention of using WCOMT in the future was relatively high (mean = 3.47, S.D. = 1.01, responding to the question item "I am willing to use this system for test in the future). The qualitative results concluded that many of them (16 among the 38 subjects) viewed that this way of testing could avoid complicated calculations in traditional tests, and helped them construct better conceptual frameworks of physics ideas. However, some of them felt bored (5 subjects) when taking the WCOMT, and others (4 subjects) complained that the system did not respond at a satisfactory speed. A detailed description of students' views and intention of using WCOMT with a larger sample (90 high school students) was presented at Tsai, Lin and Yuan's (2000) paper. Recent studies have also suggested that, to encourage students' use of concept mapping, it is important to make its possible benefits explicit to the students, especially for developmentally mature students (Santhanam, Leach & Dawson, 1998).

The relationships between students' intention of using WCOMT and their motivation and learning strategies

Students' intention of using the WCOMT system (in the future) was significantly correlated with the following motivation variables, measured by the MSLQ-TaiwanH ($p < .05$): extrinsic goal orientation, task value, control beliefs about learning, and test anxiety shown in Table 2.

(Insert Table 2)

Students put more emphasis on physics as a tool to gain other benefits (e.g., higher grade), concerned physics as a valuable subject matter, held the belief that effort may lead to better physics performance, and were more anxious during traditional test were more willing to use the WCOMT system again. This result may imply that high test anxiety students experienced test taking on the on-line system with less pressure or the test format of concept map provoked less test anxiety. It is possible that the on-line concept map testing system may help the detrimental effect of test anxiety.

On the other hand, students' intention of using the WCOMT system was significantly correlated with the execution of following learning strategies measured by the MSLQ-TaiwanH ($p < .05$), rehearsal, organization, critical thinking, metacognitive self-regulation, effort regulation, and peer learning. Whoever reported using more rehearsal strategy, more willing to organize concepts into a certain hierarchy, to question and examine before accept principles, to plan, monitor, and check learning process, to regulate effort investment, and to learn with peers, would like to use the WCOMT system again. This result may imply those who were more willing to be tested by concept map format were capable of using simpler cognitive strategies, such as rehearsal. However, they were also good at executing higher thinking skills, such as critical thinking, metacognitive self-regulation, and effort regulation, as well as management skill of learning, such as peer learning.

This study further used these factors to build regression models to predict students' intention of using WCOMT. The regression models were built through stepwise method, shown in Table 3.

(Insert Table 3)

The final model reveals that students who were more willing to execute critical thinking skills, possess higher test anxiety, and better capable of effort regulation will be more likely to use the WCOMT in the future. That is, among all the motivation and strategy variables, only three variables, critical thinking, test anxiety, and effort regulation, entered the final regression model in predicting students' intention of using the WCOMT system.

Simpler cognitive strategies (e.g., rehearsal) failed to enter the regression model. This somewhat corresponds to an assumption described earlier that WCOMT may assess students' ideas in a relatively higher level. One metacognitive strategy, critical thinking, with one management strategy, effort regulation, significantly predicted the willingness of using the on-line concept map testing system. It is also interesting to find that test anxiety is the strongest motivational predictor for future using the on-line concept map testing system. Therefore, students with higher test anxiety about traditional exams may prefer to be tested through the WCOMT system. We believe that the "recall" partial framework, as utilized in WCOMT system, provides an easy and comfortable method of using concept maps as an evaluation tool for students. Therefore, students with high test anxiety prefer this way of testing. We further hypothesize that the "free construction" concept mapping system may be preferred by low test anxiety students. Certainly, this hypothesis needs further research. It is also recognized that students' future intentions of using the WCOMT system are affected in a complex way; nevertheless, this study provided some evidence that some of students' motivation and learning strategies may be promising factors related to their future use of WCOMT.

Implications and further research

Educators always try to find other better ways of exploring or assessing students' ideas. This study described an attempt to use concept maps as a tool of assessing high school students' concepts in physics. The testing system was processed on the internet. This study revealed that students' performance on this system may provide an alternative indicator of exploring students' understandings in physics, which may somewhat differ from traditional standard tests. Students' views of using this system in general were positive. Students with higher test anxiety may prefer to be tested through such on-line system. In the paradigm of constructivism, teachers are encouraged to create student-centered learning environments and employed multiple modes of assessment (Brooks & Brooks, 1993; Tsai, 1998a, 2000a). Educators may include this way of testing as *one* of the multiple assessment manners, especially to provide this system to students with high test anxiety of taking traditional standard examinations.

