Analyzing the Effects of various Concept Mapping Techniques on Learning Achievement under different Learning Styles

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ABSTRACT

This study explored the effectiveness of different concept mapping techniques on the learning achievement of senior accounting students and whether achievements attained using various techniques are affected by different learning styles. The techniques are computer-assisted construct-by-self-concept mapping (CACSB), computer-assisted construct-on-scaffold concept mapping (CACOS), paper-and-pencil concept mapping (PAP), and traditional textbook exercise (TTE) methods. A pretest-posttest control group design was employed. The subjects were 151 students who were taking an advanced accounting course. An analysis of covariance was used to analyze the results. The research findings are fourfold: (1) the two computer-assisted concept mapping techniques (CACSB and CACOS) are more beneficial to students' learning achievement than PAP and TTE; (2) PAP is better than TTE in relation to students' learning achievement; (3) when students' different learning styles were taken into account, CACOS offers better assistance to students who have accommodating and converging learning styles, followed by CACBS, PAP, and TTE; (4) for students who have assimilating and diverging learning styles, CACSB has the most significant effects on their learning achievement, followed by CACOS, PAP, and TTE. The computer-assisted concept mapping technique needs to fit learners' learning styles. The match between learning styles and learning techniques will further enhance learning achievement.

Keywords: learning style, computer-assisted construct-by-self-concept mapping, computer-assisted construct-on-scaffold concept mapping, paper-and-pencil concept mapping

INTRODUCTION

A concept map is a hierarchically arranged, graphic representation of meaningful relationships among concepts (Hsieh, Ho, Wu, & Ni, 2016; Novak, 1990). Concept mapping is

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State of the literature

- Concept mapping is considered to be an applicable learning technique that can facilitate learners to retrieve, organize, and relate concepts.
- Although many studies have shown that concept mapping can improve learning performance, most of these studies were based on the paper-and-pencil approach.
- There are two main computer-assisted concept mapping techniques: computer-assisted construct-by-self-concept mapping (CACSB) and computer-assisted construct-on-scaffold concept mapping (CACOS). However, inconsistent findings reveal which technique is better at enhancing learning achievement.

Contribution of this paper to the literature

- This study compares the effects of the three concept mapping techniques (CACSB, CACOS, and paper-and-pencil) and traditional textbook exercise (TTE) methods on learning achievement. Furthermore, this study also considers the moderating effects of students' learning style.
- The results of this study confirm the effects of concept mapping techniques. The computer-assisted concept mapping techniques (i.e. CACSB and CACOS) have better effects than paper-and-pencil concept mapping technique. Students should consider their learning styles when selecting CACSB or CACOS as a learning method.

a learning strategy that helps learners organize various concepts (Liu, Chen, & Chang, 2010). Previous studies have demonstrated that concept mapping can improve student learning. For example, concept mapping can improve the abilities of students to solve problems (Novak, Gowin, & Johanson, 1983; Trowbridge & Wandersee, 1996), facilitate meaningful learning (Malone & Dekkers, 1984), serve as a knowledge and performance assessment tool (Chu, Hwang, & Huang, 2010; Ruiz-Primo & Schavelson, 1996), decrease student learning anxiety (Jegede, Alaiyemola, & Okebukola, 1990), record learners' cognitive transformations (Wallace & Mintzes, 1990), improve reading comprehension and writing ability (Liu, 2011), and improve memory and learning effectiveness (Chiou, 2008; Hsieh *et al.*, 2016; Huang *et al.*, 2012).

ASSIMILATION THEORY OF COGNITIVE LEARNING AND CONCEPT MAPPING

The concept mapping strategy in education is based on Ausubel's assimilation theory of cognitive learning (Ausubel, Novak, & Hanesian 1978). According to this theory, meaningful learning facilitates high-level learning and occurs when students learn by self-discovery (Ausubel, 1968). Meaningful learning is often characterized by new information linked to an existing cognitive structure, making strong connections to the current concept structure. Based on both of these theories, Novak *et al*. described concept mapping as a teaching, learning, and assessment tool in 1972. It was then developed further by Novak, Gowin, and Johansen (1983) and Novak and Gowin (1984).

Concept mapping is a useful instructional strategy that facilitates meaningful learning. Based on Ausubel's theory, a key determinant of meaningful learning is the framework of

relevant concepts or propositions that an individual possesses (Chiou, 2009; Novak *et al.*, 1983). In the learning process, learners absorb new knowledge and connect it to relevant concepts or propositions they already possess; this new knowledge then becomes intertwined with their cognitive structure. When connection strength is adequate, students will be successful (Schau & Mattern, 1997). Hence, instructors must help students develop skills for making connections between new knowledge and existing knowledge.

The most basic concept maps are composed of two concepts with one linking word; this forms a proposition. That is, 'propositions' are two or more concept labels linked by words in a semantic unit. For instance, the consolidated Balance Sheet and consolidated assets are two accounting concepts connected by the fact that combined assets are included in a consolidated Balance Sheet. "Include" is a linking word which often makes a connection or proposition meaningful. Concept maps are typically hierarchical. That is, general and inclusive concepts are at the top of the map, followed by progressively more specific and less inclusive concepts (Huang *et al.*, 2012; Novak & Gowin, 1984). For instance, consolidated equities of shareholders are included in a consolidated Balance Sheet, while subsidiary equities of shareholders are included in the consolidated equities of shareholders and subsidiary dividends are included in the subsidiary equities of shareholders. This hierarchy has three levels with the most general concepts on the top and the most specific concepts at the bottom. The 'hierarchical' character of concept maps makes meaningful learning proceed easily by subsuming new concepts or concept meanings under broad inclusive concepts (Chiou, 2009; Novak & Gowin, 1984). Connected concepts in different hierarchies in a concept map are linked by cross links. These cross links serve an important integrative function when constructing a map (Jacobs-Lawson & Hershey, 2002). For example, the relationship between the dividends of the parent company and subsidiary companies (included in the parent and subsidiary shareholders' equities, respectively) can be represented by a cross link with the linking phrase of "eliminate dividends of the parent and subsidiary companies."

COMPUTER-ASSISTED CONCEPT MAPPING

Computer-assisted concept mapping is the process by which concept map construction is aided by a computer. By incorporating computer-assisted learning and concept mapping as a learning strategy, learners can create concept maps and achieve learning effectiveness (Liu *et al.*, 2010). Advantages of computer-assisted concept mapping include easy and fast map construction, easy revisions, the possibility of instant feedback from an instructor, and good interaction between instructor and learner (Anderson-Inman & Zeitz, 1993; Kwon & Cifuentes, 2009; Liu, 2011; Liu *et al.*, 2010; Royer & Royer, 2004).

