

Students' use of web-based concept map testing and strategies for learning

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Abstract The study reported in this paper developed and evaluated a web-based concept map testing system for science students. Thirty-eight Taiwanese high school students were involved and it was found that their performance on the system was not significantly related to their achievement as measured by traditional standard tests. Their views about the use of the system, in general, were positive. An analysis of students' future use of the system and their motivation and learning strategies revealed that those with more critical thinking metacognitive activities and an effort regulation management strategy showed more willingness to use the online testing system. Moreover, students with high test anxiety showed a preference to be tested through the system.

Keywords: Concept map; Constructivist; Learning strategy; Motivation; Questionnaire; School; Science; Testing; World-wide web

Introduction

In the last 15 years, concept maps have been widely applied in teaching various disciplines, especially 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 (Novak, 1990b; Horton *et al.*, 1993; Wandersee *et al.* 1994; Elhelou, 1997; Novak, 1998). The traditional way of constructing concept maps uses paper and pencil. However, Chang *et al.* (2001) have identified some weaknesses of constructing concept maps by paper and pencil; for example, it is inconvenient for interactions and feedback between learners and instructors, and its construction is complex and difficult for learners, especially for novice students. Chiu *et al.* (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 a potential way of overcoming these limitations. Some computer-assisted concept mapping systems have been proposed (Fisher, 1990; Reader & Hammond, 1994; Chang *et al.*, 2001). With the rapid development of

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Internet technology, online web learning has become a growing interest among educators (Barrett & Lally, 1999; Owston, 1997; Stamatis *et al.*, 1999; Vescoukis & Retalis, 1999). Internet-based concept mapping systems have also been developed (Chiu *et al.*, 2000).

Concept mapping is not only a learning or metacognitive tool but can be also used as an evaluation tool (Novak & Gowin, 1984). Novak (1995) claimed that '*perhaps in time even national achievement exams will utilize concept mapping as a powerful evaluation tool*' (p. 244). This study mainly involved a web-based concept map test system for high school physics and it viewed the use of concept maps as an evaluation tool. The study investigated a group of Taiwanese high school students' performance and use of a networked concept map testing system. Also, students' intention of using the online 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; Wigfield & Eccles, 1992). Although there have been some computer-assisted concept map system developed, few researchers have explored the possible relationships between students' intention of future use and their motivation and learning strategies.

Theoretical perspectives

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

This paper reviews three major versions of computer-assisted concept mapping systems used by educators. The first version is called 'free construction' as students freely draw their concept maps on a computer. This version is the same as the 'mapping-by-self' version used by Chang *et al.*, (2001). The second and third versions are viewed as 'partial framework' concept mapping. The second version, called a 'partial recall' framework, leaves some blanks (concepts or relational links) to be filled in. In the system, the students freely type in their answers without being provided with possible answers for the concept map blanks. The third version, called 'partial recognition framework', also leaves some blanks (concepts or relational links) to be filled in but the system shows some known concept nodes and relational links from which students select to fill in the blanks. It should be noted that what Chang *et al.* (2001) called 'partial framework' concept mapping is defined in this paper as the 'partial recognition framework'. Figure 1 shows the features of these three versions.

