The Relationship between Computer-Based Concept Mapping and Creative Performance

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ABSTRACT

The intent of this study is to explore the relationship between computer-based concept mapping and creative performance. Concept mapping is a method of graphical learning that can be beneficial as a study method for concept linking and organization. Technological progress has advanced concept mapping to computerized forms. This research explores computer-based concept mapping as a creative tool to improve students' creative performance. This study examined forty students in the design department at technical universities to analyze whether computer-based concept mapping and applications improved students' video production and creative performance. The results show that (1) the application of computer-based concept mapping received approval from students; (2) students' computer-based concept mapping performance is directly related to their video production performance; and (3) students' computer-based concept mapping performance can effectively predict their creative performance.

Key words: computer-based concept mapping, concept map, concept mapping, creative invention, creative performance.

1. INTRODUCTION

Concept mapping is a virtual, graphical learning tool that uses diagrams to represent a particular knowledge domain and the relationships between concepts. Learners use different ideas to explore concepts and logic while reflecting on the adequacy of the entire knowledge structure. Through the conceptual relationship process, abstract and scattered pieces of knowledge are combined to become meaningful. This unique and innovative technique helps users incorporate known concepts into various applications.

The latest technological developments in dynamic graphics have produced concept-mapping software that allows users to organize knowledge and identify connections through spatial and visual techniques. It enables designers and users to efficiently draw 3D objects and to combine graphics with multimedia, such as words, sound effects, videos and hyperlinks to represent, discover and create new ideas. Computer-based concept mapping not only represents knowledge but also facilitates the process and makes it flexible and interesting.

Aesthetic and creative thinking is central to design. As Tu (1996) noted, in business and academic circles, creative thinking is of primary importance for design. Therefore, education seeks to inspire students' creativity and problem-solving abilities through creative thinking and solving puzzles to foster experience and growth. Research shows (Li, 2000; Tseng, 2002; Wavering, 1985) that design students have a higher sensitivity toward images and colors. Because of their visual thinking pattern, these students respond better to pictures, media and multimedia. These stimuli enhance their ability to observe, imagine and create. In addition, when addressing a single question, design students often exhibit greater creativity with figural divergent thinking to come up with answers. Thus, concept-mapping software enables dynamic graphics, and visual thinking helps designers visualize organizational concepts, incorporate resources and boost creativity during problem solving.

In addition to concept development, designers' self-awareness also changes through different timelines and periods of mapping. Concept maps accompanying student narrations allow teachers to pinpoint the students' misconceptions (Tsai, Lin, & Yuan, 2001). That is to say, concept mapping helps students reflect while informing the teacher of their educational needs. By pointing out the students' blind spots, teachers can help students avoid costly mistakes and learn more efficiently.

Concept maps are widely used for teaching, learning and evaluating in science and mathematics (Havel & Treagust, 1989; Roth & Roychoudhury, 1992; Schmid & Telaro, 1990). Computer-based concept mapping is a graphical, visual and spatial creative tool that helps guide designers to their own problem-solving paths. This is why it is important for design applications. According to Laffey and Singer (1997), concept maps can help with outlining design projects, identifying project tasks, and navigating entire projects. Tsai and Chen (1999) believe that concept maps illuminate connections between different ideas. Thus, computer-based concept mapping fits the educational objectives and demands of design students. Nonetheless, further discussion is necessary.

Based on the research motives mentioned above, this study has the following goals:

1. To explore students' actual and perceived use of computer-based concept mapping as a creative conception tool.
2. To explore the relationship between concept-mapping performance and creative performance ability.
3. To explore whether concept-mapping performance predicts creative performance ability.
4. To conduct content analysis on students' computer-based concept mapping and creative performance ability.

2. LITERATURE REVIEW

2.1 Concept Mapping and Computer-based Concept Map

Concept mapping was developed in 1972 by Joseph Novak, Professor Emeritus at Cornell University. In concept mapping, each Proposition is composed of two concept nodes, which are connected by relation links. Concepts are connected in a hierarchical structure in which general concepts are placed higher and specific concepts are placed lower (Novak, 1976; Novak & Gowin, 1984). In the process, learners must repeatedly ponder the topic structure to combine the abstract and scattered pieces of knowledge into something meaningful (Novak &

Gowin, 1984; Novak & Musonda, 1991). In other words, concept maps characterize and symbolize a knowledge concept and aid creativity and diversity in the process of embodiment (Tseng, 2001; Hammond & Allinson, 1989; Mintzes, Wandersee & Novak, 2001; Novak, 1977; Novak & Gowin, 1984).