Although many studies have shown that concept mapping can improve learning, most of these studies are based on the paper-and-pencil approach. However, some studies (Chang, Sung & Chen, 2001; Liu *et al.*, 2010) have argued that paper-and-pencil concept mapping has the following disadvantages: (a) instant feedback from teachers is inconvenient; (b) the construction of a concept map is difficult for novices; (c) if the concept map involves many

concepts, it may be too complicated to fill in all the needed information; (d) revising paper-and-pencil concept maps is difficult; and (e) a paper-and-pencil concept map is not an efficient evaluation tool. To solve these problems, researchers have developed or used computer-assisted concept mapping systems, such as Inspiration, expecting that computer-assisted concept mapping could help students efficiently construct and revise concept maps, improve the interaction between teacher and student, and enhance student learning achievement (Anderson-Inman & Horney, 1996; Anderson-Inman & Zetiz, 1993; Chang *et al.*, 2001; Liu, 2011; Liu *et al.*, 2010; Reader & Hammond, 1994; Royer & Royer, 2004).

Despite its many benefits compared to a paper-and-pencil approach, computer-assisted concept mapping also has some drawbacks. For instance, novices may get frustrated easily, feedback from experts is difficult, students' learning motivation can be decreased and students' learning does not easily focus on the subject of the mapping process (Chang *et al.*, 2001; Charsky & Ressler, 2011; Kaminski, 2002). Therefore, some researchers proposed a revised concept mapping technique: *construct-on-scaffold* (or called *select-and-fill-in*) (Kaminski, 2002; Soleimani & Nabizadeh, 2012). However, Chang *et al.* (2001, p.31) argued that the flexibility of map construction in computer-based concept mapping requires further investigation. A flexible method for students to construct maps may benefit students with different learning styles. To date, no study has determined whether students with different learning styles benefit from different concept mapping approaches. The literature indicates that students with different learning styles typically construct different concept maps and attain different learning achievements (Budd, 2004; Kaminski, 2002; Oughton & Reed, 2000; Reed & Oughton, 1998). Therefore, this study compared student learning achievement from four learning techniques, i.e. three different concept mapping methods and the traditional textbook exercise (TTE) method.

The three different concept mapping approaches are *the paper-and-pencil approach* (PAP), *the computer-assisted construct-by-self approach* (CACBS), and *the computer-assisted construct-on-scaffold approach* (CACOS). CACBS requires students to use computer software for constructing a concept map without any aid or hint. CACOS requires students to complete unfinished parts of expert-generated concept maps. This approach gives incomplete expert-generated concept maps as a scaffold in which nodes and links are blank. Students then fill in these concept maps. This technique has been proven to be effective for assessing knowledge structures (Chang *et al.*, 2001; Naveh-Benjamin *et al.*, 1998). Additionally, the approach provides an expert knowledge structure that reduces the mental load for novice students (Chang *et al.*, 2001).

LEARNING STYLE AND CONCEPT MAPPING

Learning style is the strategy that learners use in different learning contexts (Schmeck, 1983). Different learners always adopt and prefer specific learning strategies (Sarasin, 1999). Bostrom, Olfman and Sein (1990) found that individuals with different learning styles employ different training methods and produce dissimilar learning achievements. Kolb (1984) and

Shaw (2012) asserted that learning is most effective when learning strategies are based on a student's learning style.

Among learning style models, Kolb's Learning Style Model is the most widely accepted learning style model and has received a substantial amount of empirical support (Kayes, 2005; Manolis, Burns, Assudani, & Chinta, 2013; Ocepek, Bosnic, Serbec, Rugelj, 2013). The Kolb Learning Style Inventory differs from other instruments of learning style used in education. It was developed based on experiential learning theory (Kolb & Kolb, 2005). According to this theory, learning styles work on a four-stage cycle comprising concrete experience, reflective observation, abstract conceptualization, and active experimentation. Based on the cycle, learners have four styles: Accommodator, Diverger, Assimilator, and Converger (Kolb, 2006).

Accommodators prefer concrete experience and active experimentation. These students enjoy executing plans or gaining experience through missions. However, Accommodators lack organizational skills, do not enjoy thinking creatively, and generally solve problems intuitively or through trial and error. They also rely heavily on information provided by others. Therefore, Accommodators can be effective when given direct instructions (Kolb, 1985; Reed & Oughton, 1998). Their strengths lie in building relationships between concepts and practical experience, rather than simply learning by reading or through classroom exercises (Kolb, 1981).

Divergers generally prefer concrete experience and reflective observation. Their strength lies in their imaginative and analytical mind. They are effective in understanding the big picture, and enjoy autonomous, open-learning activities, such as brainstorming and innovating. Divergers also enjoy and excel at self-diagnosis and open-ended unstructured activities (Kolb, 1985; Reed & Oughton, 1998).

Assimilators tend to prefer reflective observation and abstract conceptualization. They like to observe and think. Their strengths are in their inductive reasoning skills and their ability to create theoretical models and concepts. Assimilators have the ability to organize and integrate a large amount of information. They are both inventors and thinkers. Assimilators usually develop their own way of learning when they meet a challenge (Kolb, 1985).

Convergers typically prefer active experimentation and abstract conceptualization. They are pragmatic, and are skilled at solving problems, making decisions, and gaining experience using assumptions and inferences. They believe that every question has an answer and do their best to find the answer. Convergers fully utilize their ability to hypothesize and deduce to acquire knowledge. They also make use of available resources, such as teachers, experts, or hands-on experience, to obtain knowledge (Kolb, 1984; Reed & Oughton, 1998).

Oughton and Reed (2000) demonstrated that learners with the assimilating and diverging learning styles are the most productive in constructing concept maps because individuals with these two learner styles always have diverse perspectives and are very imaginative. Learners with accommodating and converging styles prefer intuition and risk seeking and usually omit more specific concepts in their concept maps. Kaminski (2002) found

that the Accommodator and Diverger types prefer fill-in-the-blank concept maps. However, the Converger and Assimilator types, who emphasize abstract conceptualization, perform well on fill-in-the-blank concept maps. Therefore, we infer that learners with different learning styles that use various concept mapping techniques can generate different learning achievement. Therefore, this study analyzes whether the effects of different concept mapping techniques on learning achievement are influenced by various learning styles.

The primary research questions are as follows.

1. Do the different learning techniques (i.e. the three concept mapping methods and traditional textbook exercise method) have different effects on students' learning achievement?
2. Are differences in learning achievement among the three concept mapping methods and the textbook exercise method explained by differences in students' learning styles?

METHOD

Experimental design and participants

Following Chiou's (2009) method, a pretest-posttest control group design was used. Subjects were 151 students in the accounting and information department, 43 males and 108 females, from four classes at a university in Taiwan. Students in each class were randomly assigned to four groups (three experimental groups used CACOS, CACBS, and PAP and the control group used TTE). The learning style test and academic achievement pretest was administered to all the students before the experiment and they completed the academic achievement posttest at the end of the experiment. The four classes were taught by the same instructor, an experienced teacher who has taught advanced accounting for six years.