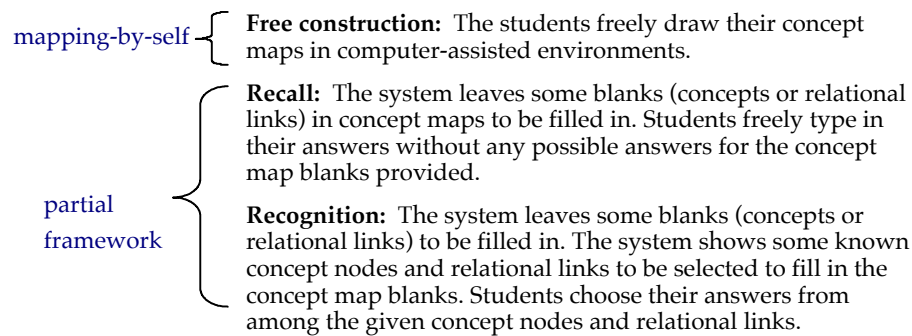


Fig. 1. Three versions of computer-assisted concept mapping systems

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

	Advantages	Possible limitations
Recognition	<ul style="list-style-type: none"> • Easy to score. • The partial framework can be used as a scaffold. 	<ul style="list-style-type: none"> • Allows low flexibility about student knowledge structures.
Recall	<ul style="list-style-type: none"> • When many students' answers are collected, it becomes easy to score. • The partial framework can be used as a scaffold or anchored conceptions for students 	<ul style="list-style-type: none"> • Typing speed may cause some problems when answering the the questions, especially for typing non-English language.
Free construction the novice	<ul style="list-style-type: none"> • Needs much more training about thinking. • Allow higher flexibility about student knowledge structures and represents personal conceptual organisation. 	<ul style="list-style-type: none"> Requires student higher-order the ideas of concept maps and use of computers. • Not easy to score. • May not be very useful for students.

Table 1 presents a further comparison of the advantages and possible limitations between these three versions. Students' answers in the partial recognition framework version are easy to score. In the recall framework version, if educators collect a mass of students' possible answers and then store them in 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 *et al.*, 2001). The free construction version may assess students' relatively higher-order thinking and it allows more flexibility over students' own knowledge structures. However, students using the free construction version may require more experience in constructing concept maps and using computers. Also, students' concept maps developed in the free construction version are not easy to score. Clearly, the partial recognition framework version allows less flexibility for students' conceptual organisation. Students in the partial recall framework version type their answers freely into the concept map blanks and so their 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 partial recall

framework. The partial framework version (either in the format of recall or recognition), as suggested by the findings derived from the Chang *et al.* (2001) study, can serve as a scaffold and it demonstrates more potential than the free construction version for helping students to learn science. The partial framework versions allow teachers to evaluate students' concept maps easily. More importantly, Taiwanese students in general do not have relevant knowledge and skills about concept maps and the use of computer networks; therefore, they may not be ready to use the free construction version yet. However, the partial recall framework version allows more freedom for students' responses than the recognition version.

This study also approached another important research question, that of motivation in using online testing systems. The socio-cognitive model of motivation (Pintrich, 1988; Pintrich & DeGroot, 1990) proposes that a highly motivated student with appropriate learning strategies, if investing enough effort, can be expected to show academic achievement. This study also explored the possible relationships between students' motivation, learning strategies and their future intention of using the Web-based CONcept Map Test (WCOMT) system. A study completed by Ross & Schulz (1999) also revealed that computer-assisted instruction did not accommodate learners of all learning styles. This study tried to address a similar issue.

In the socio-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 categorised into the following components: value (how the learning may fit personal goals), expectancy (individual's perception of possible learning success) and affect (individual's feeling during learning including test anxiety). The learning strategies are differentiated as cognitive, metacognitive and management strategies (Pintrich & Schrauben, 1992). Cognitive strategies contain three basic elements: repetitive learning, elaboration and organisation. The metacognitive strategies are critical thinking, planing, monitoring and self-regulating, and the management strategies include 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 whether the exploration of the relationships between student willingness to be tested by WCOMT and other variables (e.g. learning strategies) may not be crucial, 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 utilise multiple ways of evaluation and to create student-centred learning environments. An exploration of the interplay between students' willingness to use WCOMT and their learning strategies may give teachers some clues that WCOMT may suit particular kinds of learners. Consequently, teachers may provide student-centred ways of instruction and evaluation.

In summary, this study investigated a group of Taiwanese high school students' performance and use of an online concept map testing system. More specifically, the study was conducted to explore the following three research questions:

- What is the relationship between students' performance on the WCOMT and their scores as determined by a traditional standard test?

- What are the students' views of using WCOMT and their intention of using it as an assessment tool in the future?
- What are the relationships between students' intention of using WCOMT and their motivation and learning orientations?

Method

The subjects in the study were 38 (13 female and 25 male) Taiwan high school eleventh graders (17-year-olds). They were enrolled in a programme of civil engineering at a vocational high school and were average achievers when compared to other same-aged learners.

