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Learning through computer-based concept mapping with scaffolding aid

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Abstract Concept mapping has been applied in a variety of fields, including instruction, learning, curriculum development, and assessment. Because many empirical studies have proven the validity of concept mapping, a computer-based concept mapping system has been developed. The system provides two learning environments. In the 'construct-by-self' environment, the system provides students with the evaluation results and corresponding hints for feedback. The students construct concept maps by themselves with only the assistance of the feedback. In the 'construct-on-scaffold' environment, in addition to the feedback, the students receive an incomplete concept map, within which some nodes and links were set as blanks for the scaffold. A study comparing the effectiveness of the 'construct-by-self', 'construct-on-scaffold', and 'construct by paper-and-pencil' concept mapping showed that the 'construct-on-scaffold' had better effect for learning on biology. Both of the two computer-based procedures are helpful for students in completing their concept maps.

Keywords: Biology; Computer; Concept mapping; Comparison; Empirical; Scaffold; Secondary

Introduction

A concept map is composed of propositions defined by two concept nodes and one connecting relation link. Figure 1 shows an example of a concept map for the topic 'reproduction' in biology where the concept nodes are arranged in a hierarchical structure. Between every two nodes there is a relation link to define a proposition. 'Concept mapping' is the process of constructing a concept map for learning.

Concept mapping is consistent with the theories of knowledge representation (Anderson, 1995), constructive learning (Duffy *et al.,* 1991), and meaningful learning (Novak, 1990; Novak, 1991). It is now widely applied in teaching and learning in science education. The applications in science teaching and learning (Schmid & Telaro, 1990; Nakhleh & Krajcik, 1994), curriculum design (Starr & Krajcik, 1990; Edmondson, 1995), and knowledge structure evaluation (Novak & Gowin, 1984; Anderson & Chiu, 1989; Beyerbach & Smith, 1990; Goldsmith *et al.,* 1991; Herl *et al.,* 1996; Ruiz-Primo & Schavelson, 1996) have been approved by many researchers. Although many of them have reported that concept mapping is a

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useful tool for learning and instruction, constructing concept maps using paper and pencil has some obvious disadvantages. These are:

- It is inconvenient for a teacher to provide appropriate feedback to students during concept mapping.
- The construction of a concept map is complex and difficult for students, especially for novice students.
- Concept maps constructed using paper and pencil are difficult to revise.
- The 'paper-and-pencil' concept mapping is not an efficient tool for evaluation.

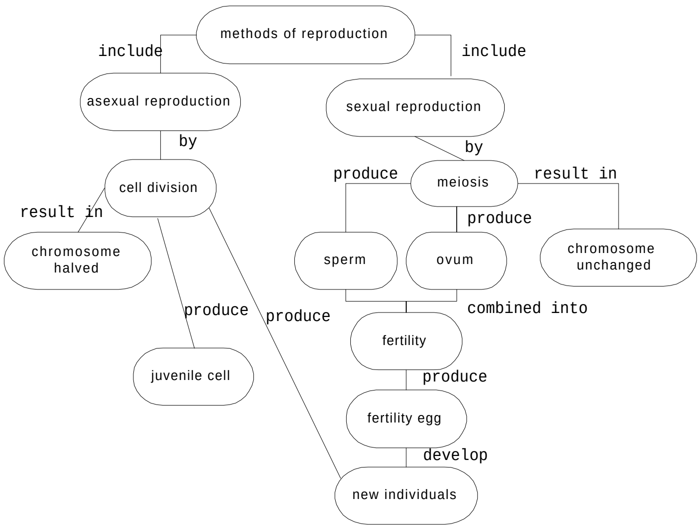

Fig. 1. An example of a concept map

Because of the above difficulties involved in 'paper-and-pencil' concept mapping, researchers built computer-based concept mapping systems to help students construct concept maps more easily. Fisher and colleagues (Fisher, 1990; Fisher *et al.*, 1990) designed a concept mapping system, namely SemNet, according to the semantic network theory. They showed that SemNet had a positive effect upon student's map construction. Reader & Hammond (1994) used hypertext techniques to implement their concept mapping system and found that those who used the concept mapping system obtained better achievement. The computer-based systems of Fisher *et al.* (1990) and Reader & Hammond (1994) overcame some of the limitations in 'paper-and-pencil' concept mapping, but some considerations must still be addressed. For example, the systems provided students with an environment in which concept maps could be constructed without any assistance. Novice students tended to be frustrated in this construction process. In addition, these systems cannot provide feedback to the students because they lack any function for evaluating the concept maps. This lack of feedback means that students have few opportunities to reflect upon their own thinking and this reduces the beneficial effects of constructing a concept map.