Instruments

Accounting achievement test

The pretest and posttest evaluated the accounting learning achievement of students. The four groups of students took the same pretest before the experiment. The pretest examined whether students had the same level of accounting knowledge prior to the experiment. Then these students used different learning techniques (i.e. CACOS, CACBS, PAP, and TTE) for learning accounting. After the experiment, these students took the posttest to assess their learning achievement.

Each accounting achievement test (*i.e.* the pretest and posttest) had 40 multiple-choice items. These test items were selected from the question pool in the textbook and were based on course progress. The students scored 2.5 points for each correct answer to the item. The topics in the accounting achievement pretest included "Business Combination" and "Investor Accounting and Reporting." The accounting achievement posttest covered themes relating to

Consolidated Financial Statements, Consolidation Techniques and Procedures, Intercompany Profit Transactions, and Consolidations - Changes in Ownership Interests.

Items were examined using two-way specification tables with sections for knowledge, comprehension, application, analysis, synthesis, and evaluation. The two-way specification table analyses ensured the content validities based on accounting teaching objectives (Fives & DiDonato-Barnes, 2013). The KR-20 reliabilities for the pretest and posttest were 0.81 and 0.84 in the current sample, respectively.

Learning style scale

A five-point Likert scale with a 12-item instrument called the learning style scale, which was developed by Kolb (1984), was used. Blakemore, McCray, and Coker (1984) and Sewall (1986) demonstrated that this instrument is appropriate for college students and adults and it has good construct validity. Veres, Sims, and Locklear (1991) also showed that this instrument accurately measures the effectiveness of these learning styles. The Cronbach Alpha coefficients of the four dimensions of the instrument were between 0.77 and 0.87 for the study sample. According to the rule of thumb, the internal consistency is good or excellent (Kline, 1999).

Concept mapping instruction

The concept mapping instructional procedures in this advanced accounting course were designed based on standardized procedures from the study by Novak and Gowin (1984, pp. 32–34) and are as follows.

(a) The instructor introduced accounting concepts and asked students to list examples.

(b) The instructor introduced linking words and asked students to list examples.

(c) The instructor introduced two concepts with one linking word to create one proposition and asked students to create their own propositions.

(d) The instructor took one unit in the textbook as an example to introduce a hierarchy and listed all important accounting concepts. The instructor and students discussed general and specific concepts.

(e) Students constructed concept maps.

(f) The instructor introduced cross links and discussed how to cross links among different hierarchies with students.

(g) Students completed final concept maps.

Figures 1 and **2** show the concept maps that were created by the students in the CACOS and CACBS groups.

Procedure

The research procedure is shown in **Figure 3** and has three experimental stages: the pretest stage, formal experimental stage, and posttest stage.
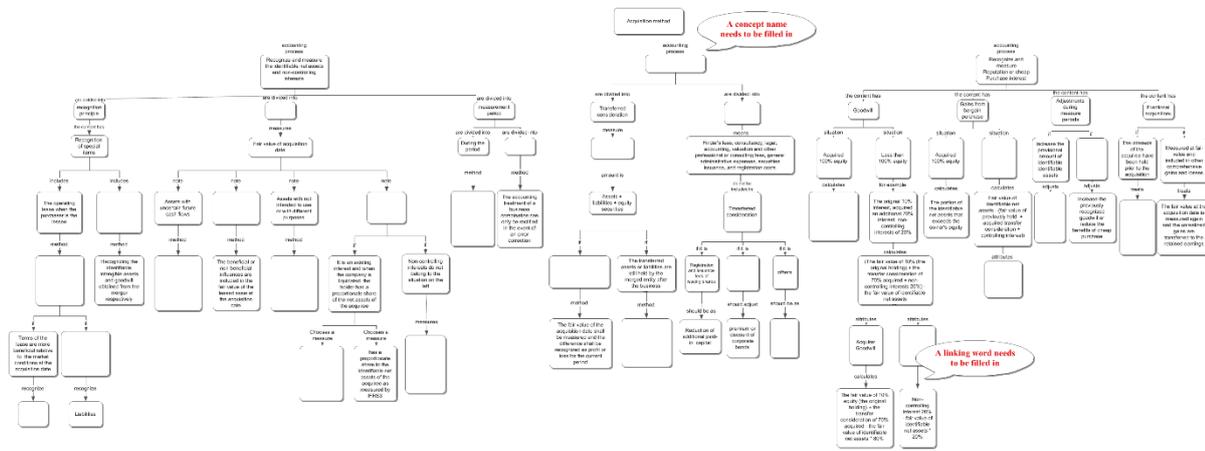
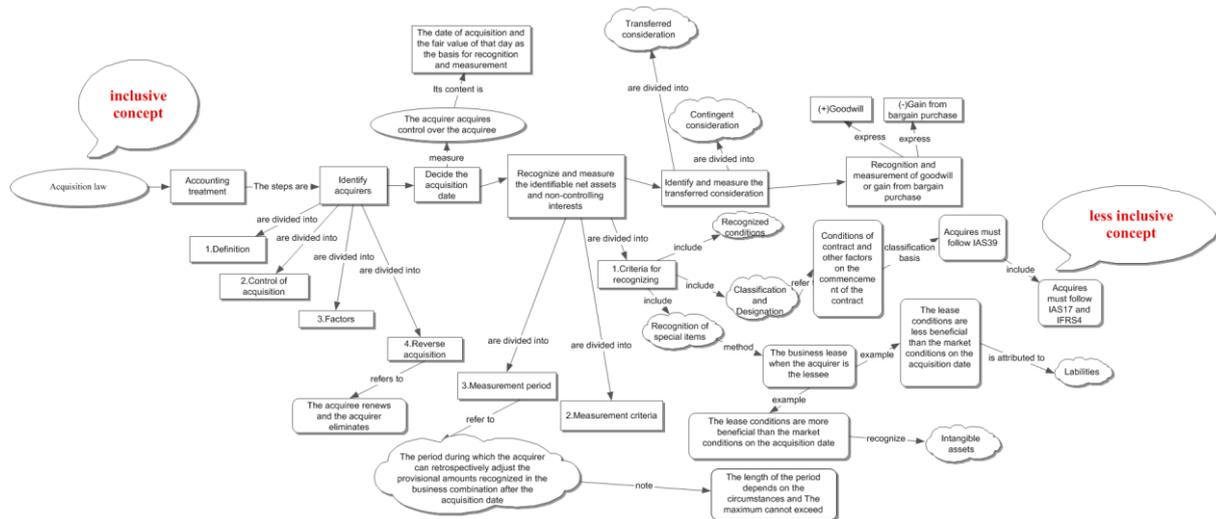**Figure 1.** An example of a fill-in-blank concept map for the CACOS group

Figure 2. A concept map constructed by a student in the CACBS group

Pretest stage

During week 1, all participants were assessed with the learning style scale. The first two chapters in the textbook were taught by the same instructor during weeks 2, 3, and 4. In week 5, the two-hour pretest was administrated as the accounting achievement pretest to ensure that students in the four groups had the same accounting knowledge.

