IMPROVING AND ASSESSING STUDENTS' CT THROUGH CONCEPT MAPPING AND CONCEPT MAPS

by

SHENG-SHAING TSENG

(Under the Direction of Michael Orey)

ABSTRACT

There remains relatively little research on the use of concept mapping activities in developing students' critical thinking skills at the high school level in Taiwan, where students are struggling to cultivate critical thinking skills and instructors lack the teaching experiences of critical thinking. In addition, little information has been provided about the relationship between concept mapping activities and critical thinking skills in previous research. This study therefore aimed to examine the effects of concept mapping activities on critical thinking skill development in a high school in Taiwan and explore the relationship between concept mapping activities and critical thinking skills.

43 participants were recruited from the course, research seminar, in the department of English at a high school in Taiwan. Class A was randomly designated as the high-directed concept mapping group and Class B as the low-directed concept mapping group. The collected data included critical thinking survey scores, concept map scores, and interviews. Concept map scores were compared with critical thinking survey scores to examine the correlation between Novak and Gowin's concept map rubric and critical thinking skills using Pearson correlation analysis. The critical thinking survey scores of the high-directed group and the low-directed

group were analyzed using a multivariate analysis of variance (MANOVA) to examine the difference in critical thinking skill development between the two groups. The interviews were analyzed using an inductive analysis approach to explore how students interpret the relationship between their concept mapping activities and their critical thinking scores.

The results indicated the example and proposition could be the elements in Novak and Gowin's concept map assessment rubric related to critical thinking skills. The multivariate results suggested that different concept mapping activities would produce different learning outcomes. The low-directed concept mapping group significantly scored higher than the high-directed concept mapping group in the critical thinking skills: inference, interpretation, analysis, evaluation, explanation. This study further found that the low-directed mapping activity was particularly useful for the inference skill. Neither the low-directed nor the high-directed mapping activity could effectively enhance the evaluation skill. Suggestions and implications are proposed to develop critical thinking skills through concept mapping activities.

INDEX WORDS: concept mapping; critical thinking, high school students

# IMPROVING AND ASSESSING STUDENTS' CT THROUGH CONCEPT MAPPING AND CONCEPT MAPS

by

SHENG-SHIANG TSENG

M.A., National Pingtung Education University, Taiwan, 2008

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2017

# IMPROVING AND ASSESSING STUDENTS' CT THROUGH CONCEPT MAPPING AND CONCEPT MAPS

by

SHENG-SHIANG TSENG

| | |
|---|---|
| Major Professor: | Michael Orey |
| Committee: | Rob Branch |
| | Theodore J. Kopcha |
| | Trena Paulus |

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
December 2017

# DEDICATION

To my mother, Hsiu-Chu Huang, you made so many sacrifices to make sure that I have everything most wonderful in the world. To my father, Ming-Chih Tseng, thank you for working so hard to give a life that we can have. I appreciate both of your love and dedicate this dissertation to you.

我的媽媽黃秀祝，一生中做出了需多犧牲，為了確保我能享有每一件事都是世上最好的。我的爸爸曾明智辛勞工作，不畏辛苦、日夜不休，就是為了讓我們家庭衣食無憂。我感激你們對我的愛及辛苦，謹將這本論文獻給你們，是你們的支持成就我，讓我能完成此論文。

ACKNOWLEDGEMENTS

This dissertation would not be completed without the assistance and support of many individuals. I would like to appreciate those who have helped me and accompanied me through the process of composing my dissertation. First and foremost, my deepest appreciation goes to my advisor Dr. Michael Orey for his patience and suggestions. I appreciated the fact that he allowed me to implement my pilot study in his class, and offered timely feedback on my dissertation. Without his guidance and professional advice, it was difficult for me to finish such a challenging task.

I am deeply indebted to my committee members—Dr. Branch, Dr. Kopcha, and Dr. Paulus. They carefully read through my dissertation and provided me with a number of valuable suggestions. With their advice and encouragement, I had the chance to solve the problems of my dissertation and make it stronger. I also give my thanks to Peggy Lai for her interest, openness, and time to enter her classroom and interview her students. This research could not have been successfully conducted without their cooperation and participation.

I would like to acknowledge my friends, Michael Tsao, Justine Chien, Sharon Lin, Neo Hao who accompanied me during my study period. They always gave me warm encouragement and accompanied me in times of challenge.

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

# CHAPTER 1

# INTRODUCTION

## Background and Motivation

Critical thinking becomes an essential competency for 21st century learners (Rotherham & Willingham, 2010). In 2001, the Taiwanese government made critical thinking one of the crucial ability to develop in high schools (MOE, 2002). The objectives of critical thinking training in high schools in Taiwan are to teach students to judge and confirm the accuracy, significance, and validity of various information sources, and connect knowledge to their lived experiences (Yeh, 2002). To accomplish the teaching objectives, high school teachers in Taiwan are asked by the Minatory of Education to design teaching activities to develop students' critical thinking skills.

The training of critical thinking skills is not easy to implement in high schools in Taiwan. Most high school teachers have focused on teaching students to absorb factual knowledge from textbooks to help students obtain high scores in college entrance exams, and they did not spend time on teaching students critical thinking skills. Historically, only eight articles in the literature have been conducted at the high school level in Taiwan to investigate and improve students' critical thinking skills (Ko, 2014). In the absence of sufficient critical thinking training, some high school students in Taiwan cannot evaluate the quality and reliability of information, nor can they synthesize information into a short summary. The lack of critical thinking further threatens the students' learning in classes. For example, students may encounter difficulty with relating newly acquired information to personal learning experiences and explaining abstract concepts by

providing examples to their instructors or classmates. These problems address the need for an instructional approach to develop high school students' critical thinking in Taiwan.

Concept mapping activities in which students transform what they know into a node-link diagram have been used to nurture students' critical thinking skills in previous research, such as Afamasaga-Fuata'I (2008), Bixler, Brown, Way, Ledford, and Mahan (2015), Daley, Shaw, Balistrier, Glasenapp, and Piancentine (1999), and Harris and Zha (2013). These studies all suggested that concept mapping activities effectively enhanced students' critical thinking skills. For example, Maneval, Fiblurn, Deringer, and Lum (2011) compared the differences between the use of a concept mapping activity and traditional care plans in a nursing program to promote critical thinking skills. Their results showed that nurses who practiced concept mapping activities scored higher in the final critical thinking test than those who were taught with traditional care plans.

The use of concept mapping activities to enhance students' critical thinking skills, however, has been limited to nursing education at the university level in the United States. There remains relatively little data on the use of concept mapping activities in developing students' critical thinking skills at the high school level in Taiwan, where students are still struggling to cultivate critical thinking and teachers lack the teaching experiences of critical thinking skill (Yang & Lin, 2004; Yang & Wu, 2012). There is a need to conduct the research at the high school level in Taiwan to examine the effect of concept mapping activities on high school students' critical thinking skill development to provide instructional suggestion for teachers.

Another research gap was that the effects of concept mapping activities on critical thinking skill development in the literature has been not consistent (e.g., Huang, Chen, Yeh, & Chung, 2012; McMullen & McMullen, 2009). The inconsistent effects of concept mapping

activities on critical thinking skills could be attributed to the use of different concept mapping activities (Ruiz-Primo & Shavelson, 1996). Concept mapping activities are mainly categorized into two types: high-directed concept mapping activities, where students fill in a skeleton concept map provided with a list of concepts and a map structure, and low-directed concept mapping activities, where students construct a concept map using self-created map structure and concepts. These two concept mapping activities have their advantages and drawbacks. The high-directed concept mapping activity could use skeleton maps as a guideline to facilitate students to learn, but it would restrict students in the given concepts and map structure. The low-directed concept mapping activity is beneficial for students to present their unique knowledge structures, but the activity is highly cognitively demanded. However, the difference in students' critical thinking performance between the two concept mapping activities remains unexplored, and little information has been provided about the relationship between the concept mapping activities and critical thinking skills. Without the information, researchers cannot provide teachers with suggestions for the design of the concept mapping activities to improve students' critical thinking skills.

The final research gap was that a concept map assessment rubric used by previous researchers to measure students' critical thinking skills has not been examined in terms of how the rubric was related to critical thinking skills. The rubric was originally developed by Novak and Gowin (1984) to assign scores to students' concept maps, and later was widely used by researchers (e.g., Daley, 1996; Daley, Shaw, Balistrieri, Glasenapp, & Placentine., 1999; Kathol, Geiger, & Hartig, 1998; Wheeler & Collins, 2003) to measure students' critical thinking through concept maps. However, these concept map scores assigned based on Novak and Gowin's concept map assessment rubric did not consistently reflect students' critical thinking (e.g., Abel

& Martha Freeze, 2006; Senita, 2008; Rosen & Tager, 2014). It remains unknown whether using Novak and Gowin's concept map assessment rubric to assign scores to students' concept maps can actually measure students' critical thinking. It is necessary to examine the relationship between the rubric and critical thinking in order to contribute the development of a concept map rubric for critical thinking assessment, and to validate the findings of previous studies using Novak and Gowin's concept map assessment rubric as a critical thinking instrument.

To fill in the research gaps mentioned above, this study had three objectives: (a) exploring the differences in critical thinking skill development between high-directed and low-directed concept mapping activities at the high school level in Taiwan, (b) understanding high school students' interpretations of the relationship between critical thinking and concept mapping activities, and (c) examining the correlation between critical thinking skills and Novak and Gowin's concept map assessment rubric.

## Conceptual Framework: Concept Mapping Activities and Critical Thinking

Concept mapping activities are an instructional practice in which learners add concepts, think about the relationships between concepts, and link concepts to form a knowledge structure in a hierarchy. The use of concept mapping activities to train critical thinking is grounded in constructivism, which argues that knowledge is seen as a "human construction that evolves as new ideas and new ways of looking at the world evolve" (Novak & Canas, 2007, p. 33). Knowledge is constructed by learners in their own way, rather than being delivered by teachers. Students may develop different levels of critical thinking for a domain of knowledge depending on how they construct their concept maps. In teaching practices, students may be asked to construct concept maps through two approaches. The first, called high-directed concept mapping,

requires the student to fill in a skeleton concept map provided by teachers or experts. The other, called low-directed concept mapping, asks students to construct maps entirely by themselves.