Concept-mapping software is designed using knowledge representation in semantic networks that highlight visual learning, external links and hyperlinks to produce concept maps using the internet. Concept maps can be saved in different formats (such as GIF and HTML). Users can easily construct ideas through graphics and make alterations at any time to perfect the concept or plan. There are stand-alone concept-mapping programs, such as Inspiration, Thinking Maps, and Decision Explorer, that target decision making and analyzing graphics. There are also networked collaborative concept-mapping programs, such as WebMap and KSI Mapper, that allow collaborative concept mapping (Chiu, et al., 2002).

Concept maps are directional, hierarchical, and sequential and are created through knowledge convergences. Through graphical representation, students can easily see the concepts that will result in knowledge migration, followed by reorganizing and reconstructing. Computer-based concept mapping is a multimedia digital learning tool that can visualize thoughts using the internet and multimedia. Whether used for concept incorporation or problem solving, concept mapping benefits both teaching and learning methods. Figure 1 shows an example of a concept map of meaningful learning which was created using the Inspiration software.

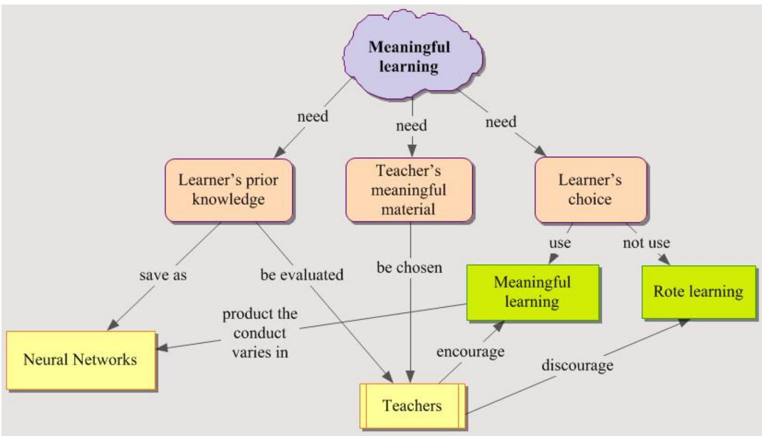

Figure 1. The concept map example of meaningful learning. (cited from Novak, 1998, p.53)

2.2 Concept Mapping and Creativity

"Designing" is a creative act that finds a solution to a problem. When programming a design curriculum, design educators focus on how to inspire students' creativity and problem-solving skills. The ability to think can be enhanced through data collection, concept mapping, the use of hypermedia and external information tools such as databases. In addition, referring to existing examples is a way to encourage and inspire creativity. This is very helpful and efficient for new designers (Lin, 2000; Tseng, 1987; Carr-Chellman & Duchastel, 2000; Jonassen, 1999).

Creating concept maps requires activity from both hemispheres of the brain. This whole-brain thinking is needed when making decisions about colors, keywords, symbols and images. Together with divergent thinking, everything one learns can be presented through visual and graphical note taking. This handy tool can be used by students to integrate ideas, brainstorm, free associate, inspire and memorize (Chen, 2004; Wycoff, 1991). Concept mapping in design education inspires creativity, enhances visual performance and helps students to think independently. Students eventually realize there is no correct answer in the world of design, and with the help of concept maps they can review and analyze their work. This process enables metacognition and enhances analytical ability (Wang & Hsu, 2008). When students have a clear understanding of the structure of a design they can access concepts, topics and relevant resources that help them perform better in their design work.

Concept maps are good for design students because they use visual graphics to organize, induce and incorporate new ideas. Teachers can use the same methods to help students see their own progress by connecting related concepts. Therefore, concept mapping not only stimulates creativity but also improves creative performance.

2.3 Creativity and Creative Performance

In a knowledge economy, innovation is critical for organizations and individuals. Originality helps with the embodiment of ideas. Through logical deduction and the incorporation of new knowledge, goals are achieved and problems are solved (Hsiao, 2002; Doku, 2000). Doku noted that originality often stems from a problem or a demand. That is to say, a creative idea occurs when an individual is looking for a solution. Therefore, creativity is the beginning of originality and involves processing, brainstorming and applied methods.

It is difficult to use an operational definition to define originality because it is vast in meaning. Thus, creativity is the key idea in theories of originality (Simonton, 2003). Different studies assign different definitions to creativity, which is itself a complex concept. However, creativity basically comprises personal characteristics, products, processes, and pressures (Cheng & Wang, 2002). Guilford, an American psychologist, performed psychometrical measures on creativity that became a beacon for future researchers. Through factor analysis, he derived four factors in creativity: fluency, flexibility, originality and elaboration (Chang, 1989). Creativity is a psychological attribute that exists in all human beings, differing only in degree. Results-oriented measurements are a more objective method of studying individual creativity. This requires analyzing the degree of creativity through fluency, flexibility, originality and elaboration of its concepts or products. In addition to personal characteristics and ability, creativity is subject to an individual's context (Chiu & Yao, 2010). Creativity increases given the right stimulation and environment because the external factors and the process of brainstorming help to realize concepts and often can promote their creative thinking. From this, we infer that individual creativity is an important predisposing factor.