Formal experimental stage

After the pretest, the experiment was conducted. Students in four classes were randomly assigned to either the CACOS, CACBS, PAP or TTE group. All computer-assisted groups (i.e. CACOS and CACBS) constructed concept maps using the Inspiration software. The CACOS group filled in blanks on incomplete expert concept maps with concepts or linking
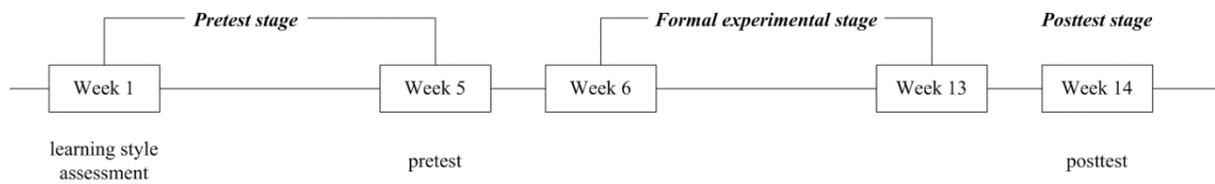
Figure 3. The research procedure

words. The CACBS group used Inspiration software to complete their own work on accounting concepts given by the instructor. The PAP group completed their concept maps by using paper and pencil. Notably, the TTE control group was the only group allowed to practice using textbook exercises during the experiment.

After the pretest, all participants were taught with the same one-way instructional method using self-prepared teaching materials for chapters 3 and 4. The experiment was conducted during two additional teaching assistant (TA) hours after each class. In the first TA time, CACOS, CACBS, and PAP concept mapping groups learned about their relative concept mapping technique, including instruction on concept maps, how to use Inspiration software (only for the computer-assisted groups), issues related to concept maps, and how to construct concept maps based on chapters 1 and 2.

In week 7, the students in the experimental groups constructed their concept maps based on learned contents. The instructor, researcher, and TAs were available to answer questions related to their concept maps. The students' concept maps were also graded by the instructor, researchers, and TAs using the guidelines presented by Novak and Gowin (1984). Misconceptions and an insufficient number of cross links were always identified in the concept maps developed by students. The teacher taught the important course contents again and then students modified their maps. This process was repeated until the end of the experiment. The experiment was executed over 8 weeks for a total of 16 hours.

During each two-hour experimental period, students in the TTE group practiced answering textbook questions; some were selected to write their answers on the board in front of the class and the teacher discussed and corrected answers. This process also continued until the end of the experiment.

Posttest

The two-hour posttest was administered in the week immediately following the experiment.

Statistical analytical approach

Effect size and analysis of covariance (ANCOVA) were used to analyze the experimental results. Effect size measures the influence strength of the learning technique (i.e. the three concept mapping techniques and TTE) and is computed as the mean score of the

Table 1. *Descriptive statistics: CACOS, CACBS, PAP, and TTE groups*

	CACOS		CACBS		PAP		TTE	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Pre-test score	49.54	14.33	48.83	13.23	50.35	12.76	50.93	11.82
Post-test score	81.32	12.23	80.62	13.18	63.89	12.94	50.43	13.28
Effect size	2.22	-	2.40	-	1.06	-	-0.04	-
N	38		38		36		35	

Note. CACOS represents the computer-assisted construct-on-scaffold group, CACBS represents the computer-assisted construct-by-self group, PAP represents the paper-and-pencil group, and TTE represents the traditional textbook exercises group. Effect size measures the influence of the learning strategy and is computed as the mean score of the post-test minus the mean score of the pre-test, divided by the standard deviation of the pre-test. N indicates the number of students.

post-test minus the mean score of the pre-test, divided by the standard deviation of the pre-test (Cohen, 1988). An ANCOVA in which the pre-test scores of the groups were the covariates and their post-test scores were the dependent variables was conducted to compare the equality of post-test means among the groups.

RESULTS

Effects of different learning techniques on learning achievement

The average pretest and posttest scores and effect size for each group were as follows: 49.54, 81.32 and 2.22 for the CACOS group; 48.83, 80.62, and 2.40 for the CACBS group; 50.35, 63.89, and 1.06 for the PAP group; and 50.93, 50.43, and -0.04 for TTE group, respectively (**Table 1**). In measuring learning achievement, the effect size for the groups from best to worst was CACBS, CACOS, PAP, and TTE. In addition, according to Cohen's (1988) rule, the two computer-assisted and paper-and-pencil concept mapping techniques all have great effects on students' learning achievement because their effect sizes are large.

ANCOVA (**Table 2**) indicated that significant differences in post-test scores among groups existed ($F = 67.74$, $p < .01$). Thus, different learning techniques (i.e. CACOS, CACBS, PAP, and TTE) impacted learning achievement after controlling for the pre-test. *Post hoc* comparisons using Fisher's least significant difference (LSD) procedure indicated that students in three concept mapping groups performed significantly better ($t = 9.80$, $p < .01$; $t = 9.29$, $p < .01$; $t = 3.32$, $p < .01$) than did the TTE group (i.e. control group). Both computer-assisted concept mapping groups (CACOS and CACBS) performed significantly better ($t = 6.49$, $p < .01$; $t = 5.98$, $p < .01$) than did the PAP group. However, no significant difference ($t = 0.52$, $p = 0.81$) in learning achievement existed between the CACOS and CACBS groups. These experimental results underline three important points. First, concept mapping techniques can elevate students' learning achievement more than traditional textbook exercises. Second, students using computer-assisted concept mapping performed significantly better than those using paper and pencil. Third, no significant difference existed in learning achievement between the two groups using computer-assisted concept mapping.

Additionally, a statistically significant difference ($F = 2.49$, $p < .05$) existed, as shown **Table 2**. The result showed that the impacts on learning achievement of the four learning

Table 2. Analysis of covariance in learning achievement posttest scores of four groups

(a) ANCOVA result

Source of variance	SS	df	MS	F
Group	23977.30	3	7992.43	67.74**
Learning style	1999.40	3	666.47	5.65**
Group*learning style	2644.99	9	293.89	2.49*
Covariate	5311.61	1	5311.61	45.02**
error	15339.01	130	117.99	

Note. The pretest score is the covariate.