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

The online concept map testing system

As described earlier, WCOMT employed the version of partial recall 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 Fig. 3 show two examples that are sample items in its simplistic form.

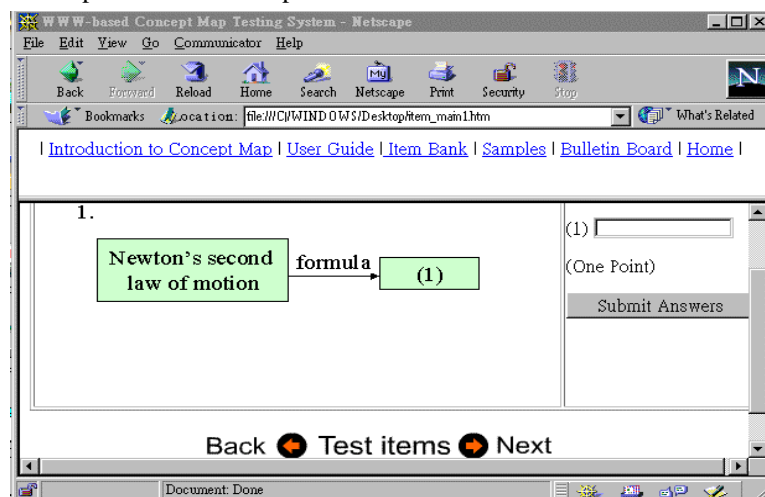


Fig. 2. A simple item used in WCOMT system

Students were asked to fill in the blank online. The blank may be a concept or a relational keyword between two concepts. In many cases, the testing system included typical concept maps, showing hierarchical levels of concepts, and more than one blank to be filled in, as illustrated in Fig. 4.

Again, it should be noted that WCOMT is somewhat different from the partial recognition framework developed by Chang *et al.* (2001) where some known

concept nodes and relational links have 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 blanks. It is thought that this modification would explore students' concepts more deeply as it allows more freedom of expression.

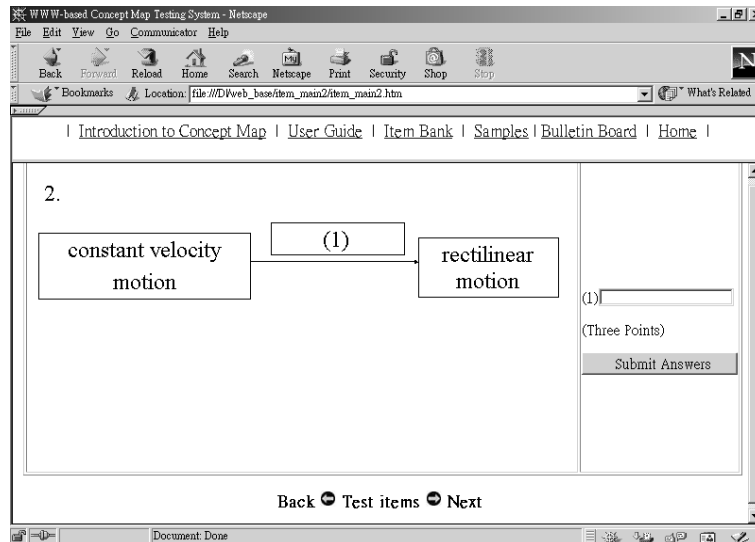
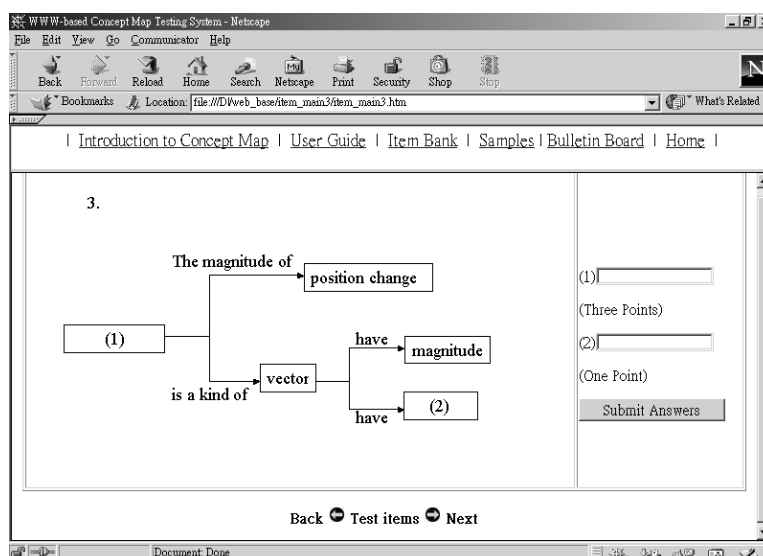