This study implemented the two types of concept mapping activities above in a "Research seminar" course in the department of English at a high school in Taiwan. The course was selected because it was designed to help first-year high school students develop critical thinking based on curriculum standards proposed by the Ministry of Education in Taiwan. Students in the course were required to identify research problems of their interest, write a research paper, and present their findings to the class. There were two sections of the course (Class A and B) in the same semester. Class A took the course on Monday morning, and Class B took the course on Tuesday morning. Each class was comprised of 35 students. Class A was randomly designated as the high-directed concept mapping group; they completed a skeleton concept map and took a critical thinking survey after the concept mapping activity. In contrast, Class B was the low-directed concept mapping group, and they had to construct a self-created concept map and took a critical thinking survey after the concept mapping activity. Both groups' concept maps were graded based on Novak and Gowin's concept map rubric. Students' map scores were compared with their critical thinking survey scores to explore the correlation between Novak and Gowin concept map assessment rubric and critical thinking skills using Pearson correlation. A follow-up interview was conducted with 4 students from each of the low-directed and high-directed groups to explore students' interpretations of the relationship between concept mapping activities and critical thinking skills. Furthermore, the critical thinking survey scores of the low-directed and high-directed groups were compared to investigate the difference in critical thinking skill development between the two groups.

## Research Questions

The purpose of this study was threefold: (a) exploring the differences in critical thinking skill development between high-directed and low-directed concept mapping activities in the context of a high school in Taiwan, (b) understanding the high school students' interpretations of the relationship between concept mapping activities and critical thinking, and (c) examining the correlation between critical thinking skills and Novak and Gowin's concept map assessment rubric. Based on the research purposes, the research questions include:

1. What is the correlation between Novak and Gowin's concept map assessment rubric and critical thinking skills?
2. What is the difference in critical thinking skill development between the high-directed group and the low-directed concept mapping group?
3. How do students interpret the relationship between their concept mapping activities and critical thinking skills?

## Significance of the Study

The significance of the present study lies in its theoretical and pedagogical implications for critical thinking improvement and assessment. As this study examined the correlation between Novak and Gowin's concept map assessment rubric scores and students' critical thinking skills, the results can help future researchers and teachers understand which components of Novak and Gowin's concept map assessment rubric may be related to students' critical thinking skills. Future researchers may revise Novak and Gowin's rubric to generate a better rubric to measure students' critical thinking skills through concept maps. Pedagogically, this study investigated the differences in students critical thinking skill development between the

low-directed and high-directed groups and explored students' interpretations of the relationship between concept mapping activities and critical thinking skills. The results would provide teachers a comprehensive understanding of the use of concept mapping activities to enhance students' critical thinking skills.

# CHAPTER 2

# LITERATURE REVIEWS

This chapter reviews the studies related to concept maps and critical thinking. I first present the definitions of "concept" and the construction of concept maps. Next, I discuss the epistemological stances on the use of concept maps in education. Finally, I explain the relationship between critical thinking and concept mapping.

## Concepts and Learning Concepts

A concept is generally defined as a unit of thought or a "perceived regularity in objects or events designated by a label" (Novak & Gowin, 1984, p. 4). Based on this definition, a concept is the basic unit of knowledge which a person possesses to reflect his understanding of a subject matter. In theory, concepts are not acquired innately. Novak and Gowin (1984) argue that individuals learn concepts by selecting specific objects/events to observe, and making mental notes throughout their observation. The selection and record-making process is shaped by the concepts which individuals have already learned. Existing concepts determine what objects/events a person will observe and what information he or she will note during the observation. In other words, concept learning is an interaction between new information and the internal knowledge of individuals. A well-organized, stable, and clear connection facilitates the learning and retention of new concepts, while a poor connection makes concepts difficult to learn and internalize.

Ausubel (1968) supports Novak and Gowin's claims about how concepts are learned by claiming that concept learning is highly related to the internal knowledge of learners, and it involves three processes: subsumption, progressive differentiation, and integrative reconciliation. Subsumption means that when learning a new concept, learners arrange the concept in line with existing concepts by placing general and inclusive concepts at the highest level. Progressive differentiation refers breaking down existing concepts into smaller components when learners gain more knowledge about the concepts. Finally, integrative reconciliation indicates that learners link existing concepts together and identify the relationships between concepts as they learn more about relevant concepts. The subsumption, progressive differentiation, and integrative reconciliation processes of concept learning show that individuals learn concepts by relating new information to existing knowledge and store the knowledge in a hierarchal structure.

The subsumption, progressive differentiation, and integrative reconciliation processes of concept learning mentioned above give rise to the use of concept maps as a tool for representing the internal knowledge of leaners (Liu, Chen, & Chang,2010; Nvoak & Gowin, 1984). Instructors can use concept maps to tap into students' cognitive structure and externalize what students already know via analysis of the hierarchy and propositions of a concept map according to given criteria (Daley, 1996; Daley, Shaw, Balistrieri, Glasenapp, & Placentine., 1999; Kathol, Geiger, & Hartig, 1998; Wheeler & Collins, 2003)

## Concepts and Concept maps

Concept maps are composed of nodes, linking lines, and hierarchy. Nodes in the form of circles or boxes denote a concept a learner already knows about an object or an event. Nodes are often labeled with a noun, a phrase, a sentence, or even a paragraph. A linking line is used to join

two concepts when there is a relationship between concepts. Words on the linking lines or arrowheads of the linking lines specify the relationship between the concepts. The combination of two concepts and a linking line forms a proposition, which is the basic unit of a meaningful statement in concept maps and the smallest unit measuring the validity of the relationship between two concepts (Ruiz-Primo, Shavelson, Li, & Schultz, 2001). The arrangement of concepts and linking lines forms the hierarchy of concept maps. In concept map hierarchy, general concepts are placed in the upper levels, and specific concepts are arranged in the lower levels. The hierarchy of concept maps is expanded either by creating new branches with the addition of concepts or by differentiating original branches within the new concepts.

The hierarchy of a concept map is expanded by creating new branches with the addition of concepts or by differentiating original branches within the new concepts. The structures of a concept map can be categorized into five types: linear, circular, spoke, tree and net (Kinchin, Hay, Adams, 2000; Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2005) (see Figure 2.1). These five different types of structures may reflect different knowledge levels of individuals. The linear structure refers to concepts arranged in a linear sequence in which a logical sequence is represented from beginning to the end, as in a line. However, if relationships between concepts are poorly depicted, the loss of a link can make it difficult to understand the meaning of the map. Similar to the line structure, the circular structure shows concepts which are chained to one to another with ends joined (Yin, et. al., 2005). In the spoke structure, concepts mainly derive from the center concept, but the non-central concepts are not directly linked to the others. Spoke concept maps are easy to read, but provide minimal information and do not foster critical thinking. The tree structure is a map constructed according to a linear chain but which also contains branches. The net structure is the most complicated concept map and can best facilitate

an understanding of the relationships among concepts. Students who created concept maps with a net structure were found to demonstrate a comprehensive understanding of the core concept and its associations with related concepts (e.g., Kinchin, Hay, Adams, 2000).

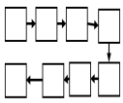
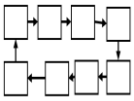
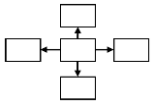
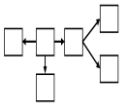
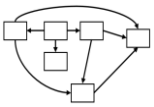
| Map structures | Linear | Circular | Spoke | Tree | Net |
|---|---|---|---|---|---|
| |  |  |  |  |  |

*Figure 2.1.* The five concept map structures.

Among the five concept map structures, the net structure is most similar to the knowledge structure of a human mind (Ausubel, 1968 Novak & Gowin, 1984), making it possible to use net-structure concept maps to represent how students learn concepts for a domain of knowledge. As shown in Figure 2.2, concept maps represent an individual's conceptual knowledge, which is comprised of concepts and propositions. Nodes can represent a concept or fragment of knowledge which a learner already knows about an object or an event. Concepts are constructed and stored in a hierarchical order in the cognitive structure of the human mind. The linking words indicate what learners know about the relationship between concepts, thus forming a proposition, the smallest meaningful unit stored in the cognitive structure. Therefore, concept maps can be used as an assessment to reflect how students organize their thinking.

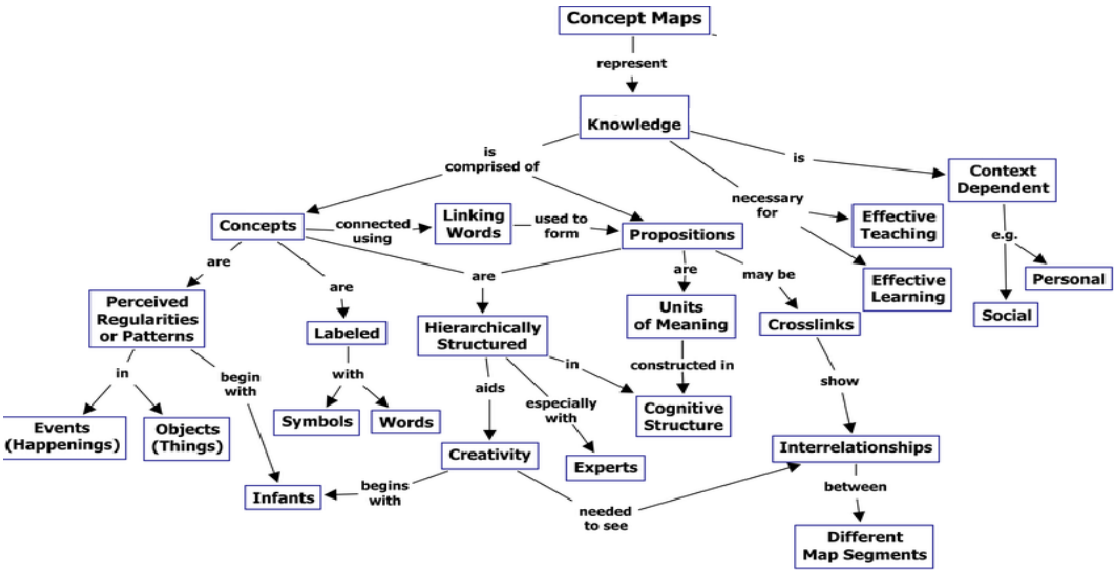



*Figure 2.2* Cognitive concept maps adapted from Novak and Cañas (2008)