This paper describes two versions of computer-based concept mapping: 'construct-on-scaffold' and 'construct-by-self'. The 'construct-on-scaffold' version, which is transformed from the 'completion strategy' (Van Merrienboer, 1990; Paas, 1992), provides students with an incomplete framework of an expert concept map, as a scaffold in which some nodes and links are reserved as blanks. Students have to fill in the blanks to complete the framework. This method is also known as the 'fill in the structure' approach, which had been demonstrated to be a valid method of using an incomplete knowledge map to assess knowledge structure (Naveh-Benjamin *et al.*, 1995; Naveh-Benjamin *et al.*, 1998). It was hoped that this kind of aid would be helpful for reducing mental load and providing a referent knowledge structure to novice students. The 'construct-by-self' version provides students with an environment to freely construct their concept maps without scaffolding aid. Both of the two versions have evaluation and hint functions. In the proposed system, an expert concept map is predefined. By comparing the expert concept map with the student concept map, the system can evaluate the student's map. The evaluation outcome and hints derived from the evaluation are then used as feedback to students. The feedback may facilitate students' learning. To test the effectiveness of this system, 'reproduction' in biology teaching was used as the experimental content. The following questions were investigated:

- Do the different versions of the concept mapping system have different effects on students' biology learning?
- Is the feedback provided by the concept mapping system helpful for students to construct maps?
- What are the students' opinions of the system?

Concept mapping system

This system supports two kinds of learning strategies for students to construct concept maps. In the 'construct-by-self' version, students construct concept maps by themselves without scaffolding aid. In the 'construct-on-scaffold' version, the system provides a scaffold, which is an incomplete expert concept map with some blank nodes and links. The students construct the concept map by filling in the blanks. The interfaces used in the two versions are shown in Figs 2 and 3. Each interface includes a concept list, a relation list, a toolbar to edit and save maps, and hint and evaluation buttons. The concept and relation lists contain all of the concepts and relations to be used. For instance, the concept and relation lists in Figs 2 and 3 include all of the concept nodes and relation links drawn in Fig. 1.

In the 'construct-by-self' environment, students select concepts or relations from the concept or relation list, and put them into the mapping area. The students then gradually create a map composed of nodes and links. In the 'construct-on-scaffold' environment, the system provides a scaffold as shown in Fig. 3. The students then select concepts or relations from the concept or relation list and fill in the appropriate blanks in the scaffold with these selections.

When students press the hint button, the system gives appropriate hints to students according to the comparisons between student and expert concept maps. The hints are presented in a partial proposition type, such as [Meiosis *result in*???] in Fig. 4. The partial proposition is made of a concept and a relation. Another concept is represented as '???'. In this way, students are provided with a partial proposition instead of a complete proposition. The system affords opportunities for students to reflect upon their materials. The 'expert concept map' button is enabled when the students have worked on constructing their maps for over 30 minutes. The function of this button is to show the expert concept map to students for reference.

When students press the evaluation button, the system compares the expert concept map with the student concept map. The system then indicates what nodes or links in the student concept map are different from those in the expert concept map.