Fig. 3 WCOMT item-relational link to be filled in

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 shows one concept map (but often more than one fill-in blank) per screen. After students finished all test items, they submitted their answers through the Internet and then could view the reference answers online. The WCOMT system is available at <http://totem.cte.nctu.edu.tw/vc/> in Chinese.



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Measurements

Scoring of concept maps

The concept map blanks in WCOMT were scored with unequal weights, ranging from 1 to 3 points. Usually, the concept in a higher hierarchical level or the keyword between two concepts was given more weight. For example, correctly answering the first item in Fig. 2 would be awarded one point, while for the item in Fig. 3 three points. This way of scoring concurs with the rationale of concept mapping that concepts at a higher level and relational 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 for each concept map blank. The agreement between these two experts for rating the scores was 82%. The score for any blank with disagreement was determined after discussion.

Some educators may argue against limiting concept maps to quantifiable measures or with schematising formal relations as the primary goal. However, regular school systems may require teachers to provide grades at least in final (summative) evaluation, no matter which assessment format they take: traditional, concept maps or any alternative. Therefore, at a certain point teachers have to quantify students' level of understanding. 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 & Demetrius (1993) and Tsai (1998b, 1999; 2000b) have developed a 'flow map' method to quantitatively represent student knowledge organisation through analysing students interview recall data. Hence, this study tried to represent students' performance on the WCOMT system in a quantitative way.

Students' views and intention of using the online 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 related issues of using the WCOMT system (e.g. the speed of screen information through the Internet, the possible influences of typing speed when using the system). The questionnaire concluded by 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.

Questionnaire exploring student motivation and learning strategies

The Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich *et al.*, 1992) was modified and adapted into a Taiwan high school version (MSLQ-TaiwanH, see Lin, 1999). In the 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 a Taiwan version, data was obtained from a sample of 143 Taiwan high students.

The result of factor analyses showed that the motivation section included 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 students' belief about success 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, organisation, 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 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's α* for 15 factors = 0.64~0.84 and for the total scale = 0.83).

Results and discussion

The relationships between performance with WCOMT and a traditional test

Students' performance on 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. It seems that such a result stemmed from the idea that students' score on WCOMT may be a better indicator for representing students' performance in relatively higher cognitive levels (e.g. knowledge integration), while traditional tests may assess students' memorisation 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 memorisation (Tsai, 1998c).

One may question that the partial recall framework, used in the WCOMT system, could miss the generation of associated ideas, while the free construction version may be a better to assess students' higher levels of thinking and knowledge integration. However, when compared 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 at 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 them. 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 tended to complain that the speed of delivering information by the WCOMT system was not quick enough (mean = 3.84, $sd = 1.20$ on a 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 online testing would cause problems of cheating (mean = 2.00, $sd = 1.25$, responding to the item: *The online*

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, *sd* = 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 timely feedback between learners and instructors, overcoming a weakness of traditional paper and pencil concept mapping.

Many of the students also agreed that they spent much time responding to the questions due to their slow typing speed (mean = 3.45, *sd* = 1.37, responding to the item: *I spent a lot of time on answering the test items due to my slow typing speed*). The partial recognition framework version, which provided some known nodes and relational keywords to be selected, may avoid the typing problem. Because typing Chinese characters is very complicated, Chang *et al.*'s system may be a trade-off. However, for languages like English, the WCOMT system, which could be viewed as a free partial recall framework version, may be a better way of assessing students' understanding.