**Approaches to Scoring Concept maps for Critical Thinking Assessment**

The emphasis on the ability to visualize students' knowledge structures provides a platform for concept maps to be used for large-scale assessment by grading students' concept maps based on a scoring system (Anohina-Naumeca, 2014). Studies have investigated the scoring system to produce reliability and validity of concept maps as assessment tools (Ruiz-Primo & Shavelson, 1996). Approaches to scoring concept maps include Novak and Gowin's (1984) concept map assessment rubric (see Table 2.1) and Ruiz-Primo, Schultz, and Shavelson's (1998) concept map assessment rubric (see Table 2.2). Novak and Gowin's (1984) concept map assessment rubric focuses on a count of map components such as nodes, links, and hierarchies. Scores were given for (a) the propositions of the concepts, (b) the hierarchical organization of the map, (c) the cross-linking of concepts, and (d) examples of the concepts. A proposition in this context is a meaningful relationship between two concepts indicated by the connecting line or linking words. Each meaningful relationship gets 1 point. Hierarchical organization entails that

each subordinate concept is more specific than the concept above it. Each valid level of the hierarchy gets 6 points. Cross-linking requires the map to show meaningful connections between one segment of the hierarchy and another segment. Each cross-link that is valid and synthesizes related concepts or propositions gets 10 points. An example is a specific instance of a concept. Each valid example of a concept gets 1 point. A concept map that demonstrates deep and complex knowledge structures is awarded a high score. The other concept map assessment rubric was developed by Ruiz-Primo, Schultz, and Shavelson (2001). Ruiz-Primo and colleagues assess students' concept maps primarily on the basis of the propositions indicated by linked concepts. The quality of each proposition in a map was rated on a 5-point scale (from 0 for invalid to 4 for valid excellent), based on the concept maps of domain experts. The results show that the proposition accuracy scores reliably reveal the differences between high-knowledge students and low-knowledge students.

Table 2.1

*Novak and Gowin's (1984) Concept map Assessment Rubric*

| **Criteria** | **Descriptions** | **Points** |
|---|---|---|
| Proposition | Is the relationship between two concepts indicated by a connecting line? | 1/each |
| Hierarchical organization | Does the concept map show hierarchy in which each subordinate concept more specific and less general that the concept above it? | 6/each |
| Cross links | Does the concept map show meaningful connections between one segment of the concept hierarchy and another segment? | 10/each |
| Examples | Specific events or objects that are valid of those designated by the concept label. | 1/each |

Table 2.2

*Ruiz-Primo, Schultz, and Shavelson's (1998) Concept Map Assessment Rubric*

| **Quality of proposition** | **Descriptions** |
|---|---|
| Excellent = 4 | Outstanding proposition. It shows a deep understanding of the relation between the two concepts. |
| Good = 3 | Complete and correct proposition. It shows a good understanding of the relation between the two concepts. |
| Poor = 2 | Correct but incomplete proposition. It shows a partial understanding of the relation between the two concepts. |
| Don't care = 1 | Although accurate, the proposition does not show understanding of the relation between the two concepts. |
| Inaccurate = 0 | Incorrect proposition. |

Novak and Gowin's (1984) concept map assessment rubric is the main instrument used to measure students' critical thinking skills based on the assumption that the concept map elements in Novak and Gowin's (1984) rubric may reflect critical thinking skills such as analysis, evaluation, and inference (e.g., Abel & Martha Freeze, 2006; Daley, et. al., 1999; Senita, 2008; Hsu, 2004). The hierarchy of concept maps could represent learners' analysis skill to place general concepts on the top level, and specific concepts on the lower level. Cross-links and propositions can reflect learners' evaluation skills as they justify and identify the relationships between concepts. Examples can reveal whether learners are equipped with the inferencing skill of gathering various claims and evidence on a topic.

Daley, Shaw, Balistrier, Glasenapp and Piancentine (1999) is the most widely-cited study which used Novak and Gowin's concept map assessment rubric to teach and evaluate students' critical thinking skills in a senior baccalaureate nursing program. The results showed that creating concept maps could effectively improve students' critical thinking skills, for the construction of concept maps requires students to think critically about meanings, propositions, and relationships among concepts. Teachers claimed that the concept map assessment rubric

effectively helped assess the knowledge and critical thinking skills of the students who did not verbally demonstrate their knowledge in class. Daley et al's study was later duplicated by Abel and Martha Freeze, (2006) who used concept maps to measure students' critical thinking skills based on a Novak and Gowin's rubric. Their study demonstrated that cross-links in a concept map were related to critical thinking skills in terms of evaluating and synthesizing knowledge. Senita (2008) also supported that the crosslinks were found to reflect students' critical thinking skills. By having students link concepts with arrowheads or write words on the links, teachers could visualize whether students could understand the existing interrelationships.

Another study that adopted Novak and Gowin's concept map assessment rubric is Hsu's (2004), which examined whether concept maps can promote college students' problem-solving and critical thinking skills in a nursing school. In the study, students were asked to watch a video and draw a concept map about the video. The students' concept maps were graded based on Novak and Gowin's rubric. There were significant differences in the proposition and hierarchy scores for concept maps between students with a higher level of critical thinking ability and those with a lower level of ability. But no significant differences were found in the cross-linking and example scores.

Although Novak and Gowin's concept map assessment rubric has been used to differentiate high-level from low-level critical thinkers by assigning scores on students' concept maps, these concept map scores did not consistently reflect students' critical thinking skills in previous studies (e.g., Abel & Martha Freeze, 2006; Senita, 2008; Rosen & Tager, 2014). In addition, Novak and Gowin (1984) indicated that the concept map rubric was developed to grade students' concept maps for general purposes. They did not indicate that the rubric was specifically designed to assess students' critical thinking. Therefore, there remains a paucity of

knowledge regarding how Novak and Gowin's rubric is related to critical thinking skills. It is necessary to examine the correlation between the rubric and critical thinking skills in order to validate the findings of previous studies using the rubric as a measurement of critical thinking skills and contribute to the development of a concept map rubric for critical thinking assessment.

## Critical Thinking and Concept Mapping

Critical thinking is an essential competency for 21st century learners (Rotherham, & Willingham, 2010). Ennis (1993) defines critical thinking as "reasonable reflective thinking focused on deciding what to believe or do" (p. 180). Staib (2003) indicates that critical thinking is an evolving process involving knowledge, attitudes, application, and reflective thinking. A consensus definition of critical thinking has been proposed by a group of 46 experts in the American Philosophical Association. They define critical thinking as "the process of self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criterion logical, and contextual considerations upon which that judgment is based" (Facione, 1990, p. 2). Based on this definition, interpretation, analysis, evaluation, inferences, and explanations are viewed as the core skills of critical thinking. **Interpretation** involves decoding significance, categorizing, and classifying the meaning of situations, data, events, or objects. Examples of interpretation include distinguishing main ideas from subordinate ideas in a text (decoding significance), developing a categorization to organize text information (categorizing), and clarifying unknown vocabulary in a text (clarifying). **Analysis** is the process of detecting and breaking down arguments, and it includes such steps as identifying the intended and the inferential relationships between paragraphs in a text. **Evaluation** involves making an assessment of the credibility of statements

and the logical strength of the relationships among statements. Evaluation may include judging if any statements or concepts contradict each other in a text, leading to a weak conclusion. **Inference** is the identification of relevant elements needed to draw conclusions and form a synthesis of related ideas into a coherent picture. **Explanation** is a cogent and coherent presentation of the results of reasoning. An example of explanation is describing the procedures and criteria used to arrive at with a conclusion.

The critical thinking skills of interpretation, analysis, inference, and evaluation could be practiced with concept mapping activities (Baugh & Mellott, 1998; Rosen & Tager, 2014). Concept mapping refers to a process in which learners construct a concept map by adding concepts, thinking about the relationships between the concepts, and linking the concepts to form a knowledge structure in a hierarchy. concept mapping is composed of three processes: subsumption, progressive differentiation, and integrative reconciliation. In the subsumption process, learners need to place general concepts on the top level and specific concepts on the level below. Such a process entails the interpretation skill of distinguishing general concepts from specific concepts, and the evaluation skill of judging whether the general concepts and the specific concepts contradict each other. In the progressive differentiation process, learners expand a concept into finer components, which requires the analysis skill of detecting and listing smaller and related concepts or examples. In the integrative reconciliation process, concepts are joined with other related concepts through linking lines. The mapping act entails the inference skill of forming a synthesis of related concepts into a coherent knowledge structure, and the evaluation skill of judging if the concepts are linked with a high level of logical strength. Therefore, individuals can practice critical thinking skills through the concept mapping process.

**Using Concept Mapping to Improve Critical Thinking Skills**

Many studies have used concept mapping activities to improve students' critical thinking in nursing programs. For example, Daley et al. (1999) showed that concept mapping activities effectively improved clinic students' critical thinking skills because the activity requires students to think critically about meanings, propositions, and relationships among concepts. Teachers claimed that concept mapping activities especially enhanced the critical thinking skills of students who had difficulty verbally demonstrating their knowledge in class. Similarly, Lee et al. (2013) investigated the development of students' critical thinking in a two-year nursing baccalaureate program. Students were divided into control and experimental groups. Both of the groups were required to complete course assignments related to critical thinking. The students in the experimental group used the concept mapping strategy to complete the course assignments. The results showed that the students in the experimental group outperformed those in the control group in the course assignments. In previous research, however, the use of concept mapping activities to improve students' critical thinking has been limited to nursing education at the university level. Little research has examined the use of concept mapping activities to develop students' critical thinking skills at the high school level in Taiwan, where high school students are calling for critical thinking skill training and high teachers did not have the experience of critical thinking skill teaching (Yang & Lin, 2004; Yang & Wu, 2012). It is necessary to conduct research to examine the effect of concept mapping activities on critical thinking skill development at the high school level to provide instructional suggestions for high school teachers.