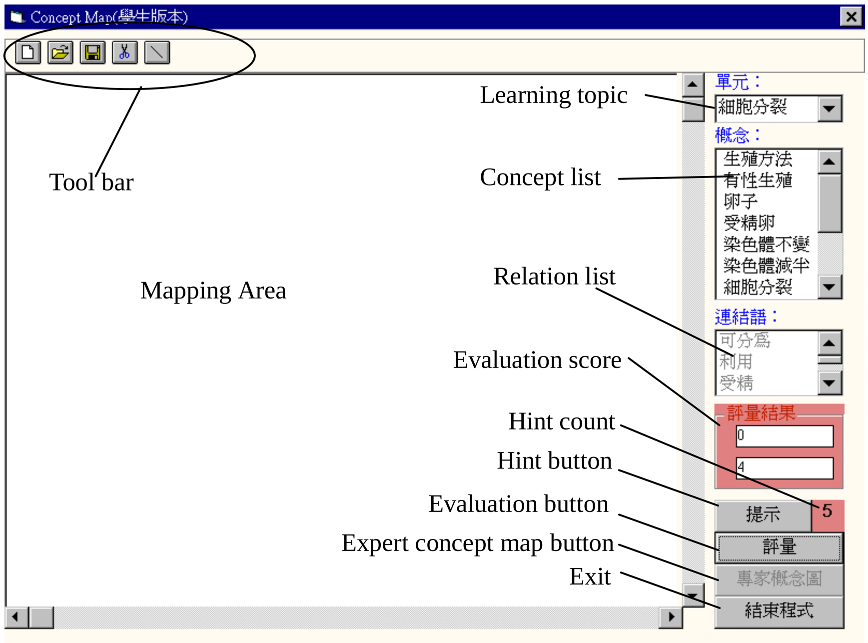

Fig. 2. Interface for the ‘construct-by-self’ version

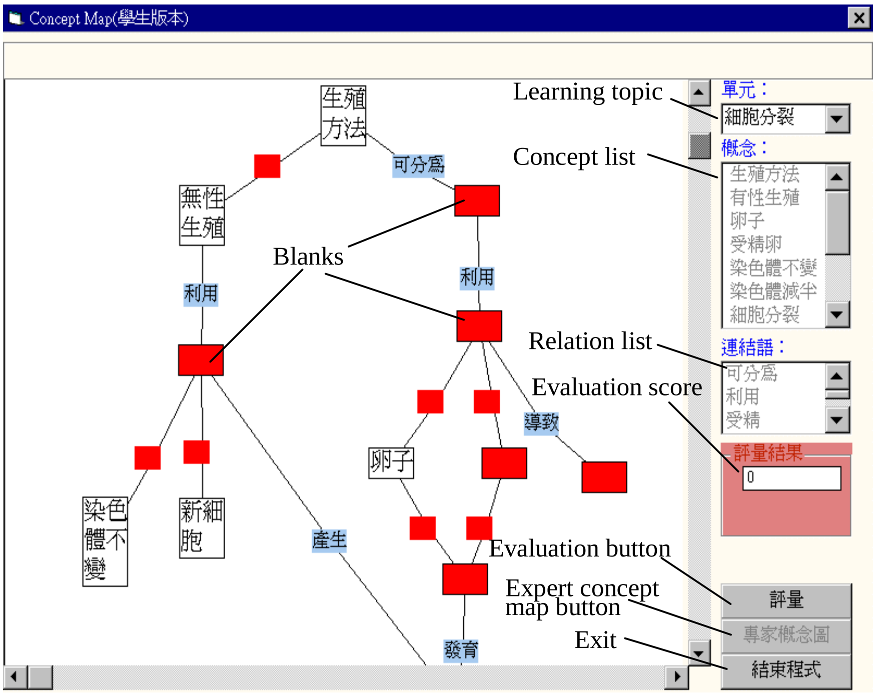

Fig. 3. Interface for the ‘construct-on-scaffold’ version

The unmatched nodes appear as blank boxes. In addition to showing the unmatched nodes or links, the system also provides an evaluation score, which can be viewed as the index of similarity between student and expert concept maps. Two similarity indices are scored on the maps constructed in the 'construct-by-self' and 'construct-on-scaffold' versions, respectively. For the 'construct-by-self' version, the scoring criteria proposed by Novak & Gowin (1984; pp. 36–37) is used for scoring concept maps, including comparing the numbers of valid propositions, valid hierarchical levels, and valid cross-links. The score for a student concept map can be divided by the score of an expert concept map to produce a ratio as the similarity index. For the 'construct-on-scaffold' version, the similarity index of a map can be calculated by the way that the number of correct answers in the blanks is divided by the number of total blanks on the map. Both of the two indices range from zero to one. Zero indicates that the two maps are completely different. One indicates that the two maps are identical.