In sum, WCOMT is a web system that employs concept maps as an assessment tool. The system can keep qualitative as well as quantitative records of students' conceptual understanding about basic physics. In the future, WCOMT will keep gathering many

concept map testing items in item bank that can be easily distributed to student users via the Internet. Our plan is to promote teachers' adopting of WCOMT in regular class. Thus the intention is not only on recording and analyzing students' conceptual understanding, but also on how to accommodate various needs of users and maintain accessibility and user friendly perspective for large user groups. Moreover, in the future, student, after answering questions in WCOMT, will access to view numerous suggested answers and to view peers' answers. Teachers can ask students to compare students' own concept maps with others and thus create possible conceptual conflicts. In this case, teachers using WCOMT may not be trapped to a peripheral aspect of concept maps.

When students have more experiences about concept maps and the use of computer network, this study may try to employ the "free construction" concept mapping version for students. Then, this study may compare students' concept maps with and without a specific misconception. In this way, we may acquire a deeper understanding about how students learn and organize scientific knowledge.

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Table 1: A comparison of three versions of computer-assisted concept mapping systems

	Advantages	Possible limitations
Recognition	a Easy to score a The partial framework can be used as a scaffold	a Allow low flexibility about student knowledge structures
Recall	a When abundant students' answers are collected, it becomes easy to score a The partial framework can be used as a scaffold or anchored conceptions for students	a Typing speed may cause some problems when answering the questions, especially for typing non-English language
Free construction	a Require student higher-order thinking a Allow higher flexibility about student knowledge structures and represent personal conceptual organization	a Need much more training about the ideas of concept maps and the use of computers a Not easy to score a May not be very useful for novice students

Table 2: The correlation between students' intention of using WCMT and their motivation and learning strategies

	M_1	M_2	M_3	M_4	M_5	M_6	L_1	L_2
Intention	0.30	0.45**	0.32*	0.40*	0.34*	0.51**	0.54**	0.24

	L_3	L_4	L_5	L_6	L_7	L_8	L_9
Intention	0.46**	0.57**	0.46**	0.11	0.43**	0.39*	0.28

* p< .05 **p< .01

Notes: **Motivation**

M_1: intrinsic goal orientation.
M_2: extrinsic goal orientation.
M_3: task value
M_4: control beliefs about learning
M_5: control beliefs about self-efficacy
M_6: test anxiety

Learning strategy

L_1: rehearsal
L_2: elaboration
L_3: organization
L_4: critical thinking
L_5: metacognitive self-regulation
L_6: time and study environment
L_7: effort regulation
L_8: peer learning
L_9: help seeking

Table 3: Regression models of predicting students' intention of using WCOMT

Model	Predictors	B	Std. Error	Beta	Sig.	R-square
1	(constant)	1.31	0.54		*	
	critical thinking	0.69	0.16	0.57	***	0.32
2	(constant)	0.41	0.57			
	critical thinking	0.56	0.16	0.46	**	
	test anxiety	0.41	0.14	0.38	**	0.46
3	(constant)	-0.77	0.70			
	critical thinking	0.46	0.15	0.38	**	
	test anxiety	0.42	0.13	0.38	**	
	effort regulation	0.44	0.17	0.31	*	0.54