Creative behavior is goal-oriented and starts from a question or demand that inspires creative development. It is an individual cognitive and psychological activity that induces a series of thoughts. This network is reflected in the output of creativity. Thus, to enhance individual creativity we must provide adequate channels for fluency, flexibility, originality and elaboration of creative thinking.

2.4 Related Theories of Concept Mapping

The original concept map that Novak developed is theory-driven (Trowbridge & Wandersee, 1998). When a teacher introduces a Proposition (concept), a knowledge set is also introduced. Faced with such a Proposition, students begin to make associations and then to select, organize, and categorize these associations, connecting ideas and drawing graphs to represent their understanding. Theories that address this process include knowledge representation, subsumption, constructivist learning and meaningful learning theories. We will discuss these theories in the following sections.

2.4.1 Knowledge representation theory

Knowledge representation theory organizes knowledge somewhat structurally (Lin, 2002). Learners draw conclusions from the concept map's hierarchy and graphics (Novak & Gowin, 1984).

2.4.2 Subsumption theory

According to Ausubel's (1963) theory of subsumption, individuals recognize, connect and incorporate new information into higher-level concept groups. That is to say, learners put new concepts into a larger, more comprehensive category and then reorganize or classify the new and old information.

2.4.3 Constructivist learning theory

This theory argues that knowledge is constructive. In combination with new knowledge, learners generate knowledge and meaning from their past experiences. At first, learners assign simple meanings to objects and phenomena. Knowledge becomes more complicated as learners become more experienced (Jonassen, 2000a). Essentially, constructivism says that (1) learners are the center of learning, and knowledge is constructed based on their past experiences; (2) new knowledge is constructed based on experience or old knowledge; (3) learning incorporates and gives meaning to the old and the new; and (4) knowledge is complicated and contextual, and learners must exhibit their understanding in complex situations (Jonassen, 2000b). Constructivism is about building new ideas on old knowledge, and creativity and thinking are emphasized. Learners can therefore flexibly construct their own mental modes and cognition.

2.4.4 Meaningful learning

Under the meaningful learning theory, new knowledge is deliberately combined with the old cognitive structure. Scholars (Ausubel, Novak & Hanesian, 1978; Novak, Gowin & Johansen, 1983) argue that to see fruitful learning results, concepts must be endowed with meaning. They claim that meaningful learning builds upon an original cognitive structure that has already been comprehended. Novak (1998) proposed three prerequisites for meaningful learning: (1) learner's prior knowledge; (2) teacher's meaningful material; (3) learner's choice. In other words, teachers should prepare meaningful material according to the individual's prior knowledge. This enables the students to make sense of their learning by building on old knowledge and their own cognitive structures.

As we can see, to establish an effective design curriculum and learning environment, teachers must incorporate design education, pedagogical theory and practice, and information technology. Incorporating computer-based concept mapping into pedagogy will help teachers create a meaningful environment in which learning theories help students become active learners, leading to learning achievements and the resolution of complicated puzzles.

2.5 Content Analysis

Content analysis, also known as archival research, is the study of the content of communication or textual information for specific questions. It is an unobtrusive measurement that attempts to explain, forecast, or control the content. The content should be documented, preserved and of communicative value (Babbie, 2009). Content analysis has the following four attributes (Weber, 1989): (1) it builds on the communicative document; (2) it combines "qualitative and quantitative methods"; (3) it preserves a series of reliable documents that could last for centuries; (4) compared to interviewing, it is less interrupted by its own methodology.

In light of this, content analysis is economical, safe, unobtrusive and involves processes that occur over long periods of time. It saves researchers time and money. Researchers do not have to jump through hoops to test hypotheses, and the recorded transcript does not change over time. Because it is unobtrusive, content analysis does not interfere with the behavior of communicators (Babbie, 2009). However, in addition to these advantages, Wimmer and Dominick (1991) described the biggest limitation of content analysis: researchers' subjectivity. This is because contexts are based on the researchers' understanding of the background data. When the researchers' backgrounds and experiences are similar to those of the author, the content analysis outcome is more likely to be accurate. In order to promote objectivity in research, researchers require adequate data to construct a context that is close to reality.