Table 2.3 provided a summary of the previous research which examined the effects of the concept mapping activities upon the critical thinking skill development, and indicated that the

effects of concept mapping activities on the critical thinking skill development were not consistent. As Table 2.3 showed, the interpretation scores improved in every study but not in Maneval et al. (2011). The evaluation scores showed significant progress in every study but not in Lee et al. (2013) and Maneval et al. (2011). The inference scores improved in every data set except that of Maneval et al. (2011). Explanation scores, however, showed no significant improvement in Lee et al. (2013) and Maneval et al. (2011).

Table 2.3

*The Effect of Concept Mapping on Critical Thinking Skills*

| Subscales of critical thinking | Interpretation | Analysis | Evaluation | Inference | Explanation | Overall critical thinking |
|---|---|---|---|---|---|---|
| Huang, Chen, Yeh, & Chung, 2012 | N/A | ○ | ○ | ○ | N/A | ○ |
| Lee, Chiang, Liao, Lee, Chen, & Liang, 2013 | N/A | N/A | ✕ | ○ | ✕ | ○ |
| McMullen, and McMullen (2009) | N/A | ○ | ○ | ○ | N/A | ○ |
| Maneval, Filburn, Deringer, & Lum, 2011 | ✕ | ○ | ✕ | ✕ | ✕ | ✕ |
| Wheeler & Collins, 2003 | N/A | ○ | ○ | ○ | N/A | ○ |

Notes: ○ = improved, ✕ = not improved, N/A = unexamined

The inconsistency of the effects of concept mapping on critical thinking skills could be attributed to the different use of concept mapping activities (Ruiz-Primo & Shavelson, 1996). Concept mapping activities through which students graphically represent concepts are

categorized into two types: high-directed and low-directed (Ruiz-Primo, 2004). The high-directed concept mapping activity requires students to fill in concept maps based on concepts, connecting lines, and map structures which are already provided by teacher. In contrast, the low-directed concept mapping activity allows students to use self-created concepts, connecting lines, and map structures to construct a map. The different use of concept mapping could lead to different effects of concept mapping on critical thinking (Ruiz-Primo & Shavelson, 1996). The high-directed concept mapping may be a better way for students to practice critical thinking because the task provides a template that guides them step-by-step through the process. Students also preferred constructing a partially complete map because they could produce better maps from scratch (Chang, Sung & Chen, 2001). In contrast, the low-directed concept mapping task may be difficult for students, especially novice or low-achievers, as the task provides no directions and little scaffolding. Students may feel confused about how to start a concept map and what to do with concept mapping so as to improve their critical thinking abilities.

Little research has explored whether students show any difference in critical thinking skill development in terms of interpretation, analysis, evaluation, inference, and explanation between low-directed and high-directed concept mapping activities. Concept mapping tasks were not clearly described in previous studies, such as Huang et al. (2012), Lee et al. (2013), Wheeler and Collins (2003), and Maneval, et al. (2011). Without addressing this question, researchers could not provide teachers with comprehensive suggestions for using concept mapping to improve students' critical thinking.

# CHAPTER 3

# METHODOLOGY

The purpose of this study was three-fold. First, the study explored the differences in critical thinking skill development between high-directed and low-directed concept mapping activities in the context of a high school in Taiwan. Second, the study investigated high school students' interpretations of the relationship between concept mapping activities and critical thinking. Third, the study examined the correlation between critical thinking skills and Novak and Gowin's concept map assessment rubric. Based on the research purposes, the research questions were:

1. What is the correlation between Novak and Gowin's concept map assessment rubric and critical thinking skills?
2. What is the difference in critical thinking skill development between the high-directed and the low-directed concept mapping groups?
3. How do students interpret the relationship between their concept mapping activities and their critical thinking skills?

## Participants

Seventy students were recruited from a course entitled "English Topic Seminar" in the English department at a high school in northern Taiwan. The course was designed to help first-year high school students develop critical thinking skills based on curriculum standards proposed

by the Ministry of Education in Taiwan. In the course, students were required to research a topic of their interest, write a research paper, and present their findings to the class. The instructor indicated that the students in the course were considered low-level critical thinkers and could be potential participants for this study

There were two sections of the course in the same semester (Class A & Class B). Class A took the course on Monday morning, and Class B took the course on Tuesday morning. Each class was comprised of 30 students. IRB approval was obtained by the University of Georgia and informed consent procedures were followed. Twenty-three students from Class A and 20 students from Class B agreed to participate in this study. The students who did not signed the assent form were asked to complete the concept mapping activities, but they did not have to fill out the critical thinking survey.

## Research Design

The research was conducted over four weeks (see Table 3.1). This study randomly designated Class A as the low-directed concept mapping group and Class B as the high-directed concept mapping group to investigate the difference in critical thinking skill development between the low-directed and high-directed concept mapping activities. Within the four weeks, each group read three English articles, drew two concept maps, and completed three critical thinking surveys. The three articles were selected from an English textbook which the course instructor was using in her class. This English textbook was designed for English as a Foreign Language high school students, and the basic vocabulary size required for the readers was 3,500-6,000 words. Each article contained around 350 to 400 words and four to five paragraphs, and all of the articles were expository texts (see Table 3.2 & Appendix E).

Table 3.1

*Research Design for Low-directed and High-directed concept mapping Groups*

| **Tasks** | **Timeline** | **Low-directed concept mapping group** | **High-directed concept mapping group** |
|---|---|---|---|
| Task 1 | Week 1 | ● Read Text I **w/o concept mapping**<br>● Take a critical thinking survey | ● Read Text I **w/o concept mapping**<br>● Take a critical thinking survey |
| Task 2 | Week 2 | ● Read Text II **with low-directed concept mapping**<br>● Take a critical thinking survey | ● Read Text II **with high-directed concept mapping**<br>● Take a critical thinking survey |
| Task 3 | Week 3 | ● Read Text III **with low-directed concept mapping**<br>● Take a critical thinking survey | ● Read Text III **with high-directed concept mapping**<br>● Take a critical thinking survey |
| | Week 4 | ● Interviews | ● Interviews |

Table 3.2

*Reading Materials*

| Tasks | Topics | Length/Words | Theme |
|---|---|---|---|
| **Task 1** | TV commercials | 414 | Business |
| **Task 2** | Green building | 355 | Environment |
| **Task 3** | Parenting | 399 | Education |

**Low-directed concept mapping group**

Table 3.1 shows that the low-directed group read Text I without concept mapping in week 1, read Text II with the low-directed concept mapping activity in week 2, and read Text III with the low-directed activity in week 3. The low-directed group were asked to construct concept

maps with self-created nodes, links, and map structures. The students were free to make decisions on how many nodes to include in maps, which nodes to connect, and which words to use to explain a relationship. The major challenge of the low-directed concept mapping group was that students might have had no idea about how to start a concept map or what they should include in the map. Therefore, instruction was provided in this study to teach the students how to create concept maps; however, the instructor and the researcher did not tell the students what to include in their concept maps. First, the students listed the ten to fifteen key concepts from the reading and ranked the list of concepts from general to specific. Second, the students identified the specific concepts which were related to the general concepts in some way, and then they tied the general and specific concepts with connecting lines and labels that described the relationships between concepts. Finally, the students looked for cross-linkages that tied concepts from one side of the map to the other. A critical thinking survey was given to the students after each of the readings in weeks 1, 2, and 3. The critical thinking survey represented students' critical thinking performance in tasks 1, 2, and 3.

**High-directed concept mapping group**

The high-directed group read Text I without concept mapping in week 1, read Text II with the high-directed concept mapping task in week 2, and read Text III with the high-directed concept mapping activity in week 3. In the high-directed group, the students were asked to fill in a skeleton map in which a vocabulary list and a concept map structure was provided (see Appendix F). In this study, the skeleton concept map was developed by the course instructor and the researcher who first worked separately to review the readings to identify important concepts from the readings. Then, the instructor and the researcher compared and discussed the lists of

selected concepts to reach a consensus. After that, instructor and the researcher each created their own concept maps with the lists of selected concepts, and then compared and modified each other's concept maps until consensus was reached. A critical thinking survey was distributed to the students after they completed the readings in weeks 1, 2, and 3. The critical thinking survey represented the students' critical thinking performance in tasks 1, 2, and 3.

## Interviews

A follow-up interview was conducted with participants in the high-directed and low-directed concept mapping groups and with the course instructor in week 4 to understand students' interpretation of the relationship between concept mapping activities and critical thinking. The interview process was divided into two phases: selecting participants and interviewing the participants.

### *Participant selections*

The course instructor and four students from each of the low-directed and high-directed groups were selected to participate in interviews in this study. Patton (1990) indicated that "more can be learned from intensively studying extreme or unusual cases than can be learned from statistical depictions of what the average case is like" (p. 170). Extreme case sampling was thus used to select the students from the low-directed and high-directed groups. In this study, eight students whose concept maps scores were not consistent with their critical thinking survey scores were selected from two groups: Four from the high-directed group and four from the low-directed group.

Multiple steps were used to locate the students whose map scores were inconsistent with their critical thinking survey scores. First, the inconsistency between the concept map scores and the survey scores was calculated by subtracting the individual student's critical thinking survey scores from his or her concept map scores. Then, the inconsistency scores were ranked in order within the low-directed and high-directed groups. Four students were recruited from the top 10 most inconsistent in each of the high-directed and low-directed groups. Finally, the course instructor was asked by the researcher to send out an invitation to the 10 students. However, four students in the high-directed group, and four students in the low-directed group indicated their willingness to be interviewed.