(b) post hoc comparisons

Groups differences	Difference in means	t
CACOS-CACBS	0.70	*0.52*
CACOS-PAP	17.43	6.49**
CACBS-PAP	16.73	5.98**
CACOS-TTE	30.89	9.80**
CACBS-TTE	30.19	9.29**
PAP-TTE	13.46	3.32**

* p < .05 ** p < .01.

techniques varied with learning styles. The interaction between group (i.e. learning technique) and learning style was statistically significant ($F = 2.49$, $p < .05$).

The Impacts of learning styles on the relationships between the four learning techniques and learning achievement

To investigate the impacts of learning styles on the relationship between the four learning techniques and learning achievement, data were analyzed further. The ANCOVA result (**Table 3**) showed that for Accommodator students, the group variable was statistically significant ($F = 23.25$, $p < .01$), indicating that after controlling for pre-test scores, different learning techniques had a significant effect on students' learning achievement. The *post hoc* comparisons showed that learning achievement in the CACOS, CACBS, and PAP groups was significantly better than that of the TTE group ($t = 7.96$, $p < .01$; $t = 5.42$, $p < .01$; $t = 2.84$, $p < .01$), while learning achievement of the CACOS and CACBS groups was also significantly better than that of the PAP group ($t = 5.13$, $p < .01$; $t = 2.51$, $p < .05$), and learning achievement of the CACOS group was significantly better than that of the CACBS group ($t = 2.74$, $p < .01$). Thus, for Accommodators, concept mapping techniques enhances their learning achievement better than the traditional method of doing textbook exercises, and computer-assisted concept mapping is also more effective for their learning achievement than paper-and-pencil concept mapping. CACOS assists Accommodator students more in terms of learning achievement than CACBS.

For Diverger students, the ANCOVA result (**Table 4**) showed that after controlling for covariates, a statistically significant difference existed among the post-test scores for the four groups ($F = 24.93$, $p < .01$). The *post hoc* comparisons showed that the CACOS, CACBS, and

Table 3. Analysis of covariance in posttest scores of four groups (Accommodator)

(a) ANCOVA result

Source of variance	SS	df	MS	F
Group	6634.40	3	2211.47	23.25**
Covariate	1745.44	1	1745.44	18.35**
Error	3424.79	36	95.13	

Note. The pretest score is the covariate.

(b) post hoc comparisons

Groups differences	Difference in means	t
CACOS-CACBS	11.54	2.74**
CACOS-PAP	22.50	5.13**
CACBS-PAP	10.96	2.51*
CACOS-TTE	33.50	7.96**
CACBS-TTE	21.96	5.42**
PAP-TTE	11.00	2.84**

Note. The average pretest and posttest scores of the CACOS group are 50 and 87, the average pretest and posttest scores of the CACBS group are 50.27 and 75.46, the

average pretest and posttest scores of the PAP group are 49.75 and 64.5, and the average pretest and posttest scores of the TTE group are 52.5 and 53.5.

* $p < .05$ ** $p < .01$.

Table 4. Analysis of covariance in posttest scores of four groups (Diverger)

(a) ANCOVA result

Source of variance	SS	df	MS	F
Group	5946.86	3	1982.29	24.93**
Covariate	682.50	1	682.50	8.58**
Error	1908.18	24	79.51	

Note. The pretest score is the covariate.

(b) post hoc comparisons

Groups differences	Difference in means	t
CACOS-CACBS	-11.57	-2.37*
CACOS-PAP	11.51	2.87**
CACBS-PAP	23.08	5.38**
CACOS-TTE	28.46	5.89**
CACBS-TTE	40.03	8.17**
PAP-TTE	16.95	3.47**

Note. The average pretest and posttest scores of the CACOS group are 45.36 and 76.79, the average pretest and posttest scores of the CACBS group are 46.07 and 88.36, the

average pretest and posttest scores of the PAP group are 49.17 and 65.28, and the pretest and posttest scores of the TTE group are 47.5 and 48.33.

* $p < .05$ ** $p < .01$.

PAP groups attained significantly higher learning achievement levels than the TTE group did ($t = 5.89$, $p < .01$; $t = 8.17$, $p < .01$; $t = 3.47$, $p < .01$), while the CACOS and CACBS groups had significantly higher achievement levels than did the PAP group ($t = 2.87$, $p < .01$; $t = 5.38$, $p < .01$), and the CACOS group had significantly lower learning achievement levels than that of the CACBS group ($t = -2.37$, $p < .05$). Thus, for Divergers, concept mapping offers more assistance in terms of learning achievement than traditional textbook exercises, and computer-assisted concept mapping is better than using a paper and pencil. Furthermore, Divergers who use the CACBS method will receive greater assistance in terms of learning achievement than those who use the CACOS method.

Table 5. Analysis of covariance in posttest scores of four groups (Assimilator)

(a) ANCOVA result

Source of variance	SS	df	MS	F
Group	7697.76	3	2565.92	15.73**
Covariate	2345.79	1	2345.79	14.38**
Error	5219.87	32	163.12	

Note. The pretest score is the covariate.

(b) post hoc comparisons

Groups differences	Difference in means	t
CACOS-CACBS	-9.14	-2.19*
CACOS-PAP	14.44	2.07*
CACBS-PAP	23.58	4.39**
CACOS-TTE	28.47	4.16**
CACBS-TTE	37.61	6.51**
PAP-TTE	14.03	2.16*

Note. The average pretest and posttest scores of the CACOS group are 50.28 and 79.72, the average pretest and posttest scores of the CACBS group are 44.55 and 88.86, the average pretest and posttest scores of the PAP group are 47.22 and 65.28, and the average pretest and posttest scores of the TTE group are 46.25 and 51.25.

* p < .05 ** p < .01

For Assimilators, the ANCOVA result (**Table 5**) showed that the main effect was significant, F = 15.73, p < .01, indicating that after controlling for pre-test scores, different learning techniques significantly impacted students' achievement. The *post hoc* comparisons show that the CACBS group scored significantly higher than the CACOS group on the posttest (t = -2.19, p < .05), the CACOS and CACBS groups scored significantly higher than the PAP group (t = 2.07, p < .05; t = 4.39, p < .01), and the CACOS, CACBS and PAP groups all scored significantly higher than the TTE group (t = 4.16, p < .01; t = 6.51, p < .01; t = 2.16, p < .05). These experimental results demonstrate that for Assimilators, using a concept mapping technique is superior to TTE; computerized concept mapping is superior to traditional PAP; and CACBS is superior to CACOS.

For Convergers, after controlling for pre-test scores, the effect of the group variable on post-test scores was statistically significant (F = 17.90, p < .01) (**Table 6**). The *post hoc* comparisons demonstrate that the CACOS group had significantly higher learning achievement level than that of the CACBS group (t = 2.15, p < .05), the CACOS and CACBS groups had significantly higher academic achievement levels than the PAP group (t = 4.24, p < .01 ; t = 2.06, p < .05), and the CACOS, CACBS and PAP group had significantly higher learning achievement levels than the TTE group did (t = 7.04, p < .01; t = 4.46, p < .01; t = 2.16, p < .05). That is, the most effective way to enhance the learning achievement of Convergers is to employ the CACOS method. The second best method is CACBS, the third is PAP, followed by TTE.