3. RESEARCH DESIGN AND IMPLEMENTATION

3.1 Research Design

This study selected forty students majoring in design to take lessons on

Inspiration, a computer-based concept mapping software package. The training consisted of four weekly two-hour lessons, yielding eight hours of total class time. Next, the students used the concept mapping software to conduct creative conceptions of their digital films. Finally, the students completed their digital videos. This study was conducted in five stages. In the first stage, we used an original questionnaire to measure the students' perceptions (attitude, effect) regarding the application of computer-based concept mapping as a tool for creative thinking. During the second stage, we evaluated the students' applications of computer-based concept mapping. In the third stage, we evaluated the students' digital films. The fourth stage investigated the relationship between the concept maps and their creations. Finally, in the fifth stage, we performed a content analysis of the concept maps and films. The research procedures are shown and illustrated in Figure 2 below:

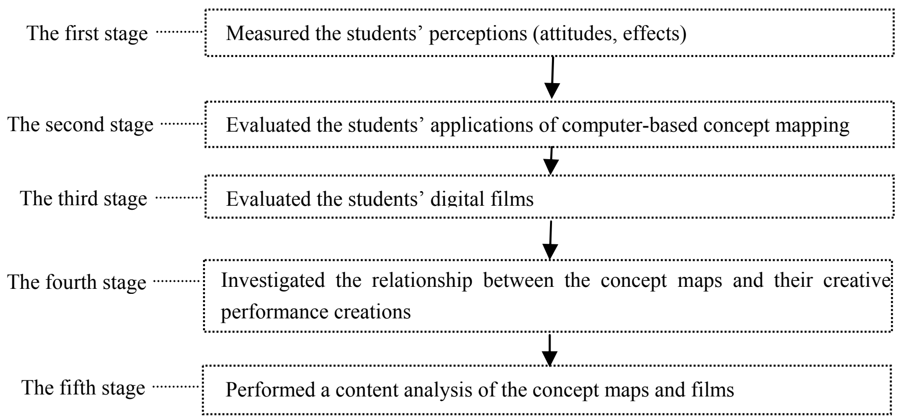

Figure 2. Research procedures.

3.2 Research Participants

Getting started with concept maps and digital films

Concept maps allow learners to organize their prior concepts and experiences and build new knowledge on individual concepts. With this in mind, this study adopted purposive sampling that selected forty junior students in the Department of Design. In an effort to explore the potential of concept mapping, we chose digital film for our production medium. To facilitate evaluation, students were given only one topic: green design.

Experts in computer-based concept maps and film

This study invited five education and design experts to review the concept maps and films of the forty students. The students were graded according to the scoring system listed in Table 1. The experts had the following credentials: (1) a

Ph.D. (including doctoral students) or college professor (including assistant professors or equivalent); (2) full theoretical understanding of and/or experience in concept mapping; and (3) experience in digital pedagogy.

Analysis of concept maps and creativity

After the evaluations, we organized the grades for the concept maps and digital films into the following categories: excellent (85-95%), adequate (75-84%), and inadequate (65-74%). Finally, we selected twenty-four files for content analysis.

3.3 Research Tool

3.3.1 Questionnaire measuring student's attitudes towards concept-based concept mapping

This research used an original questionnaire to understand students' perceptions about applying computer-based concept mapping. The questionnaire used a 5-point Likert scale and had four distinct sections. Higher scores represented a more positive attitude. We used factor analysis and internal consistency reliability analysis to evaluate the reliability and validity of the measurements. The first section of the questionnaire contained eight questions that measured students' opinions about the differences between written plans and concept maps as creative thinking tools. The ten questions in the second section measured the students' opinions about using concept mapping and written planning as tools for creative thinking. The third section had seven questions that measured the difference in students' attitudes toward concept mapping using a pen and paper and computer-based concept mapping. The fourth section had ten questions and measured the student's opinions about the effectiveness of computer-based concept mapping and paper-and-pen concept mapping.

3.3.2 Computer-based concept mapping

Stuart (1984) saw concept maps as evaluative tools for the following three reasons: (1) concept maps reflect students' thinking processes; (2) concept maps reflect students' achievements; (3) concept maps help students comprehend and memorize. When producing concept maps, students must put comprehensive concepts (nodes) on a higher level with related sub concepts linked beneath them. Words and arrows are used to represent relationships among concepts (Jonassen, 1984; Stewart, 1984).

3.3.3 Digital film evaluation

The digital films were graded by the experts based on the following five elements: (1) message; (2) aesthetics; (3) overall multimedia performance; (4) degree of technical difficulty; and (5) creativity. The first four standards each accounted for 15% of the grade and "creativity" accounted for 40%. This helped us measure how concept maps impact creativity.

3.4 Research Limitation

In this study, the subjects took a computer-based concept mapping course for eight hours and used the concept mapping software to conduct concept maps and complete their digital videos. This study was conducted in five stages (see Figure 1), and then a *content analysis* was performed for all the students' concept maps. The study chose forty subjects due to the limitations of time and materials.