***Interviewing participants***

Individual interviews were conducted with the selected students and the course instructor. The interviews took place in the class via Skype and were recorded via iPad using Voice Record App. Due to the restriction of the time, the instructor only allowed the 20 minutes for each interview. In the interviews, the students spoke to me in Mandarin Chinese about their concept maps and their critical thinking surveys in conjunction with the reading texts.

The semi-structured interview was adopted in this study because the semi-structured interview allowed me to get more access to participants' responses and to focus the interviews on specific topics with lead-off questions (Carspecken, 1996). Two interview guides (see Appendix H & I) were designed with lead-off questions to start the interviews on topic domains: the concept mapping and the critical thinking survey. The first interview guide was used to ask students to describe their experiences with the low-directed or high-directed concept mapping and their responses to the critical thinking survey. The other interview guide was used to ask the

course instructor about her reactions to the low-directed and high-directed concept mapping tasks in relation to students' critical thinking performances. A set of covert categories and follow-up questions was generated in the interview guide to help me think about what I would expect the participants to address for each topic domain during the interview.

## Data Collection and Analysis

The collected data included critical thinking survey scores, concept map scores, and interviews to answer research questions (see Table 3.3).

Table 3.3

*Data Collection and Analysis*

| Research Questions | Data Sources | Data Analysis Methods |
|---|---|---|
| 1. What is the correlation between Novak and Gowin's concept map assessment rubric and critical thinking skills? | ● Concept map scores<br>● critical thinking survey scores | *Pearson correlation* |
| 2. What is the difference in critical thinking skill development between the high-directed and the low-directed group? | ● critical thinking survey scores | *MANOVA* |
| 3. How do students interpret the relationship between their concept mapping activities and their critical thinking skills? | ● Interviews | Inductive analysis approach |

**Research Question 1: What is the correlation between Novak and Gowin's concept map assessment rubric and critical thinking skills?**

Research question 1 was to examine the correlation between Novak and Gowin's concept map assessment rubric and critical thinking skills. This study used Novak and Gowin's (1984) rubric to assign scores to students' concept maps, and used a critical thinking survey to measure students' critical thinking skills. The correlation between students' concept map scores and critical thinking survey scores represents the correlation between Novak and Gowin's rubric and critical thinking skills.

***Concept maps scores***

Students' concept map scores were assigned by me based on Novak and Gowin's (1984) concept map rubric (see Figure 3.1). Scores were given for (a) the propositions of the concepts, (b) the hierarchical organization of the maps, (c) cross-links between the concepts, and (d) examples of the concepts. The term "propositions" refers to the meaningful relationships between two concepts indicated by the connecting line or linking words. Each meaningful relationship gets 1 point. The hierarchical organization entails that each subordinate concept is more specific than the concept above it. Each valid level of the hierarchy gets 6 points. The cross-links criterion requires the map to show meaningful connections between one segment of the hierarchy and another segment. Each cross link that is valid and synthesizes related concepts or propositions gets 10 points. Valid examples should provide specific instances of a concept. Each valid example of a concept gets 1 point. The range of concept map scores is as low as zero but up to infinity.

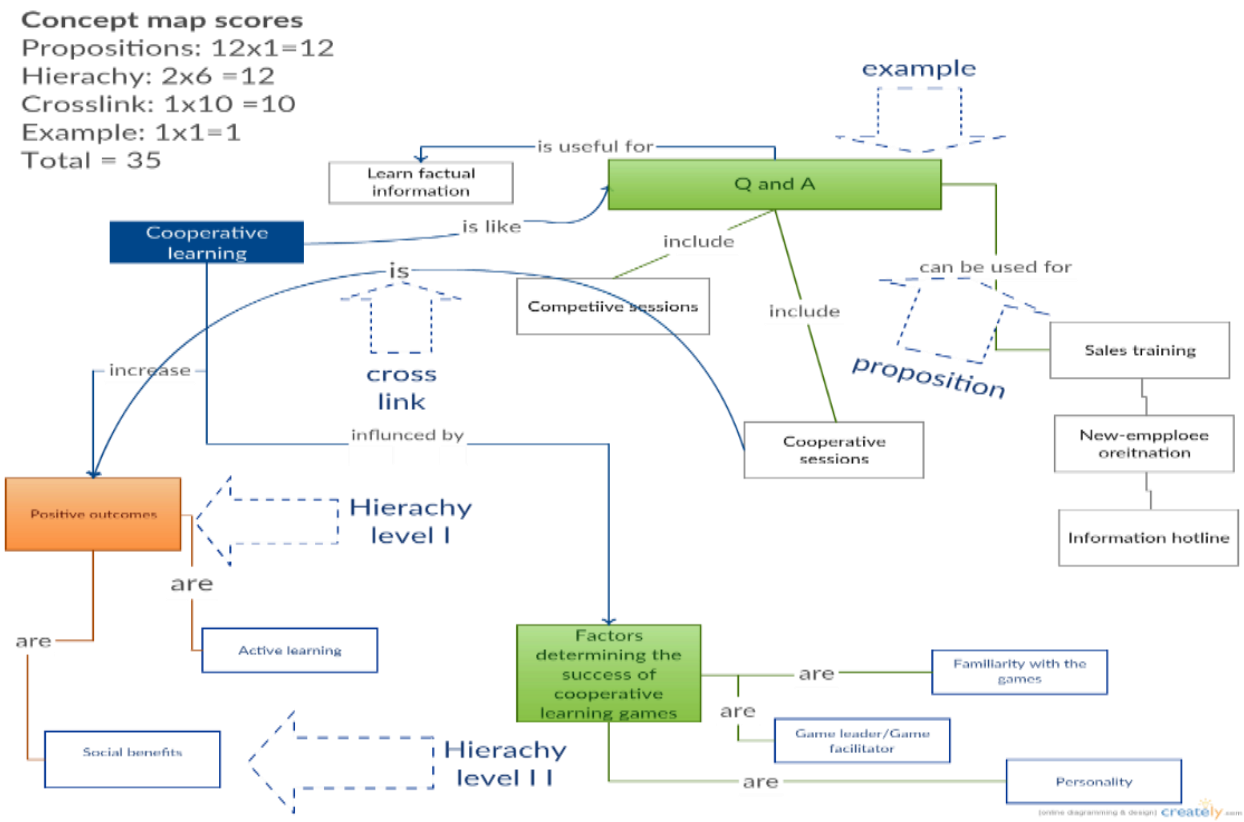



*Figure 3.1.* An example of concept map analysis based on Novak and Gowin's scoring system.

### *Critical thinking survey scores*

A critical thinking survey was distributed to high-directed and low-directed groups after they completed the readings in weeks 1, 2 and 3 to reflect their critical thinking skills. The critical thinking survey developed by Zhou, Yuhong, and Yuan (2015) was adapted to measure students' critical thinking skills in this study (see Appendix G). Although a number of instruments for measuring critical thinking have been constructed (e.g., the California Critical Thinking Skill Test), Jie's instrument was selected because it has been specifically designed to assess students' critical thinking in reading contexts, and its validity and reliability have been established (Jie, Yuhong, & Yuan, 2015).

The critical thinking survey was comprised of three sections (see Appendix G). The first section asked students for their background information. Students were only asked to fill out the background information the first time. Independent from the assigned reading text, the second section contained 21 Likert-scale items to measure students' critical thinking in terms of interpretation, analysis, evaluation, inference, and explanation skills (5=agree; 4=basically agree; 3=hard to say; 2=not quite agree; 1=disagree).

Students' critical thinking survey scores were compared with their concept map scores to examine the correlation between critical thinking skills and Novak and Gowin's concept map rubric using Pearson's correlation analysis. Table 3.4 represents an analysis framework of the relationship between critical thinking scores and concept map scores. Pearson's correlation analysis was used because it can reveal the strength of a linear relationship between the concept map scores and the critical thinking survey scores in which the value of *r* approaching 1 or -1 indicates a high correlation.

Table 3.4

*Relationship Between Critical Thinking Scores and Concept Map Scores*

| **critical thinking skill scores** / **Concept map scores** | Interpretation | Analysis | Evaluation | Inference | Explanation | Overall critical thinking |
|---|---|---|---|---|---|---|
| Propositions of the concept maps | *r* | *r* | *r* | *r* | | *r* |
| Hierarchical organization of the maps | *r* | *r* | *r* | *r* | | *r* |
| Cross-links between the concepts, | *r* | *r* | *r* | *r* | | *r* |
| Examples of the concepts | *r* | *r* | *r* | *r* | | *r* |

**Research Question 2: What is the difference in critical thinking skill development between the high-directed and the low-directed groups?**

Research question 2 examined the difference in critical thinking skill development between the high-directed group and the low-directed group. The critical thinking survey mentioned above was delivered to the high-directed group and the low-directed group in Tasks 1, 2, and 3 to measure their critical thinking skill development. The critical thinking survey scores of the two groups were analyzed using a multivariate analysis of variance (MANOVA) to compare the critical thinking skill development between the two groups in Tasks 1, 2, and 3. The reason for using MANOVA was that it can determine the differences between multiple dependent variables affected by changes in one or multiple independent variables (Bray & Maxwell, 1985). In this study, the dependent variables are the overall critical thinking scores and the sub-scores of critical thinking (interpretation, analysis, evaluation, inference, and

explanation) on the critical thinking survey. The independent variable is the concept mapping task (the low-directed task and the high-directed task).

**Research Question 3: How do students interpret the relationship between their concept mapping activities and their critical thinking skills?**

Research question 3 intends to explore how students interpret the relationship between their concept mapping activities and their critical thinking skills. The instructor was also interviewed to affirm what students said in the interviews.

***Data analysis of interviews***

The interview data were analyzed using an inductive analysis approach (Attride-Stirling, 2001; Seidman, 2006) featuring a sequence of activities including (1) organizing and reading through data, (2) coding data, (4) generating themes, (5) interrelating themes, and (6) interpreting the themes. ATLAS.ti 7 Windows a Qualitative Data Analysis Software, was used to transcribe and analyze interview data to pursue the transparency of data analysis (Paulus, Lester, & Dempster, 2014).