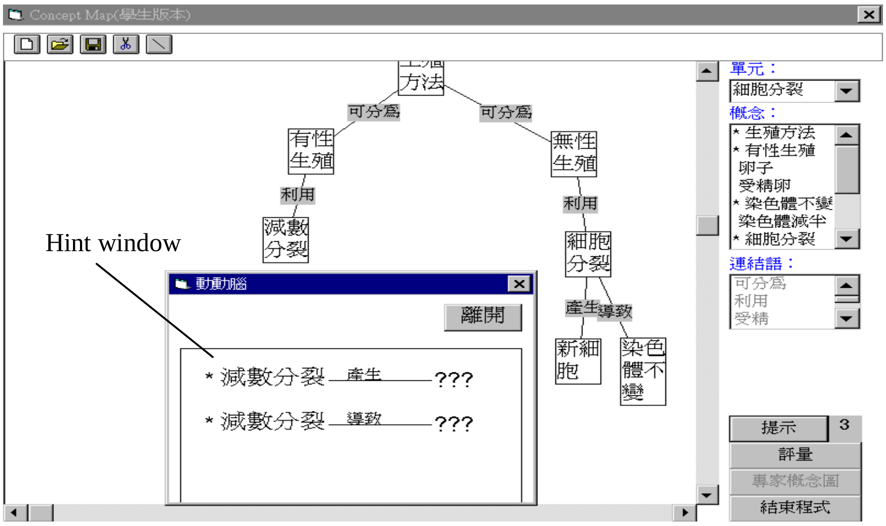

Fig. 4. Hint represented in partial proposition type

Experiment

Students

Forty-eight seven-grade students, 23 females and 25 males, selected from three classes of one junior high school in Taipei, participated in this experiment. Each class included 15, 16 or 17 students. Those students were studying their second semester course of General Biology.

Experimental design

This experiment employed a pre- post-test control group design. Each class was randomly assigned to one of the 'construct-by-self', 'construct-on-scaffold', or 'construct by paper-and-pencil' groups. Because the subjects of these three groups might have different prerequisite biology knowledge, their biology achievement scores from the previous semester, which was a composite score derived from two middle-terms and one final exam, were used as pre-test scores and served as the covariate of the analysis of covariance (ANCOVA) for the post-test scores of a biology achievement test.

Materials

Subject domain. The contents of two chapters in the biology textbook for the seventh grade were used as the experimental materials. Table 1 shows the detailed contents. The contents of Chapter 5 (coordination) were used for practice, teachers could do some demonstrations and students could operate the concept mapping procedure. The contents of Chapter 7 (reproduction) were used for the formal experiment. Two experienced teachers of biology in junior high school were invited to select the concepts and relations. These two teachers then cooperatively constructed the expert concept maps for all of the sections in Table 1.

Table 1 Contents of experimental materials

Chapters	Contents
Chapter 5 Coordination	Section 1 Stimulus and Response Section 2 The Nervous System Section 3 Endocrine Gland Section 4 The Behaviours of Animals
Chapter 7 Reproduction	Section 1 Cell Division Section 2 Asexual Reproduction Section 3 Sexual Reproduction Section 4 Animals′ Behaviours of Reproduction

Biology achievement test. A 23-item multiple-choice test in which each item scored three points. This test was constructed to measure the subjects' learning on the contents of 'reproduction'. This achievement test included about 90% of the concepts used in the concept mapping system. The item analysis data from a sample of 82 seventh-grade students showed that the KR-20 reliability was 0.76 and the split-half reliability was 0.68.