3.5 Data Analysis

3.5.1 Descriptive statistical analysis and correlation analysis

This research attempts to understand students' perceptions about using computer-based concept mapping as a creative thinking tool. We designed a chart to measure relative attitudes and knowledge and used Pearson's product-moment correlation to analyze students' attitudes about the relationship between the four aspects.

3.5.2 Evaluation of computer-based concept mapping

To evaluate the computer-based concept maps, we modified McClure and Bell's (1990) grading system. The scoring standards included the following four items: (1) the logic of each concept; (2) the rationale of the links; (3) the correct labeling of arrows; (4) the accuracy of linking phrases. Each concept is the beginning of a creation; therefore, each concept was graded with two points per item (1). The rest of the items were given only one point. The results were calculated and are shown in Table 1.

Table 1. *Grading system for computer-based concept maps*

Component	Description	Grade
Concept	the logic of each concept	2 points for logical concepts
Relationship among concepts	the rationale of the links	1 point for correct relationship
Arrow	the correct labeling of arrows	1 point for correct arrow
Linking Phrase	the accuracy of linking phrases	1 point for correct linking phrase

3.5.3 Digital film evaluation

This study used Kendall's coefficient of concordance to assess agreement among raters' evaluations of forty digital films.

3.5.4 Analysis of concept maps and creativity

This study ran a Pearson product-moment correlation and simple regression analysis on the "creativity" score to measure the correlation and predictability between concept maps and creativity.

4. RESEARCH RESULTS

4.1 Perceptions (Attitudes and Effects) Analysis of Students Applying Computer-Based Concept Mapping

This research used an attitudinal measurement of the four aspects to determine the suitability of computer-based concept mapping as a creative tool for students. Analysis of the students' perceptions used the principal component method to conduct factor extraction and the orthogonal oblique method to conduct factor rotations. The four aspects in the questionnaires (described above) all received a factor, with variances of 64.11%, 63.51%, 66.54% and 66.04%, respectively. Furthermore, the internal consistency reliability α coefficient for the four aspects was .915, .936, .909 and .941, respectively. This shows that the measuring scale had good reliability and validity. These results also indicate that this scale was suitable for measuring the students' perceptions about applying computer-based concept mapping and their attitudes towards using concept mapping and written planning. Table 2 shows that the mean of each question was between 3.394 and 3.758. Within this range, students' were most positive in their approval of concept mapping as "interesting" with an overall mean of 3.625. Based on the questions shown in Table 2, students thought that the concept map was easy to use, revisable, and students had the desire to draw a concept map to plan their work. In other words, compared to written planning, students had a more positive attitude toward the acceptance and practicality of concept mapping.

Table 2. *Comparisons of attitudes toward concept mapping and written planning*

Number	Question Content	Mean	Standard Deviation
1	Compared to writing a plan, drawing a concept map is easier	3.697	0.684
2	Compared to writing a plan, drawing a concept map is more fun	3.758	0.708
3	Compared to writing a plan, I prefer to draw a concept map to plan my work	3.394	0.747
4	Compared to writing a plan, I have more confidence in constructing a concept map	3.576	0.663
5	Compared to writing a plan, using concept maps can improve the quality of my design work	3.697	0.810
6	If my concept map or written plan is not ideal, reconstructing a concept map will be easier than writing a plan	3.606	0.788
7	If I need to understand a special topic, I prefer to construct a concept map rather than putting it into words	3.606	0.747
8	Compared to writing a plan, I am more likely to apply concept mapping in future designs or studies	3.667	0.692
Overall mean		3.625	0.579

This research looked at concept mapping as a tool for creative thinking and analyzed students' perceptions of concept mapping and written planning. Table 3 shows that the mean of each question is between 3.455 and 3.818. Of these questions, the highest approval rating was given to the helpfulness of concept linking, with an overall mean of 3.612. Compared to written planning, students hold a more positive attitude towards concept mapping as a creative tool.

This research considered attitudes toward computer-based concept mapping and paper-and-pen concept mapping. Table 4 shows that the mean of each question is between 3.303 and 3.606. The highest approval was given to evaluation and analysis before beginning a design. The overall mean is 3.459, indicating that students hold a more positive attitude toward the acceptance and practicality of computer-based concept mapping than toward written concept mapping.