The data analysis started by transcribing interviews and cataloguing interviews using initials or pseudonyms for the teacher and students. In the transcript, for example, R refers to the researcher of this study, T refers to the teacher, and other letters represent initials of the students in this study. The transcription files were named with the date of the interview and the interviewee's pseudonym. For example, the file of Peter's interview data recorded on Dec. 26th in 2016 would be named Peter.11_26_16 .

After transcribing interviews, the researcher read through the transcripts to obtain general ideas about what participants were saying and to write down first thoughts on each transcript, and then selected one transcript and opened it with the research question to make sure the analysis of the interview aligned with the research question (see Figure. 3.2). While reading the transcript, interesting passages were marked by the researcher with a list of possible topics related to the research question. Once finishing reading all the transcripts, similar topics were clustered and designated a code for each topic cluster.

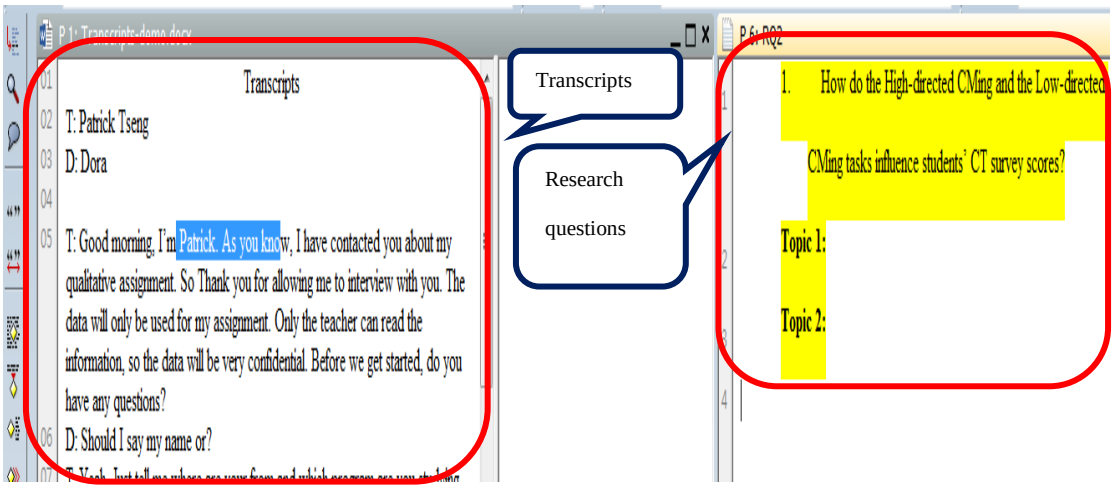



*Figure 3.2.* Coding data using ATLAS.ti

Using the codes, the researcher went back to the transcripts again, labeled the marked passages with codes, and determined whether the codes needed to change during the coding analysis. Next, the researcher read through the marked passages under each code to generate themes which were broad enough to cover the ideas of the labeled passages and then refined the recurring themes. The themes were represented and displayed as a network in order for me to visualize the interrelationships among the themes. The final stage of the data analysis was to

interpret the meaning of themes based on the research questions, the theories in which this study is grounded, and the relevant literature.

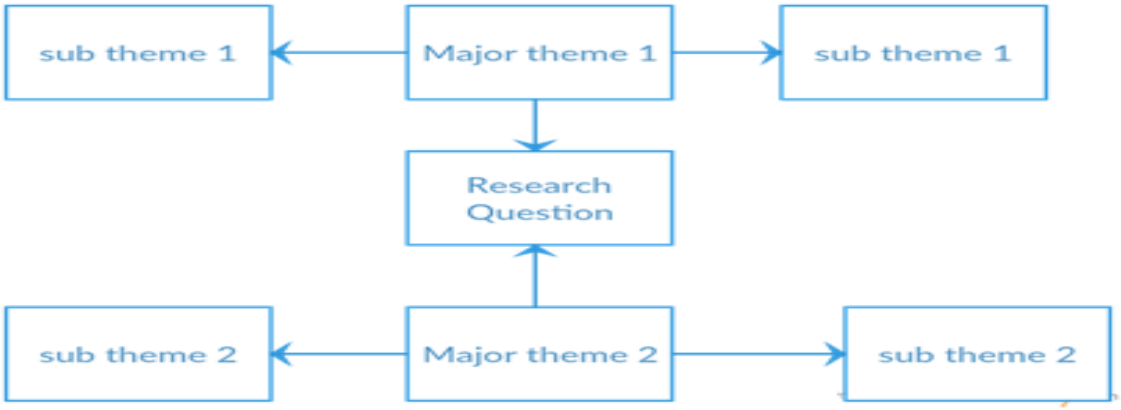



*Figure 3.3.* A network of themes

# CHAPTER 4

# RESULTS

This chapter was organized in accordance with the three research questions: (a) What is the correlation between Novak and Gowin's concept map assessment rubric and critical thinking skills? (b) What is the difference in critical thinking skill development between the high-directed group and the low-directed concept mapping group? (c) How do students interpret the relationship between their concept mapping activities and their critical thinking scores?

## Research Question 1: Correlation between Novak and Gowin's concept map assessment rubric and critical thinking skills

This study used Novak and Gowin's (1984) concept map assessment rubric to assign scores to students' concept maps, and used a critical thinking survey to measure students' critical thinking skills. A Pearson correlation was performed between students' concept map scores and their critical thinking survey scores to show the correlation between Novak and Gowin's concept map assessment rubric and critical thinking skills. The Pearson correlation was performed within the high-directed group and the low-directed group separately, since the nature of concept mapping activities differed between the low-directed and high-directed groups. Table 4.1 represented the correlation between critical thinking survey scores and concept map scores within the low-directed group in Task 2, which was the first time that the students constructed concept maps. The results showed that within the low-directed group, the example scores were

positively and statistically correlated with the interpretation scores, $r = .48$, $p < .05$, and with the analysis scores, $r = .38$, $p < .05$. The students who provided more examples of concepts tended to score higher on the critical thinking survey scores in terms of the interpretation and analysis. In addition, Cohen (1988) suggested that a correlation coefficient of .371 or above is considered a strong correlation. Based on Cohen (1988), the results showed that the example scores had strong correlation with the interpretation and the analysis scores.

Table 4.1

*Correlation Between Critical Thinking Survey Scores and Concept Map Scores in Task 2 Within the Low-directed Group (N=23)*

| critical thinking survey scores / Concept map scores | Inference | Interpretation | Analysis | Evaluation | Explanation |
|---|---|---|---|---|---|
| Proposition | .03 | .31 | .20 | .08 | .14 |
| Hierarchy | .21 | .36 | .19 | .10 | -.04 |
| Crosslink | .27 | .23 | .14 | .06 | .26 |
| Example | .33 | .48* | .38* | .10 | .24 |

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

Table 4.2 presented the correlation within the high-directed group. No correlation was found between concept map scores and critical thinking survey scores. Further, the hierarchy and crosslink scores within the high-directed group could not be calculated by the Pearson correlation, because there was no variation in the hierarchy and crosslink scores within the high-directed group. The no variation in the hierarchy and crosslink scores was attributed to the nature of the high-directed concept mapping task in which the students were restricted in a given concept map structure and therefore they did not have opportunities to develop their own map structures. The results might suggest that Novak and Gowin's concept map assessment rubric

was not an appropriate instrument to measure students' critical thinking skills in the high-directed concept mapping activity.

Table 4.2

*Correlation Between Critical Thinking Survey Scores and Concept Map Scores in Task 2 Within the High-directed group (N=20)*

| critical thinking survey scores / Concept map scores | Inference | Interpretation | Analysis | Evaluation | Explanation |
|---|---|---|---|---|---|
| Proposition | -.13 | -.07 | -.12 | -.18 | .15 |
| Hierarchy | . | . | . | . | . |
| Crosslink | . | . | . | . | . |
| Example | .28 | .13 | .09 | .03 | .14 |

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

Another Pearson correlation was conducted to show the correlation between critical thinking survey scores and concept map scores within the low-directed group in Task 3, which was the second time that the students created their concept maps after reading (see Table 4.3). The results showed that there was no statistical correlation between critical thinking survey scores and concept map scores. However, based on Cohen (1988) who suggested that a correlation coefficient of .371 or above is considered a strong correlation, the hierarchy scores were positively related to interpretation scores, and the example scores were negatively related to inference scores. The inconsistent finding in terms of the correlation between Tasks 2 and 3 could be attributed to the small sample size in Task 2 (N = 23) and Task 3 (N = 12). Correlations calculated on data collected from a small sample below 30 could be affected substantially by any changes in scores (Goodwin & Leech, 2006), leading to the fact that both Tasks 2 and 3 could not produce consistent correlation between concept map scores and critical thinking scores.

Table 4.3

*Relationship Between Critical Thinking Scores and Concept Map Scores in Task 3 Within the Low-directed Group (N=12)*

| critical thinking survey scores / Concept map scores | Inference | Interpretation | Analysis | Evaluation | Explanation |
|---|---|---|---|---|---|
| Proposition | -.22 | .23 | -.11 | .15 | .07 |
| Hierarchy | -.29 | .39 | .28 | -.13 | .17 |
| Crosslink | -.13 | .30 | -.36 | -.26 | -.36 |
| Example | -.52 | .22 | -.31 | -.30 | -.26 |

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

**Research Question 2: Differences in critical thinking skill development between the high-directed and the low-directed concept mapping groups**

Students in this study were divided into the low-directed group and the high-directed group to participate in three tasks. In Task 1, the two groups took a critical thinking survey after reading an article but did not construct a concept map after reading. A MANOVA was performed to measure differences in critical thinking skills (i.e., inference, interpretation, analysis, evaluation, and explanation) between the high-directed group and the low-directed group before the implementation of the concept mapping activities. The mean and standard deviation of the critical thinking skill scores for the two groups were shown in Table 4.4.