Questionnaires for concept mapping. Two questionnaires were constructed to investigate students' opinions about our system and the 'paper-and-pencil' concept mapping method. One questionnaire includes items concerning the difficulties students encountered during their map constructions, the belief that concept mapping is helpful to their learning, and the affective acceptance of concept mapping as a useful learning tool. All students from the three groups answered this questionnaire. The other questionnaire was constructed especially to investigate computer-based groups' opinions on the 'construct-by-self' or the 'construct-on-scaffold' concept mapping system. Both of the questionnaires used a 4-point Likert scale. For each item, 1 indicated 'strongly disagree', 2 indicated 'disagree', 3 indicated 'agree', and 4 indicated 'strongly agree'.

Procedures

General orientation. The meaning, methods and operational procedures of the computer-based or paper-and-pencil based concept mapping were demonstrated to the students of the three groups . The contents of 'coordination' were used as the practice material. This phase took about one hour.

Formal experiment. The day after the subjects finished their formal biology lessons, they worked individually with computer or paper-and-pencil to construct concept maps about the contents of that lesson, one section each week. Each section took approximately 50 min. During the map-construction process, the two computer-based groups could revise their maps according to the feedback provided by the system. The paper-and-pencil group was allowed to construct their maps using only their own judgement. The formal experimental phase lasted four weeks.

Post-test. Immediately after the last formal experiment, the subjects took the biology achievement test and answered the questionnaires about concept mapping.

Results

Learning effects of concept mapping system

The three groups' biology achievement scores from the previous semester (which served as pre-test scores) and their post-test scores are shown in Table 2. The adjusted post-test scores, which represent the post-test scores adjusted according to the differences in pre-test scores between the three groups, are also listed together with the three groups' average similarity indices for the four final concept maps. The similarity indices of the 'construct-by-self' and 'construct-on-scaffold' groups were scored by this system. The similarity index of the 'paper-and-pencil' group was scored according to the scoring rubrics proposed by Novak & Gowin (1984) by the two teachers who constructed the expert concept maps. All of the three indices ranged from zero to one.

Table 2. Means (and standard deviations) of the pre-test, post-test, adjusted post-test scores, and the similarity indices

Groups	Pre-test	Post-test	Adjusted Post-test	Similarity indices
Construct by self	63.0	48.8	42.05	0.761
(n = 15)	(17.8)	(18.3)	(19.6)	(0.142)
Construct on scaffold	49.1	46.7	52.52	0.924
(n = 16)	(21.4)	(24.2)	(23.3)	(0.072)
Paper-and-pencil	55.0	41.1	41.59	0.621
(n = 17)	(16.9)	(20.0)	(20.8)	(0.167)

To compare the learning effects of two versions of the concept mapping system and the paper-and-pencil concept mapping, a one way analysis of covariance was conducted on the post-test scores of the three groups. Pre-test scores were used as the covariate to control the potential differences in the students' biology knowledge.

Table 3. Analysis of covariance in achievement in biology

Source of Variance	SS	df	MS	*F*
Between groups	1159.9	2	579.9	3.79*
Within groups (errors)	6741.2	44	153.2	

* $p < 0.05$

The test of homogeneity of regression showed that the homogeneity of regression of the three groups was not different ($F_{2,42} = 0.01$, $p > 0.05$). The results of ANCOVA shown in Table 3 indicated that after the influence of pre-test was controlled, the post-test scores of the three groups were significantly different ($F_{2,44} = 3.79$, $p < 0.05$). Table 4 showed that after *post hoc* comparison using the LSD (or least

Table 4. *Post hoc* comparisons of post-test scores (p values of LSD comparison)

Groups	Adjusted means	Construct-by-self	Construct-on-scaffold	Paper-and-pencil
Constructing-by-self	42.05	--------	0.029*	0.919
Constructing-on-scaffold	52.52		-------	0.016*
Paper-and-pencil	41.59			-------

*$p < 0.05$

significant difference) method, the post-test score of the 'construct-on-scaffold' group was significantly better than those of the 'construct-by-self' and 'paper-and-pencil' groups ($p < 0.05$). This indicated that the 'construct-on-scaffold' concept mapping system had a better learning impact on students than the 'construct-by-self' and 'paper-and-pencil' mapping methods. The post-test score of the 'construct-by-self' group was not better than that of the 'paper-and-pencil' group, revealing that the 'construct-by-self' concept mapping system and the 'paper-and-pencil' concept mapping method had the same effects on biology learning.