Table 3. *Comparisons of concept mapping and written planning*

Number	Question	Mean	Standard Deviation
1	Drawing concept maps helps me manage the key points of the design.	3.727	0.719
2	Drawing concept maps helps me organize and clarify different design concepts.	3.758	0.708
3	Drawing concept maps helps me integrate the knowledge and technology I have learned previously.	3.576	0.751
4	Drawing concept maps helps me think creatively about my design.	3.697	0.728
5	Drawing concept maps helps me correct my incorrect concepts.	3.455	0.711
6	Drawing concept maps helps me clearly express my design concept.	3.576	0.708
7	Drawing concept maps helps me to evaluate and analyze more clearly before designing.	3.515	0.712
8	Drawing concept maps helps me notice which topics I do not fully understand.	3.485	0.712
9	Drawing concept maps helps me link related concepts.	3.818	0.635
10	Drawing concept maps helps me realize which knowledge or techniques I still need to learn.	3.515	0.667
Overall mean		3.612	0.562

Table 4. *Comparisons of attitudes toward paper-and-pen concept mapping and computer-based concept mapping*

Number	Question	Mean	Standard Deviation
1	Compared to paper-and-pen concept mapping, using computer-based concept mapping to plan a design is easier.	3.333	0.924
2	I feel that using computer-based concept mapping can enable me to evaluate and analyze more clearly before I make my design.	3.606	0.827
3	Compared to paper-and-pen concept mapping, computer-based mapping can help me design the work I want faster.	3.303	0.637
4	Compared to paper-and-pen concept mapping, computer-based mapping can more clearly express my design concept.	3.394	0.659
5	Compared to paper-and-pen concept mapping, I prefer to use computer-based concept mapping to design my work.	3.515	0.795
6	If I have the opportunity, I am more willing to use computer-based concept mapping to design my work than to use paper and a pen.	3.515	0.755
7	Based on this experience with computer-based mapping, I will apply it to my other studies in the future more than paper-and-pen concept mapping.	3.545	0.794
Overall mean		3.480	0.618

This research also analyzed students' perceptions of using computer-based concept mapping. Table 5 shows that each question has a mean between 3.333 and 3.697. Concept mapping is most effective for clearly expressing design concepts. The overall mean is 3.521, indicating that students believe that applying computer-based concept mapping has a positive effect on their creative performance.

Table 5. *Comparisons of the effects of computer-based concept mapping and paper-and-pen concept mapping*

Number	Question	Mean	Standard Deviation
1	Computer-based concept mapping helps me handle the key points of my design.	3.576	0.663
2	Computer-based concept mapping helps me organize and clarify different design concepts.	3.606	0.704
3	Computer-based concept mapping helps me reduce problems when I am designing.	3.545	0.754
4	Computer-based concept mapping helps me discuss my design (work) with my teachers or classmates.	3.515	0.795
5	Computer-based concept mapping helps my creative thinking.	3.545	0.666
6	Computer-based concept mapping helps me plan my design work more systematically.	3.545	0.666
7	Computer-based concept mapping enables me to more clearly evaluate and analyze before I design.	3.424	0.708
8	Computer-based concept mapping helps me design the work I want faster.	3.333	0.692
9	Computer-based concept mapping helps me express my design concept more clearly.	3.697	0.728
10	Computer-based concept mapping helps me realize which concepts I need to learn.	3.424	0.792
Overall mean		3.521	0.581

Table 6. *Correlation analysis of students' attitudes*

	Attitude A	Attitude B	Attitude C	Attitude D
Attitude A	1.000			
Attitude B	0.821***	1.000		
Attitude C	0.416*	0.534**	1.000	
Attitude D	0.420*	0.530**	0.826***	1.000

Note. * $p < .05$, ** $p < .01$, *** $p < .001$.

Finally, this research analyzed students' attitudes and knowledge regarding these four aspects. Table 6 shows that Attitude A (preference for concept mapping over written planning) and Attitude B (better creative performance using concept mapping than using written planning) have a high positive correlation (r = .821, p <.001), indicating that when students are happier using concept mapping, their creative performance improves. Furthermore, Attitude C (preference for computer-based concept mapping over paper-and-pen concept mapping) and Attitude D (better creative performance using computer-based concept mapping rather than using paper-and-pen concept mapping) also have a high positive correlation (r = .826, p <.001), indicating that when students are happier using concept mapping, the effect of their creative performance is better. Other aspects of students' attitudes all show a medium positive correlation level.

In conclusion, it is apparent that students hold a positive and approving attitude toward computer-based concept mapping. Between computer-based concept mapping and written planning, students prefer to use concept mapping more in terms of its acceptance, practicality and effect. Further analysis of computer-based concept mapping and paper-and-pen concept mapping shows that computer-based concept mapping has a higher approval rating among students. Hence, students are more willing to use computer-based concept mapping as a tool for creative thinking and their creative performance is improved.

4.2 Evaluation of Concept Maps and Creativity

Five expert raters in related fields evaluated the participants' concept maps and creativity. When grading the concept maps, they referred to McClure and Bell (1990) and used their own discernment to assess the films' creativity. We used Kendall's coefficient of concordance to assess agreement among the raters. Kendall's coefficient of concordance helped us test the unanimity among N films and k judges to test the judges' reliability. Kendall's W in the scores of the concept maps was calculated as .931, where χ^2=153.55 (p = .000). This means that the judges' ratings were unanimous. As for creative performance, Kendall's W=0.863 and χ^2=168.36 (p = .000), which also shows unanimity.