A homogeneity test was performed and showed that the multivariate result did not violate the assumption of MANOVA (see Table 4.5). The multivariate result indicated that there was no significant difference between the high-directed group and the low-directed group in the critical thinking skill scores, Wilk's lambda = .92, $F(5, 38) = .64$, $p = .67$ (Table 4.6). Therefore, the

two groups had similar critical thinking skill scores before the concept mapping activities were implemented.

Table 4.4

*Means and Standard Deviations for the Critical Thinking Survey Scores in Task 1*

| **Critical thinking skills** | **Groups** | ***Mean*** | ***SD*** | ***N*** |
|---|---|---|---|---|
| 1. Inference scores | Low-directed group | 3.05 | .77 | 23 |
| | High-directed group | 3.36 | .77 | 20 |
| 2. Interpretation scores | Low-directed group | 3.10 | .86 | 23 |
| | High-directed group | 3.10 | .67 | 20 |
| 3. Analysis scores | Low-directed group | 3.29 | .88 | 23 |
| | High-directed group | 3.33 | .78 | 20 |
| 4. Evaluation scores | Low-directed group | 3.23 | .66 | 23 |
| | High-directed group | 3.30 | .72 | 20 |
| 5. Explanation scores | Low-directed group | 3.26 | .95 | 23 |
| | High-directed group | 3.30 | .95 | 20 |

Table 4.5

*Homogeneity Test in Task 1*

| Critical thinking skills | ***F*** | ***Sig.*** |
|---|---|---|
| Inference | .27 | .61 |
| Interpretation | .33 | .57 |
| Analysis | .07 | .80 |
| Evaluation | .06 | .81 |
| Explanation | .00 | .98 |

Table 4.6

*Multivariate Effects for the Concept Mapping Activity in Task 1*

| | **Critical thinking skills** | ***Wilk's lambda*** | ***F*** | ***Sig.*** |
|---|---|---|---|---|
| Concept mapping activities | 1. Inference scores | .92 | .64 | .67 |
| | 2. Interpretation scores | | | |
| | 3. Analysis scores | | | |
| | 4. Evaluation scores | | | |
| | 5. Explanation scores | | | |

The concept mapping activities were implemented in Task 2 in which the low-directed group constructed a self-created concept, while the high-directed group filled in a skeleton concept map. Both groups took a critical thinking survey after the concept mapping activities. A MANOVA was conducted to measure the differences in the critical thinking skill development between the two groups after the concept mapping activities. The mean and standard deviation of the critical thinking scores for the two groups were shown in Table 4.7. A homogeneity test was performed and showed that the multivariate result did not violate the assumption of MANOVA (see Table 4.8). The multivariate result indicated that there was significant difference in the critical thinking scores between the high-directed and low-directed groups, Wilk's lambda = .74, $F(5, 337) = 2.75$, $p = .03$ (Table 4.9). The effect size (Eta Square,$\eta^2$) $\eta^2 = .27$ indicated 27% of the dependable variables is associated with the concept mapping activities. The results suggested that the implementation of the different concept mapping activities led to the differences in the critical thinking skill development.

As the MANOVA result was statistically significant, univariate ANOVAs were further performed to investigate the difference in each of the critical thinking skill scores between the high-directed group and the low-directed group using the significance at .01 as a way of

controlling for Type I error (see Table 4.10). The univariate ANOVA results showed that there were significant differences in the inference scores, $F(1, 41) = 8.18$, $p = .01$, the interpretation scores, $F(1, 42) = 8.32$, $p = .01$, the evaluation scores, $F(1, 42) = 8.08$, $p = .01$, and the explanation scores, $F(1, 42) = 11.41$, $p < .00$ between the high-directed group and the low-directed group. Based on Cohen (1988), the effect size of .20, .50, and .80 denote small, medium, and large effect sizes respectively. The results showed a small effect size in the inference scores, $\eta^2 = .17$, the interpretation scores, $\eta^2 = .17$, the evaluation scores, $\eta^2 = .17$, and the explanation scores, $\eta^2 = .22$. The ANOVA results suggested that the low-directed group scored higher on inference, interpretation, analysis, evaluation, and explanation than the high-directed concept mapping group.

Table 4.7

*Means and Standard Deviations for the Critical Thinking Survey Scores in Task 2*

| **Critical thinking skills** | **Groups** | ***Mean*** | ***SD*** | ***N*** |
|---|---|---|---|---|
| 1. Inference scores | Low-directed group | 3.68 | .67 | 23 |
| | High-directed group | 3.06 | .76 | 20 |
| 2. Interpretation scores | Low-directed group | 3.90 | .66 | 23 |
| | High-directed group | 3.26 | .79 | 20 |
| 3. Analysis scores | Low-directed group | 3.82 | .70 | 23 |
| | High-directed group | 3.35 | .79 | 20 |
| 4. Evaluation scores | Low-directed group | 3.58 | .61 | 23 |
| | High-directed group | 3.01 | .70 | 20 |
| 5. Explanation scores | Low-directed group | 3.72 | .65 | 23 |
| | High-directed group | 3.00 | .75 | 20 |

Table 4.8

*Homogeneity Test in Task 2*

| **Critical thinking skills** | ***F*** | ***Sig.*** |
|---|---|---|
| Inference | 1.62 | .21 |
| Interpretation | 1.51 | .23 |
| Analysis | .40 | .53 |
| Evaluation | .56 | .46 |
| Explanation | .52 | .48 |

Table 4.9

*Multivariate Effects for the Concept Mapping Activity in Task 2*

| | **Critical thinking skills** | ***Wilk's lambda*** | ***F*** | ***Sig.*** | $\eta^2$ |
|---|---|---|---|---|---|
| Concept mapping activities | 1. Inference | .73 | 2.69 | .04 | .27 |
| | 2. Interpretation | | | | |
| | 3. Analysis | | | | |
| | 4. Evaluation | | | | |
| | 5. Explanation | | | | |

Table 4.10

*Univariate Effects for the Concept Mapping Activity in Task 2*

| **Variables** | ***SS*** | ***df*** | ***MS*** | ***F*** | **Sig.** | $\eta^2$ |
|---|---|---|---|---|---|---|
| 1. Inference scores | 4.14 | 1 | 4.14 | 8.18 | .01 | .17 |
| 2. Interpretation scores | 4.35 | 1 | 4.35 | 8.26 | .01 | .17 |
| 3. Analysis scores | 2.32 | 1 | 2.32 | 4.21 | .05 | .09 |
| 4. Evaluation scores | 3.40 | 1 | 3.40 | 8.08 | .01 | .17 |
| 5. Explanation scores | 5.50 | 1 | 5.50 | 11.40 | .00 | .22 |

Task 3 was implemented one week after Task 2 to assure the results of Task 2. In Task 3, the high-directed and low-directed concept mapping groups repeated the same procedures as in

Task 2. A homogeneity test was performed and showed that the multivariate result did not violate the assumption of MANOVA (see Table 4.12). A MANOVA was conducted and the result indicated that there was significant difference between the high-directed and low-directed groups in the critical thinking survey scores, Wilk's lambda = .50, $F(5, 16) = 3.19$, $p = .04$ (Table 4.13). The Task 3 results, corresponding to the results of Task 2, showed that different concept mapping activities led to differences in six critical thinking survey scores.

Univariate ANOVAs were performed to examine the differences in each of the critical thinking skill scores between the high-directed group and the low-directed group at .01 as a way of controlling for Type I error (see Table 4.14). The univariate ANOVA results showed that there were significant differences in the analysis scores, $F(1, 20) = 11.59$, $p < .00$, the evaluation scores, $F(1, 20) = 12.26$, $p < .00$, and the explanation scores, $F(1, 20) = 9.03$, $p = .01$ between the high-directed and low-directed groups. Based on Cohen (1988), the effect size of .20, .50, and .80 denote small, medium, and large effect sizes respectively. The results showed a small effect size in the analysis scores, $\eta^2 = .37$, the evaluation scores, $\eta^2 = .38$, the explanation scores, $\eta^2 = .31$, and the total critical thinking scores, $\eta^2 = .34$. Corresponding to the Task 2 results, the Task 3 results showed that the low-directed concept mapping group obtained significantly higher analysis, evaluation, and explanation scores. However, unlike the Task 2 results, the Task 3 results showed no difference in the critical thinking survey scores on inference and interpretation between the high-directed and low-directed groups. The differences in the multivariate results between Tasks 2 and 3 could be attributed to the small sample size in Task 3, in which only 23 students filled out the CT survey and completed the concept map. The small sample size might affect the validity of the Task 3 results.

Table 4.11

*Means and Standard Deviations for the Critical Thinking Survey Scores in Task 3*

| **Critical thinking skills** | **Groups** | ***Mean*** | ***SD*** | ***N*** |
|---|---|---|---|---|
| 1. Inference | Low-directed group | 3.90 | .53 | 12 |
| | High-directed group | 3.40 | .81 | 10 |
| 2. Interpretation | Low-directed group | 3.92 | .45 | 12 |
| | High-directed group | 3.50 | .63 | 10 |
| 3. Analysis | Low-directed group | 3.96 | .44 | 12 |
| | High-directed group | 3.30 | .47 | 10 |
| 4. Evaluation | Low-directed group | 3.88 | .46 | 12 |
| | High-directed group | 3.08 | .61 | 10 |
| 5. Explanation | Low-directed group | 3.92 | .55 | 12 |
| | High-directed group | 3.28 | .43 | 10 |

Table 4.12

*Homogeneity Test in Task 3*

| **Critical thinking skills** | ***F*** | ***Sig.*** |
|---|---|---|
| Inference | 2.97 | .1 |
| Interpretation | 1.34 | .25 |
| Analysis | .36 | .56 |
| Evaluation | 2.22 | .15 |
| Explanation | .25 | .62 |

Table 4.13

*Multivariate Effects for the Concept Mapping Activity in Task 3*

| | **Critical thinking skills** | ***Wilk's lambda*** | ***F*** | ***Sig.*** | $\eta^2$ |
|---|---|---|---|---|---|
| Concept mapping activities | 1. Inference | .50 | 3.19 | .04 | .49 |
| | 2. Interpretation | | | | |
| | 3. Analysis | | | | |
| | 4. Evaluation | | | | |
| | 5. Explanation | | | | |