The similarity index represents the degree of similarity between the student and expert concept maps, which may be viewed as an index of accuracy and completeness of the student concept map. A one-way analysis of variance (ANOVA) was conducted to contrast the differences in the similarity indices between the three groups and the results showed that there were significant differences between the three groups ($F_{2,45} = 21.1$, $p < 0.01$ (see Table 5).

Table 5. Analysis of variance in similarity indices

Source of Variance	SS	df	MS	*F*
Between groups	0.755	2	0.378	21.1*
Within groups (errors)	0.807	44	0.018	

* p<0.01

As shown in Table 6, the *post hoc* comparisons of LSD indicated that the similarity index of the 'construct-on-scaffold' group (index = 0.92) was significantly higher than those of the other two groups. The index for the 'construct-by-self' group (index = 0.76) was also significantly higher than that of the 'paper-and-pencil' group (index = 0.62). This result indicated that both of the two computer-based groups achieved more complete and accurate maps than the group using paper and pencil.

Table 6. *Post hoc* comparisons of similarity indices (*p* values of LSD comparison)

Groups	Construct-by-self	Construct-on-scaffold	Paper-and-pencil
Construct-by-self	--------	0.001*	0.005*
Construct-on-scaffold		-------	0.000*
Paper-and-pencil			-------

*$p < 0.01$

Students' opinions on concept mapping strategies

Students' responses to the questionnaires are shown in Table 7. The responses for each item were converted into 'agree' (answers of 'strongly agree' or 'agree') or 'disagree' (answers of 'strongly disagree' or 'disagree'), and were submitted to a χ^2 test. The main findings may be summarised as follows:

- On the difficulties encountered during map construction: 94% of the students reported that map construction was effort-demanding work and needed elaborate consideration (item 1). Seventy-five percent of the students agreed that an increase in the concept nodes and relation links increased the difficulties of map construction. The majority of students (87%, 100%, and 77% for the three groups, item 2) agreed that they needed and had hoped for assistance during their map constructions. The hints (92%, item 4) and the feedback (82%, item 5) were important functions. These opinions confirmed that the scaffolding and guiding procedures designed in this system were appropriate for students.

Table 7. The percentage (and number) of agreement on the items in the questionnaire *

	Items	**Groups**			
		By self	**By scaffold**	**Paper & pencil**	χ^2
	The opinions about concept mapping (for all groups)				
1	Constructing a concept map is a stimulating and effort-demanding job.	93.3 (14)	87.5 (14)	100 (17)	2.2
2	When I was constructing a map and encountered an impasse, I usually wished I could get some assistance.	86.7 (13)	100 (16)	76.5 (13)	4.2
3	The number of concept nodes and relation links did not affect the map-construction load.	26.7 (4)	31.3 (5)	17.6 (3)	0.85
4	I can complete a map by myself, so the hints were not necessary.	20.0 (3)	0 (0)	5.9 (1)	4.3
5	Knowing the accuracy of a map is important for map construction.	73.3 (11)	87.5 (14)	76.5 (13)	1.1
	The effectiveness of using concept mapping (for all groups)				
6	Concept mapping is helpful to biology learning.	100 (15)	93.8 (15)	70.6 (12)	7.2**
7	Concept mapping is helpful for organising lesson contents.	93.3 (14)	87.5 (14)	82.4 (14)	0.88
8	Concept mapping is helpful for mastering the learning materials.	93.3 (14)	93.8 (15)	70.6 (12)	4.6
9	It's much easier to catch the essential concepts after map construction.	93.3 (14)	93.8 (15)	64.7 (11)	6.6**
	Affective acceptance of concept mapping (for all groups)				
10	Learning the skill of concept mapping is too difficult.	53.3 (8)	58.8 (8)	50.0 (10)	0.27
11	I like the teacher using concept mapping as . an instructional aid	86.7 (13)	87.5 (14)	53.0 (9)	6.8**
12	If it's possible, I would like to use concept mapping in my future studies.	93.3 (14)	87.5 (14)	53.0 (9)	8.8**
13	It's boring to construct a concept map; I will not do it any more.	26.7 (4)	12.5 (2)	23.5 (4)	1.1
	Using the computerised concept mapping (for two computer-based groups)				
14	I think it would be easier to construct a map through paper and pencil.	26.7 (4)	25.0 (4)		0.01
15	Constructing a concept map using the computer is very interesting.	86.7 (13)	93.8 (15)		0.44
16	Providing some parts of a map would be helpful for thinking.	93.3 (14)	87.5 (14)		0.30
17	The function of 'Hint' in the system is of no use for map-construction.	26.7 (4)	18.8 (3)		0.28
18	When I was constructing a map, I benefited a lot from the 'Evaluation' function of the system.	1.9 (14)	93.3 (15)	93.8	