Table 6. Analysis of covariance in posttest scores of four groups (Converger)

(a) ANCOVA result

Source of variance	SS	df	MS	F
Group	6926.58	3	2308.86	17.90**
Covariate	809.00	1	809.00	6.27*
Error	4515.05	35	129.00	

Note. The pretest score is the covariate.

(b) post hoc comparisons

Groups differences	Difference in means	t
CACOS-CACBS	9.59	2.15*
CACOS-PAP	20.42	4.24**
CACBS-PAP	10.83	2.06*
CACOS-TTE	32.24	7.04**
CACBS-TTE	22.65	4.46**
PAP-TTE	11.82	2.16*

Note. The average pretest and posttest scores of the CACOS group are 51.04 and 80.42, the average pretest and posttest scores of the CACBS group are 54.44 and 70.83, the average pretest and posttest scores of the PAP group are 55.94 and 60, and the average pretest and posttest scores of the TTE group are 54.77 and 48.18.

$* p < .05 \ ** p < .01.$

DISCUSSION AND CONCLUSIONS

The computer-assisted concept mapping techniques (i.e. CACOS and CACBS) enhances more learning achievement

This study finds that computer-assisted concept mapping techniques (i.e. CACOS and CACBS) significantly enhance the learning achievement of students when compared to PAP and TTE. The experimental results are consistent with findings by previous studies (Chang *et al.*, 2001; Liu, 2011; Royer & Royer, 2004). Moreover, this study finds that PAP is better than TTE at improving students' learning achievement.

The positive effect of concept mapping on enhancing students' learning achievement has been supported by studies in many disciplines (Chiou, 2008, 2009; McConnell, Steer, and Owens 2003; Novak and Musonda 1991; Novak *et al.*, 1983). This study empirically supports the effectiveness of concept mapping to promote students learning in accounting. The primary purpose in accounting is to correctly construct financial statements. There are a lot of related and complicated concepts, such as assets, liabilities, shareholders' equities, and revenues of parent companies and subsidiary companies, in accounting. A thorough understanding of the relationships among different accounting concepts is essential. The concept mapping technique can allow students to clarify and understand the complex relationships among these concepts.

Further, the structure of financial statements is hierarchical. The Balance Sheet concept is a more general and total assets, current assets, and the cash under current assets are more specific concepts. This hierarchical structure in accounting is also consistent with the hierarchical presentation of the concept mapping. Therefore, concept mapping can provide

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effective assistance so that students can understand, differentiate, and organize the logical and interrelated relationships among concepts in financial statements. That is, concept mapping facilitates learning by codifying relationships among concepts. Mistakes will be reduced when students completely comprehend the relationships among accounting concepts, which are then manifested as improved academic performance.

Therefore, by using concept mapping techniques, students learn different accounting concepts and are able to organize them, and eventually develop a mental structure based on the relationships among concepts.

This study further finds that computer-assisted concept mapping techniques outperform PAP in improving students' learning achievement in accounting. Many studies (Chang *et al.*, 2001; Charsky & Ressler, 2011; Liu, 2011) have also pointed out that PAP has some weaknesses. For example, teachers are unable to provide fast feedback to students, the technique is difficult for novices, covering all related concepts in a single concept map is difficult, correcting a paper-and-pencil concept map is time-consuming, and overly complicated paper-and-pencil concept maps may reduce a student's learning motivation. Computer-assisted concept mapping allows students to easily and rapidly construct concept maps, and receive faster teacher feedback (Royer & Royer, 2004; Liu, 2011). Interactions between teachers and students in the computer-assisted concept mapping method are more efficient and effective (Anderson-Inman & Zeitz, 1993; Liu *et al.*, 2010). Thus, teachers can help students more as they construct their concept maps via computer software. Their learning frustration and anxiety is also decreased. Consequently, students are more inclined to use concept mapping as a learning method, and they also improve their learning achievement simultaneously. Finally, the computer-assisted concept mapping technique is not restricted by the limits of physical paper size and can include more information in a concept map.

Different learning styles affect the effectiveness of various concept mapping techniques

The experimental results of this study reveal no significant differences in learning achievement exist between CACOS and CACBS. This result differs from the findings of Chang *et al.* (2001) and Soleimani and Nabizadeh (2012). However, Chang *et al.* (2001) also noted that students preferred CACBS to CACOS for learning. Therefore, we should explore whether a moderating variable which influences the different effects of CACOS and CACBS on learning achievement exists. Chang *et al.* (2001) suggested that learning style could be a potential important moderator. Therefore, this study further investigated whether the moderating effects of learning styles exist.

The results of this study show that different learning styles (i.e. Accommodators, Divergers, Assimilators, and Convergers) do influence the learning achievement of students using various concept mapping techniques.