4.3 The Relationship between Computer-Based Concept Maps and Creativity Performance

This study examined correlations between two scores for forty students. Six students did not submit their concept maps; therefore, we analyzed thirty-four films. The correlation coefficient r = .400 ($p < .05$), showing medium-strong positive correlation. This study used the concept map grades as independent variables and creativity as a dependent variable to indicate a predictive relationship. In the regression, the concept map scores have been shown to explain thirteen percent of the variance in creativity (R^2=.13 ($p < .05$). From the results above, we see that computer-based concept mapping is positively correlated to students' creativity with a strong predictive relationship. Higher grades for concept maps yield more creative results.

4.4 Content Analysis of Computer-Based Concept Maps and Creativity Performance

To better grasp the relationship between concept maps and creativity, this study used content analysis for twenty-four films. Due to limitations of space, we list and analyze the concept mapping and creativity grades for ten students (as shown in Table 7).

4.4.1 Content analysis of excellent assignments

Student A's concept map exhibited a clear order and a hierarchical and causal relationship between concepts. The map had a distinct concept, and different levels were labeled in various colors. The diversified concepts included multiple examples, revealing great creativity. These characteristics were also apparent in Student A's film, which combined drawings and animation to create an eye-catching visual feast that went well with the topic. The student's abundant creativity was apparent in paper folding, paper crumpling, paper cutting, color spray, objects and watercolor. The topic was extremely well defined, and a serious issue was expressed in a lively and vivid way.

We saw mature graphic skills and clear representative concepts expressed through hierarchy, links and linking phrases in Student B's concept map. The student used cross-links to express progressive changes and causal, inclusive and hierarchical relationships. Instead of boxes or circles, concepts were represented using balloon shapes, expressing the student's creativity. The tidy design demonstrated aesthetic, observant and imaginative feeling. The assignment took us on a ride through our environment. We could observe how the images told the story of our degraded environment and caused the viewer to ruminate on the topic through a perfect combination of images, music and subtitles.

The concept map of Student M focused on description and imagination of the topic. The branched concepts were all logical, and the arrows and linking phrases were assigned accurately. The creative development and the final production were beautiful. The underlying message of the film, titled "Air & Water Pollution," was more abstract, inviting deeper contemplation. The assignment had no direct connection with the original concept map, reflecting modifications during the production process. However, we still recognized it as a well-thought-out creation. The student employed a somewhat difficult production technique, encouraging viewers to dig deeper into the theme.

As for Student P, the concept map was clear, definite, and imaginative, with logical concepts and linking phrases. The distinct hierarchy clarified its central topic and logic. After the concept development, the assignment was presented and revolved around three major themes. The danger of water pollution was well presented through a perfect use of software. Viewers could resonate with the current predicament. As a result, the outcome was a success.

Table 7. *The scores for concept maps and creativity performance*

ID	Concept Map	Creativity
Student A	88% (Excellent)	94% (Excellent)
Student B	88% (Excellent)	89% (Excellent)
Student D	83% (Adequate)	80% (Adequate)
Student J	80% (Adequate)	78% (Adequate)
Student K	71% (Inadequate)	67% (Inadequate)
Student L	78% (Adequate)	78% (Adequate)
Student M	91% (Excellent)	91% (Excellent)
Student P	88% (Excellent)	87% (Excellent)
Student R	79% (Adequate)	79% (Adequate)
Student V	69% (Inadequate)	66% (Inadequate)

4.4.2 Content analysis of adequate assignments

Student D presented a logical and rich concept map, and the film was an excellent realization of the concept. The photos contained various themes, and different background music was cued to different storylines, producing multiple sensations for viewers. However, the theme switched from “pollution” to “make recycling routine,” followed by “be your own farmer” and “Taiwan’s long-term green project.” The image of sowing was shown twice on screen, emphasizing that “one gesture goes a long way in sustaining the environment.” This design did not fully interpret the motif.

Student J’s concept map was rich in content and showed precise logic. Labeling colors coupled with better graphic design, would have made the topic and idea more distinct. However, the concept map contains clusters of elements and only focuses on air and waste pollution. The rich material showcased a distinct theme, but the recurrent black and white subtitles were monotonous. The topic was the dire pollution situation, but the message was unclear. The concept map could complement and illuminate the theme, bringing the production to the next level.

In Student L’s concept map, ideas were presented in a linear manner. The theme was evident, and instead of hierarchical systems, concepts were differentiated by color. The graphics complemented the text, bringing the creation to life. Nonetheless, only one subconcept was assigned to each concept, demonstrating a simple logic. The first half of the film was monotonous and simple. The second half took an interesting turn by combining video footage with photographs. The mix showed variety, but also inconsistency. Viewers might find it hard to connect the content to the topic without subtitles.