* The χ^2 is calculated from the differences of percentages of agreement and disagreement (or 100% subtracted percentage of agreement) between three or two groups.

** $p < 0.05$

- With regard to the belief that concept mapping is helpful to learning: all students in the 'constructing by self' group and 94% in the 'constructing on scaffold' group expressed positive opinions on concept mapping as a useful strategy for biology learning. Only 71% of the students in the 'paper-and-pencil' group believed that concept mapping was helpful to learning. The majority of students in the two computer-based groups agreed that concept mapping could help them master or acquire the essential points of their learning materials (94% in item 8 and item 9). This percentage was higher than that of the paper-and-pencil group (71% and 65% in item 8 and item 9).

- For affective acceptance of concept mapping: about half of the students said that the skill of concept mapping was difficult to learn. The students in the 'construct-by-self' and the 'construct-on-scaffold' groups would have liked their teacher to use concept mapping as an instructional aid (88% on average, for item 11) or would like to use concept mapping as a strategy for future learning (91% on average, for item 12). The number of these students was greater than the students in the 'paper-and-pencil' group (53% for item 11 and 12).

Regarding the questionnaire for the two computer-based groups, 73% in the 'construct-by-self' group and 75% in the 'construct-on-scaffold' group said that constructing maps with a computer might be easier than constructing a map using paper and pencil. Ninety percent of all the students agreed that constructing a map in the computer was very interesting. The majority of students agreed that the 'Hint' and 'Evaluation' functions provided by the system were very beneficial to their map-construction (on average, 76% and 94% for item 17 and item 18).

Discussion and conclusions

The proposed concept mapping system can serve as a useful learning strategy

In the 'construct-by-self' procedure, students acquired the similarity index and relevant hints as feedback. In the 'construct-on-scaffold' procedure, in addition to that feedback, students were provided with the framework of an expert concept map. The experimental results indicated that the 'construct-on-scaffold' system had more positive effects on students' biology learning than those of the 'construct-by-self' and 'paper-and-pencil' methods. There was no significant difference between the learning effects of the 'construct-by-self' and the 'paper-and-pencil' methods. The fact that learning through a scaffold produced the best learning effects may result from the reduced workload of the scaffold aid. Paas (1992) suggested that to avoid a possible overload on students, a 'completion strategy' (similar to the 'construct-on-scaffold' method) is a good way of presenting learning materials. The framework of an expert concept map provided the user with a 'semistructure' for their learning content and reduced cognitive load. The energy saved was used to work on the blanks in the framework and master the entire content.

There may be two explanations for the finding that there was no significant difference in the learning effects between students in the 'construct-by-self' and 'paper-and-pencil' groups. One is again the workload. Although the similarity index, evaluating outcomes and guiding hints to the students who constructed through the system were provided, forming a structure of the contents without more support may be still too difficult. Another possibility is the achievement–treatment interaction effect. Tobias (1976) hypothesised that the higher a person's level of prior achievement, the less instructional support is required. Following the same assumption, Alvermann (1981) proposed that the lower ability learner will benefit more from the graphic organiser strategy. Similarly, Kintsch (1990) found that the higher comprehender used elaborate strategies less frequently than the lower comprehender. Since the prior biology achievement of the 'construct-by-self' group was the highest among the three groups, it is possible that their higher prior knowledge made them less engaged and benefited less from the concept mapping strategy than the other two groups. Both possible causes, however, remain to be further explored. What is worthy of further mention is that although the learning effect of the 'construct-by-self' group is not better than that of the 'paper-and-pencil' group, its percentages of map-completion and acceptance of concept mapping are higher than those of the 'paper-and-pencil' group. This study confirmed the concept mapping system as a useful tool for learning which is consistent with the results of many studies about the applications of concept mapping (Novak & Gowin, 1984; Schmid & Telaro, 1990; Nakhleh & Krajcik, 1994).