Notes: *p<.05, **p<.01, ***p<.001

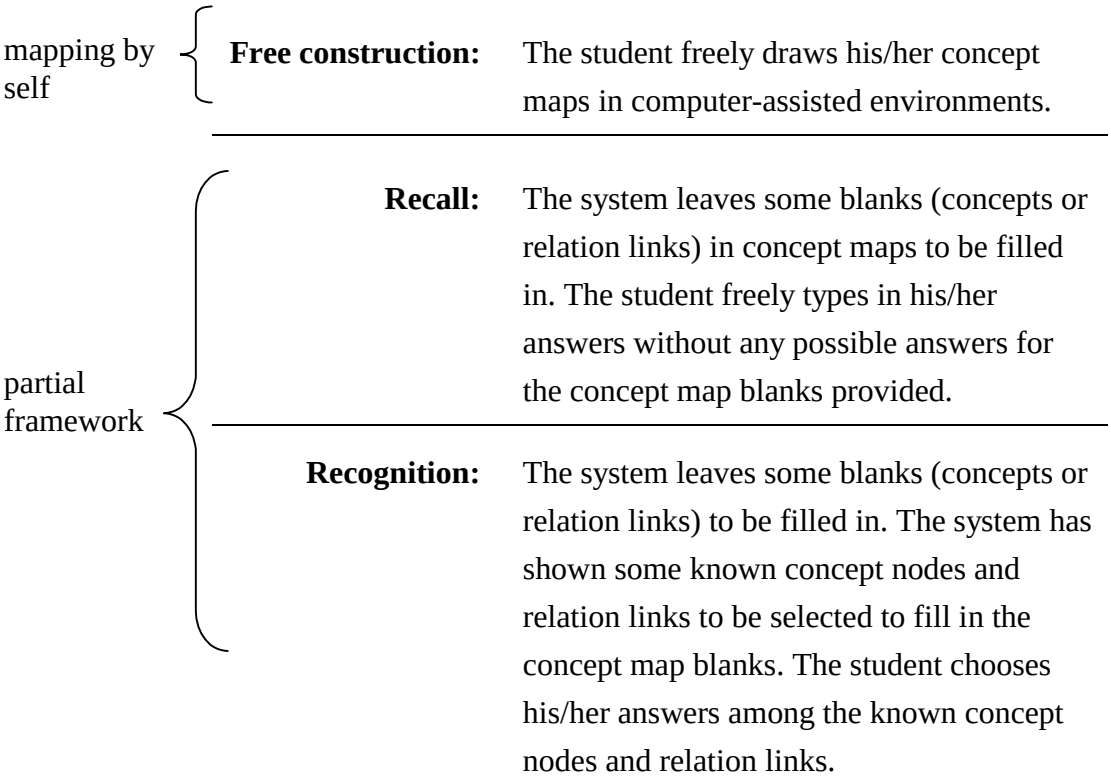

Figure 1: Three versions of computer-assisted concept mapping systems

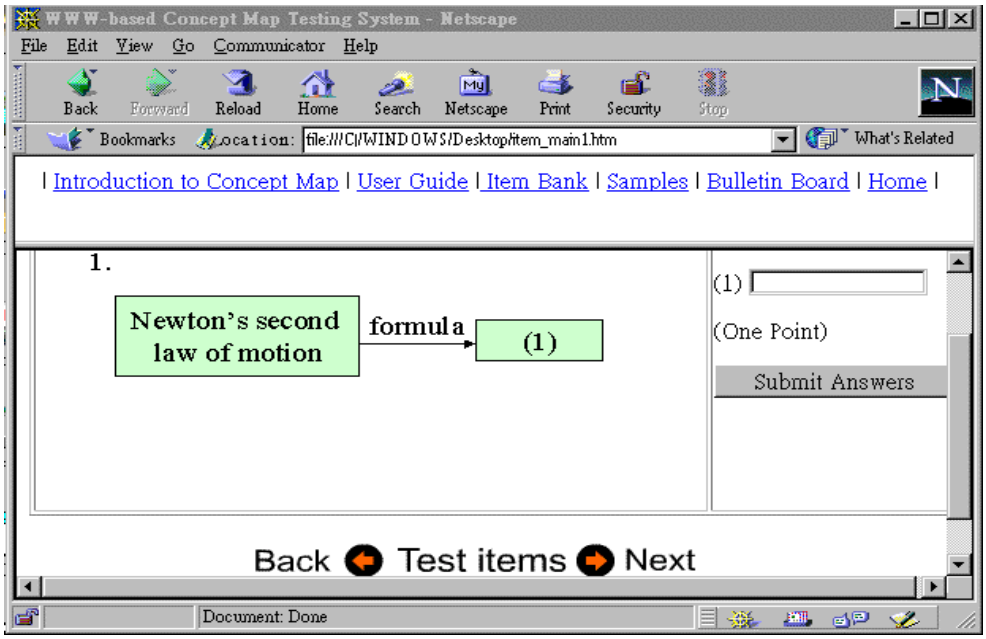