Figure 4-7 show examples of concept map constructing by Accommodators, Divergers, Assimilators, and Convergers. The concept map in **Figure 4**, constructed by an Accommodator
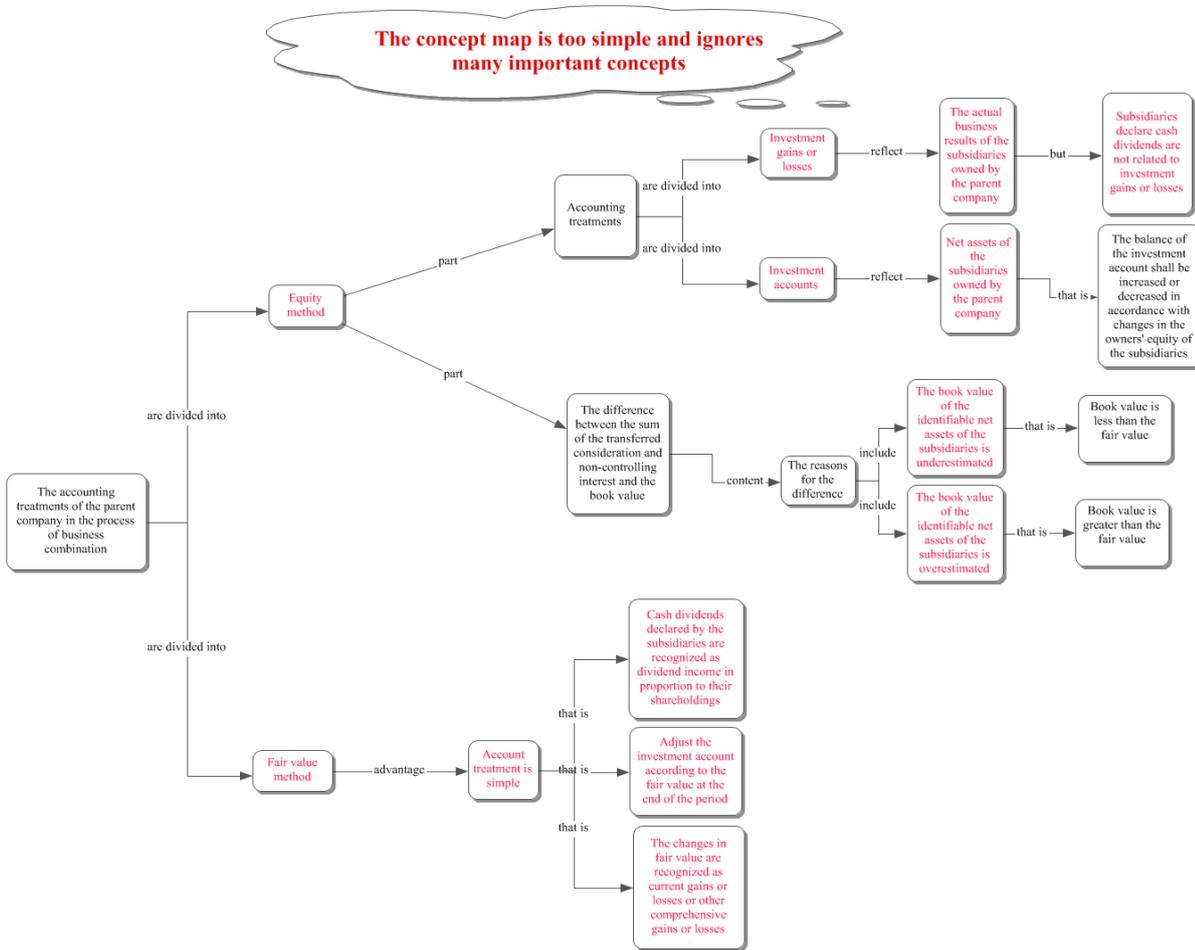
Figure 4. A concept map constructed by an Accommodator

is very simple, but it ignores many important concepts. The same situation exists in **Figure 7**, a concept map constructed by a Converger. On the contrary, **Figure 5** is a concept map constructed by a Diverger which includes a wide and complete range of concepts. **Figure 6** is a concept map constructed by an Assimilator which also includes complete concepts and has complicated and integrated cross links. Comparing these examples, it can be shown that concept maps constructed by Assimilators and Divergers are more complicated and complete than those constructed by Accommodators and Convergers.

For Accommodators, CACOS can enhance learning achievement better than CACBS can. Accommodators are weaker in organizational skills and are not interested in thinking deeply (Kolb, 1984). They usually miss and ignore many important concepts when they construct a concept map (Oughton and Reed, 2000). Therefore, it is hard for them to create a concept map from scratch (i.e. CACBS). CACOS provides students a basic concept map
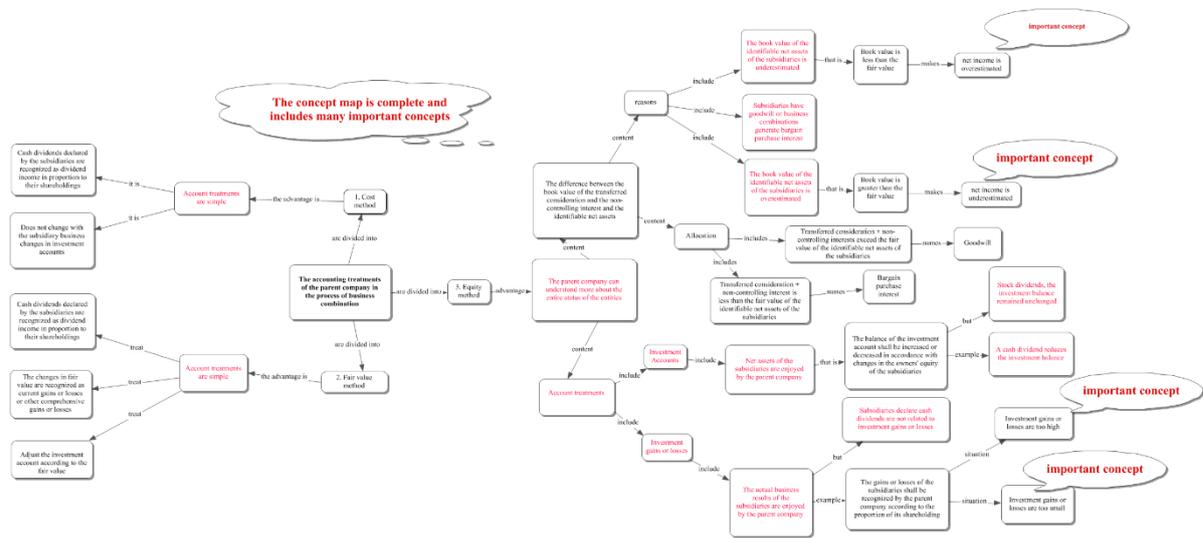
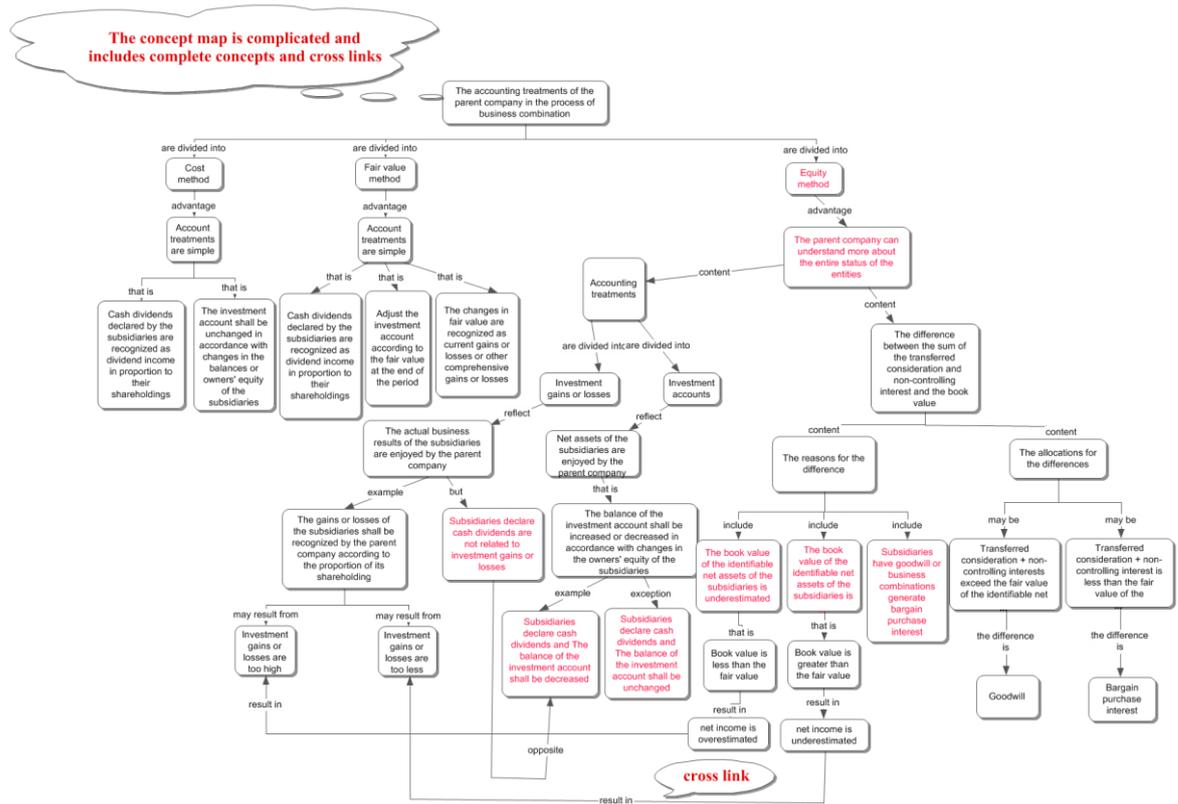**Figure 5.** A concept map constructed by a Diverger