Providing feedback during map construction is important

Reader & Hammond (1994) and Fisher (1990) found that students were either unable to complete or unwilling to revise their concept maps. In their studies, little feedback for map construction was mentioned. The present study found that the appropriate feedback provided by the system could effectively help students revise and complete their concept maps. Since the similarity index represents the degree of similarity between the student and expert concept maps, this index may also be viewed as an index of completeness and accuracy. The similarity indices of the two computer-based groups were much higher than that of the paper-and-pencil group to which feedback was unavailable. This finding indicates that the two computer-based groups did do a better job in revising or completing their concept maps. Students' opinions on the use of concept mapping may also serve as indirect evidence. The majority of students in the two computer-based groups said that they had benefited a lot from the evaluation and hint functions. They also expressed much more positive acceptance of concept mapping as a future study tool. The feedback function in this system may not only reduce the possibility of frustration caused by trial-and-error, but also further stimulate students' positive attitudes and active participation in the map construction.

Students' reflective thinking can be facilitated through guided learning

One of the important functions of a learning system is to develop reflective thinking by students (Collins & Brown, 1988). To integrate small pieces of knowledge into a complete and elaborate knowledge structure is by no means an easy job. Although Novak & Gowin (1984) considered concept mapping as a tool for learning how to learn, this study found that about 50% of the junior high school students felt that using concept mapping as a learning tool was difficult . This study successfully demonstrated that guided learning (Brown & Campione, 1993) could effectively stimulate reflective thinking in students and encourage the revision and completion of their concept maps. Using guided concept mapping, some of the disadvantages of the traditional paper-and-pencil concept mapping method can be overcome.

Although it was found that concept mapping with a scaffold produced a more positive effect on student learning, two points are worthy of further consideration. Firstly, the flexibility of map construction in computer-based concept mapping requires further investigation. Heeren & Kommers (1992) recommended that the flexibility of map construction is a major principle in concept mapping. A flexible method for students to construct maps may benefit a greater number of students with different learning styles or skills. In this study, the students using the 'construct-on-scaffold' version outperformed the students using the 'construct-by-self' version, yet the 'construct-by-self' version evoked the highest percentage of students who wanted to use concept mapping in their future studies (see Table 7, item 12). It is possible that the semistructure provided by the 'construct-on-scaffold' version serves as a useful learning adjunct in short/medium-term learning. Possibly, this adjunct becomes a kind of constraint that limits students' map construction, especially when their knowledge becomes more sophisticated. On the contrary, after long-term learning, the flexibility in the 'construct-by-self' version may turn out to be a more valuable tool for self-learning. Anyway, more experiments involving students' characteristics and learning duration are needed to verify if a trade-off exists between the map construction complexity and learning efficiency.

Secondly, in this study, the 'construct-on-scaffold' version provided students with a semistructure by which students may learn well in the short/medium-term. The long-term learning effects through this assistance remain to be tested. Such scaffolding can be combined with the functions of the 'construct-by-self' version for the long-term learning. This combination may promote students to engage in deeper learning and follows scaffold-fading instruction (Day *et al.*, 1989). Through the scaffold-fading instruction, a semistructure is first provided for students who complete the blanks in the semistructure. In the earlier stages, this makes the work less difficult and in later stages, students are gradually allowed to construct their own maps independently and process the learning material in deeper, more idiosyncratic ways (Sung *et al.*, 2000). By the ways mentioned, concept mapping with scaffold-fading instruction may be optimised to more adaptable and efficient learning.

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