Figure 2: A simple item used in WCOMT system

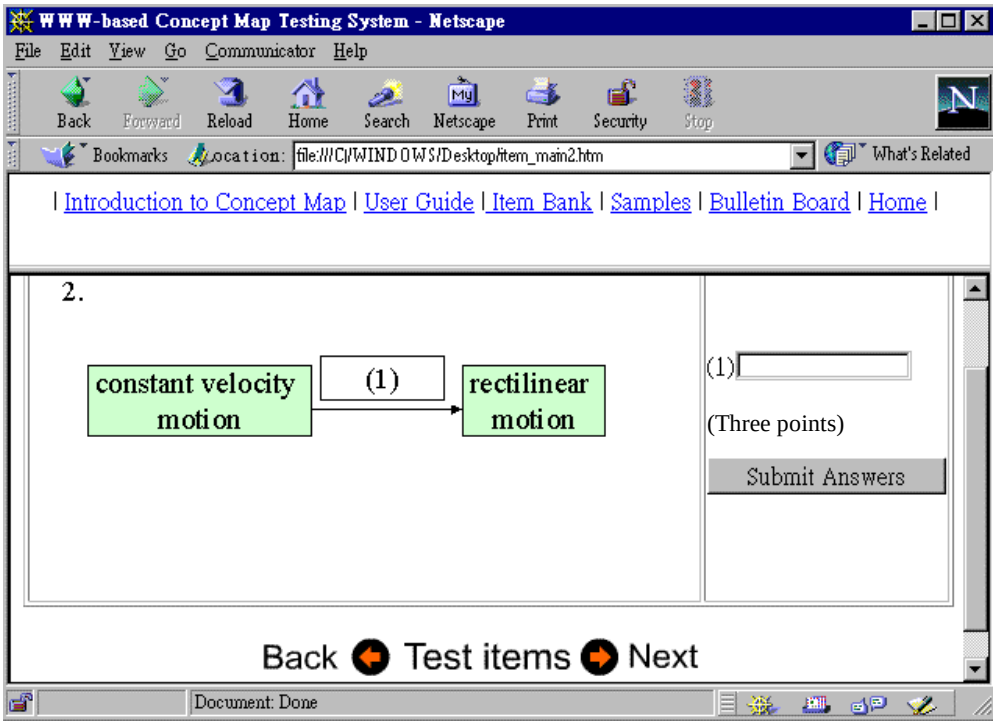

Figure 3: WCOMT item-relation link to be filled in

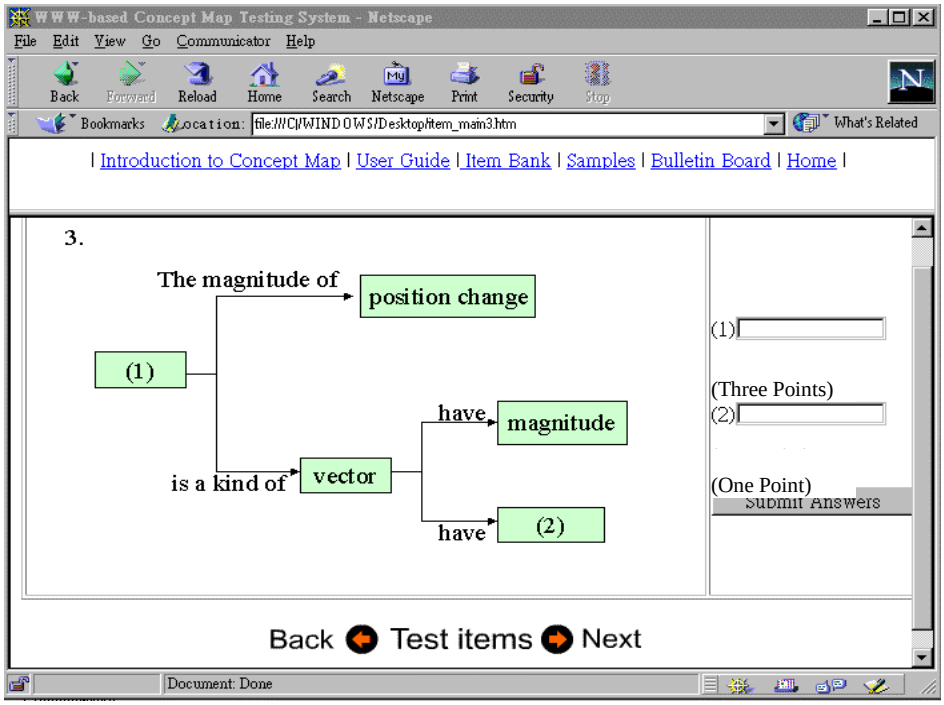

Figure 4: WCOMT item-multiple blanks