Finally, students' intention of using WCOMT in the future was relatively high (mean = 3.47, *sd* = 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) thought that this way of testing could avoid complicated calculations in traditional tests, and helped them construct better conceptual frameworks for physics ideas. However, some of them felt bored (five subjects) when taking the WCOMT and four 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 by Tsai *et al.* (2000). Recent studies have also suggested that, to encourage students' use of concept mapping, it is important to make its possible benefits explicit, especially for mature students (Santhanam *et al.*, 1998).

Students' intentions of using WCOMT, their motivation and learning strategies

Students' intentions of using the WCOMT system (in the future) was significantly correlated with the following motivation variables, measured by the MSLQ-TaiwanH ($p < 0.05$): extrinsic goal orientation, task value, control beliefs about learning and test anxiety (as shown in Table 2).

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

On the other hand, students' intentions of using the WCOMT system was significantly correlated with the execution of the following learning strategies (measured by the MSLQ-TaiwanH, $p < 0.05$): rehearsal, organisation, critical thinking, metacognitive self-regulation, effort regulation and peer learning. Those who reported using more rehearsal strategy were more willing to organise concepts into a certain hierarchy, to question and examine before accepting 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 in the 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 skills of learning, such as peer learning.

Table 2. Correlation between students' intention and their motivation and learning strategies.

	M1	M2	M3	M4	M5	M6	L1	L2
Intention	0.30	0.45**	0.32*	0.40*	0.34*	0.51**	0.54**	0.24
	L3	L4	L5	L6	L7	L8	L9	
Intention	0.46**	0.57**	0.46**	0.11	0.43**	0.39*	0.28	

* $p < 0.05$ ** $p < 0.01$

Key:	Motivation	Learning strategy
	M1: intrinsic goal orientation.	L1: rehearsal
	M2: extrinsic goal orientation.	L2: elaboration
	M3: task value	L3: organisation
	M4: control beliefs about learning	L4: critical thinking
	M5: control beliefs about self-efficacy	L5: metacognitive self-regulation
	M6: test anxiety	L6: time and study environment
		L7: effort regulation
		L8: peer learning
		L9: help seeking

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

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

Model	Predictors	B	Std. Error	Beta	Sign.	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

Key: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The final model reveals that students who are more willing to execute critical thinking skills, possess higher test anxiety and are better capable of effort regulation, will be more likely to use 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' intentions.

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' concepts at a relatively high level. One metacognitive strategy (critical thinking) with one management strategy (effort regulation) significantly predicted the willingness to use the online concept map testing system. It is also interesting to find that test anxiety is the strongest motivational predictor for future use of the testing system. The partial recall framework, as used in WCOMT system, may provide 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.

It is further hypothesised that the free construction concept mapping system may be preferred by low test anxiety students but this needs further research. It is also recognised that students' future intentions of using the WCOMT system are affected in a complex way; nevertheless, this study provides evidence that some of the students' motivation and learning strategies may be promising factors regarding their future use of WCOMT.

Implications and further research

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

In the future, WCOMT will continue to gather concept map testing items in an item bank that can be easily distributed to student users via the Internet. The plan is to promote teachers' adoption of WCOMT in regular classes. Thus the intention is not only on recording and analysing students' conceptual understanding but also on accommodating various needs of users and maintaining accessibility and a user friendly perspective for large user groups. Moreover, in the future, after answering questions in WCOMT, students will be able to view numerous suggested answers and to view peers' answers. Teachers can ask students' to compare their own concept maps with those of others and thus create possible conceptual conflicts. In this case, teachers may not be trapped by the peripheral aspect of concept maps.

When students have more experience of concept maps and the use of the computer network, the research may try to employ the free construction concept mapping version. This research will then be able to compare students' concept maps with and without a specific misconception leading to a deeper understanding of how students learn and organise scientific knowledge.

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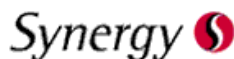
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