Student R chose recycling as the theme, and the connection between the concepts, arrows, and links was logical. Illustrations should be added to the layout to enliven the picture. Generally speaking, this is a textbook concept map. Three objectives were conveyed in the film through narration. This increases audience approval as they find the hidden moral. The production used the concept map as foundation to express key ideas, and the outcome was a success.

4.4.3 Content analysis of inadequate assignments

The concept map of Student K targeted the issue of water pollution. The train of thought, hierarchy, arrows and linking phrases demonstrated faulty logic. The hard work behind the rich ideas was evident, but there was room for improvement. The correlation between the video and the concept map was weak, and the concept was ambiguous. There were long pauses in a single frame, such as cars in the street or the shot of sky. Audiences might find it hard to grasp the idea and gradually lose interest in the film. However, the subtitles were in accordance with the topic. With the right modifications, the final project could be brought back on track.

Student V decided to emphasize the practical side of green design and explore the practicability of green design products. The concept focused on the issue of practicability, diverging from the teacher’s requirements. This might be why the concept, which was only briefly mentioned in the film, was unclear and did not follow the concept map. It is highly likely that this student misunderstood how the concept map works, leading to its improper utilization. A revised version of the concept map may improve the level of production.

5. CONCLUSIONS AND IMPLICATIONS

5.1 Conclusions

Creative thinking ability is very important to a designer. Concept mapping can help students learn to organize and symbolize knowledge by drawing. This can facilitate students' attainment of the goals of meaningful learning and increasingly effective knowledge, which expands thinking ability, stimulates creativity and arouses inspiration. The teaching method of learning and resolving problems through visual thinking suits the characteristics and needs of students in the field of design. This research shows the effect of assisting learning with concept mapping by comparing a group and a control group. The research results suggest the following conclusions.

5.1.1 Application of computer-based concept mapping is approved by students

Student acceptance is the most important factor to determine whether a new educational method can reach a predicted effect or goal. Methods must be suitable for individual students' learning styles (Ardito et al., 2004) and must focus on users' needs by providing effective educational tools. In this way, educational methods can improve learners' knowledge construction and ability, producing maximum results with little effort. This research shows that students in the design field demonstrate greater recognition and approval of computer-based concept mapping than traditional written planning methods. Students perceive computer-based concept mapping as more acceptable, practicable, and effective than pen-and-paper concept mapping. In other words, students' attitudes towards using computer-based concept mapping are positive and approving, and they believe that this method can improve their creative abilities. Therefore, computer-based concept mapping is a suitable creative thinking tool for design departments.

5.1.2 Positive correlation between students' concept mapping and creativity performance

This study examined whether concept mapping helps students create digital films. The results of the content analysis and expert evaluations showed that computer-based concept mapping benefits students' creative and thinking abilities. Students learn to use the software, think about and construct a design structure, solve design problems, clarify concepts and use it to produce their work, thus increasing their imaging, visualizing and dimensional thinking abilities. To put it another way, there is a significant positive relationship between concept maps and creative performance. This is also reflected in students' perceptions. Thus, computer-based concept mapping has an effect on the creative performance ability of students in a design department.

5.1.3 Predicting creativity from computer-based concept mapping performance

Teaching materials are used to effectively incorporate knowledge and promote learning. The score analysis and previous research results suggest that students who master computer-based concept mapping have a better creative performance. Therefore, creativity can be predicted from previous performance. In other words, when students build designs through concept maps, they get a better idea of the design's conception, content and expression, allowing them to generate ingenious creations. Teachers can guide students' concept mapping or conduct remedial teaching to improve performance.

5.2 Implications

Various factors influence students' learning results, such as suitable materials and learning methods. A suitable learning tool is the most important aspect of a good learning method. It can help learners construct and apply knowledge (Papert, 1996/1997) and can improve learning motivation and effectiveness (Peck, Jonassen & Wilson, 1999; Soloway et al., 1996; Williamson, 2005). Computer technology adds additional value to concept mapping, bringing visual and dynamic advantages. This facilitates the creation of a new pedagogy that emphasizes both theory and practice. This study used systematic research to prove that computer-based concept mapping is a helpful creative tool for students in design departments. Computer-based concept mapping can stimulate creativity and help students analyze and integrate design inspiration to develop a design structure. Computer-based concept mapping can be applied to other fields to construct and develop systematic knowledge structures, and it can be popularized and used in various applications. Future studies can build on this systematic study and analysis.

ACKNOWLEDGMENTS

This article adopted part of the research results of the 2009 National Science Council Research Projects (Project Number: NSC 98-2410-H-163-010). We sincerely appreciate the funding of the government.

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