Figure 6. A concept map constructed by an Assimilator

structure. Then, students fill in blanks with suitable answers in the structure. This kind of scaffolding (i.e. CACOS) is the most effective learning technique for Accommodators.
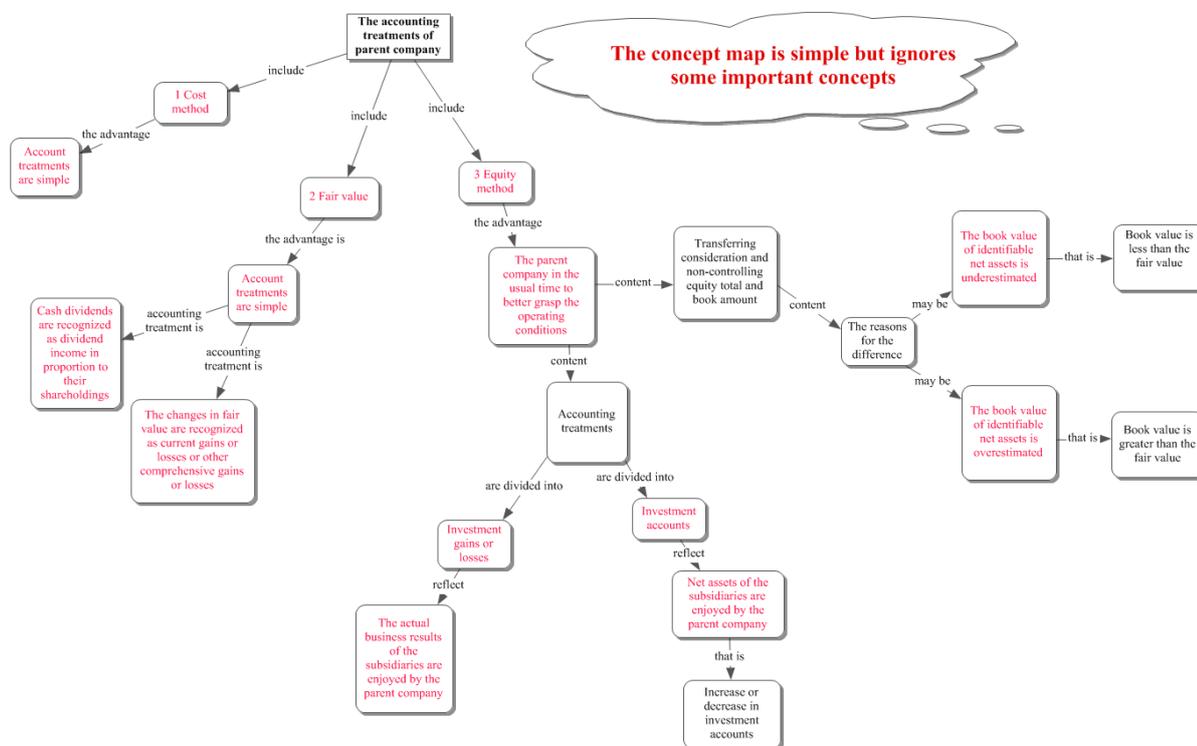
Figure 7. A concept map constructed by a Converger

For Divergers, CACBS is more effective in enhancing students' learning achievement than CACOS. Divergers are more imaginative, and analytical, and have better organizational skills (Oughton and Reed 2000). They can effortlessly develop complicated concept maps from nothing. Therefore, CACBS is the most suitable learning technique for Divergers.

For Assimilators, CACBS is more beneficial than CACOS. Since meticulous planning, making connections between knowledge, and understanding relationships between concepts are required in CACBS, Assimilators can work well using this technique because their forte lies in their ability to organize and integrate large amounts of information. Through the process of thinking about materials and creating concept maps, Assimilators can thoroughly understand different concepts and their relationships, which increase learning performance. Furthermore, Oughton and Reed (2000) found that Assimilators are very productive and use many relevant concepts when constructing concept maps. Oughton and Reed's results are consistent with our findings. Thus, CACBS is more effective and better suited than CACOS for Assimilators.

For Convergers, CACOS promotes learning achievement better than CACBS. Oughton and Reed (2000) discovered that Convergers often ignore many concepts when constructing concept maps. This study also found that Convergers produced few concepts in their concept maps and their maps were not complete. Thus, CACBS is not appropriate for them because

they usually leave out concepts and construct incomplete concept maps. This defeats the effectiveness of CACBS. CACOS is a semi-complete concept map provided by an expert. It is the most suitable method for Convergers because they are skilled at filling in concepts or linking words. Therefore, CACOS is the most suitable learning technique for Convergers.

The computer-assisted concept mapping technique needs to fit learners' learning styles. The match between the learning style and the learning technique will further enhance learning achievement. Results of this study provide a valuable reference for the computer-based concept mapping literature.

Although this study provided a lot of new and meaningful insights for concept mapping, it has several limitations that also represent opportunities for future research. First, it should be noted that the results may be marginally impacted by the Hawthorne effect. Students may share their concept mapping experiences with each other. However, the Hawthorne effect is commonly found and unavoidable in research studies that evaluate the usefulness of teaching and learning methods (Chiou, 2009). Second, qualitative research is suggested to deeply investigate the characteristics of different learning styles and their relations to concept mapping. Third, future study can consider different learning style models and measure other learning outcomes, e.g. skills, satisfaction, continuous use intention.

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