Table 4.14

*Univariate Effects for the Concept Mapping Activity in Task 3*

| **Critical thinking skills** | ***SS*** | ***df*** | ***MS*** | ***F*** | **Sig.** | $\eta^2$ |
|---|---|---|---|---|---|---|
| 1. Inference | 1.34 | 1 | 1.34 | 2.99 | .10 | .13 |
| 2. Interpretation | .95 | 1 | .95 | 3.30 | .08 | .14 |
| 3. Analysis | 2.36 | 1 | 2.36 | 11.59 | .00 | .37 |
| 4. Evaluation | 3.49 | 1 | 3.49 | 12.26 | .00 | .38 |
| 5. Explanation | 2.25 | 1 | 2.25 | 9.03 | .01 | .31 |
| 6. Total critical thinking survey | 49.50 | 1 | 49.50 | 10.37 | .00 | .34 |

**Summary of the differences in critical thinking skill development between the high-directed and the low-directed concept mapping groups**

Table. 4.15 provides a summary of the critical thinking skill scores between the high-directed group and the low-directed groups in three tasks. In Task 1, the multivariate results suggested no significant differences in the critical thinking scores between the two groups before the concept mapping activity was implemented. In Task 2, the low-directed group constructed a concept map entirely on their own, while the high-directed group filled out a skeleton concept map. The results showed that the low-directed group significantly scored higher than the high-directed group in the inference, interpretation, analysis, evaluation, and explanation skills. In Task 3, the two groups repeated the same procedure as they did in Task 2. The low-directed group obtained significantly higher critical thinking survey scores on analysis, evaluation, and explanation. The differences in the inference and interpretation scores between two groups had become not significant in Task 3. However, the quantitative results might have its limitation because the sample size was marginal.

Table 4.15

*Multivariate results of the Critical Thinking Survey Scores Between the Two Groups*

| | Interpretation | Analysis | Explanation | Evaluation | Inference |
|---|---|---|---|---|---|
| Task 1 | H=L | H=L | H=L | H=L | H=L |
| Task 2 | H<L | H<L | H<L | H<L | H<L |
| Task 3 | H=L | H<L | H<L | H<L | H=L |

Note: H stands for high-directed group; L stands for low-directed group

**Research Question 3: Students' interpretations of the relationship between concept mapping activities and critical thinking skills**

Using extreme case sampling, eight students whose concept map scores were not consistent with their critical thinking survey scores (see Table 4.16) were interviewed to explore how students interpret the relationship between concept mapping activities and critical thinking skills (Research Question 3). This section describes (a) the use of concept mapping as a summarizing activity; (b) the consequences for using concept mapping as a summarizing activity; (c) the reasons for engaging in the concept mapping as a summarizing activity; (d) the relationships between the low-directed concept mapping activity and critical thinking skills; (e) the limitation of the skeleton concept map in the high-directed activity; (f) and the relationship between the high-directed concept mapping activity and critical thinking skills.

Table 4.16

*Critical Thinking Survey Scores of the Participants for Interviews*

| | | | |
|---|---|---|---|
| Low-directed Groups | **Participants** | **critical thinking survey scores** (Scores ranged from 10.05 to 22.50 among 23 participants) | **Concept map scores** (Scores ranged from 7 to 36 among 23 participants) |
| | John | 22.35 | 11 |
| | Nick | 19.85 | 33 |
| | Nicole | 16.9 | 7 |
| | Cindy | 15.8 | 11 |
| High-directed Groups | **Participants** | **critical thinking survey scores** **(**Scores ranged from 9.5 to 21.05 among 20 participants) | **Concept map scores** **(**Scores ranged from 12 to 24 among 20 participants) |
| | Zach | 14 | 23 |
| | Steve | 20.85 | 14 |
| | Bob | 16.6 | 20 |
| | Bill | 15.4 | 20 |

## Concept Mapping as a Summarizing Activity for the Low-directed Group

The results showed that the four students engaged in the low-directed concept mapping activity by writing down the essential concepts of the text and adding relevant examples in the concept maps. For example, John provided the following response when asked to talk about his concept map,

Excerpt 1

1. P: Can you tell me about your concept map?
2. John: The center of the map is “Green building.” I created the map based on the main points of each paragraph in the text. Like, in the paragraph #1, 2, and 3, each paragraph mentioned one key feature of green building. So, there were three keys. I used them to support the green building.

John indicated that he created his concept map by identifying what he perceived as the important concepts in each paragraph of the text. These important concepts, for example, included the green building, and the features of the green building, such as reducing pollution, protecting health, and resource using, as John stated, "Like, in paragraphs #1, 2, and 3, each paragraph mentioned one key feature of the green building. So, there were three keys. I used them to support the green building."

After John wrote down the main points of the text in their maps, he started adding examples in his concept map. When asked why he wanted to add examples and how he added the examples, John explained as follows:

Excerpt 2

1. P: I found you had added some examples in your maps? Can you tell me more about that?
2. John: Just like what I said. I wrote down the main ideas of each paragraph. Then, found some examples from the text and put the examples in the map. I read through the text to find examples. Examples were usually the objects which can give a specific picture.

John stated that he went back to the original text, read through the whole paragraph, and looked for specific concepts that were related to the main ideas of the text. The purpose of adding examples in the concept map was to illustrate the general main points. Based on Excerpts 1 and 2, creating concept maps for John was a summarizing activity to help him restate the main points of the text information with concrete examples.

**Consequences of Concept Mapping as a Summarizing Activity**

When students used concept mapping as a summarizing activity, they did not have incentives to provide linking phrases to specify the relationship between concepts. The students were asked to link concepts with lines and define the linking lines with phrases in the low-directed concept mapping activity. However, all the four students did a good job at adding linking lines in their maps, but Nicole, Cindy and John did not provide linking phrases in their concept maps when they mainly used their concept maps to summarize the text information. As shown in Excerpt 3, Cindy provided the following responses for why she did not label the linking lines.

Excerpt 3

1. P: I remember that the course instructor asked you to describe the relationships between the concepts. It looks like you did not do that. Why not?
2. Cindy: Because I had no idea what I was drawing during that time.
3. P: Why? You drew the map?
4. Cindy: Yes, but while creating the map, I was just copying the important phrases or sentences from the reading and putting them on the map. I was not thinking during the mapping process.
5. P: Why not?
6. Cindy: Because the concept mapping activity was just about listing the main ideas of the text.

Cindy stated that she did not provide linking phrases in the concept mapping activity, even though she was asked to do so. It was mainly because the "concept mapping activity was

just about listing the main ideas of the reading." She focused on identifying the main ideas and relevant examples of each paragraph and then wrote them down on the map. However, such behavior led to the problem that Cindy was merely "copying the important phrases and sentences from the reading, and pasting them on the map." She was not evaluating the text information in the concept mapping activity, which could be the negative consequence of using concept maps to summarize the main ideas of the text.

**Reasons for Concept Mapping as a Summarizing Activity**

The reason why the students regarded concept mapping as a summarizing activity might have to do with their previous learning experiences with concept mapping activities before this research. The instructor provided her observations about the concept mapping activity and her previous teaching experiences with concept mapping activities before this research.

Excerpt 4

1. P: Can you describe what happened when you assigned the high-directed/low-directed concept mapping task?
2. Course instructor: Actually, neither of the two groups of students felt the activity was difficult to complete. For the low-directed group, the major problem for the students was to specify the relationships between concepts. It was possible because students felt that the concept mapping activity was to write down the main ideas of the text in the map, but they did not have training in identifying the relationships between nodes.
3. P: Did you give the students any training about the concept mapping activity before? Can you tell me about that?

4. Course instructor: Yes, it was like this. I used the concept map to help students comprehend the text. I showed the students a skeleton map in which some nodes of the map were empty. I gave students some keywords and asked the students to raise their hands to tell me what I should put in these empty nodes. But I did not ask them to tell me the relationship between the nodes.

The instructor stated that she had implemented concept mapping activities in her class before this study. She would display a skeleton concept map in which some nodes were empty and some keywords of the text were provided, and then she asked the students to raise their hands to indicate which words should fill in the empty nodes. Based on her description, the concept mapping activity was mainly used to teach the students to locate the main ideas of the reading to improve students' reading comprehension. This might explain why the students mainly used the concept mapping activity to summarize text information.

**Relationship Between the Concept Mapping activity and Critical Thinking Skills for the Low-directed group**

Four students were interviewed to interpret the relationship between the low-directed concept mapping activity and critical thinking skills including interpretation, analysis, evaluation, inference, and explanation. Table 4.17 provides a summary of the interview findings. The low-directed concept mapping activity was related to the interpretation, analysis, explanation, and inference skills. However, the evaluation skill had little to do with the concept mapping activity. Representative excerpts were selected to illustrate how the students interpreted the relationship between the critical thinking skills and the concept mapping activity.

Table 4.17

*A Summary of the Relationship Between Concept Mapping Activities and Critical Thinking skills for the Low-directed group*

| | Interpretation | Analysis | Explanation | Inference | Evaluation |
|---|---|---|---|---|---|
| Low-directed activity | Related | Related | Related | Related | Not related |

***Interpretation, Analysis, and Explanation Skills for the Low-directed Group***

The four students stated that interpretation, analysis, and explanation skills were related to the concept mapping activity, because the activity enabled them to locate the main ideas of each paragraph of the text and see the connections between the text ideas. For example, Nicole described how the interpretation skill was related to the concept mapping activity in Excerpt 5.

Excerpt 5

1. P: Do you think the concept mapping activity is good for critical thinking skills?
2. Nicole: Yes.
3. P: Why?
4. Nicole: Because before creating the map, I did not quite understand the text. But after drawing the map, I could understand the main ideas of the text.
5. P: What is the most difficult part when creating your concept map?
6. Nicole: I guess it is to find the main ideas of the text.
7. P: How did you like your concept map?
8. Nicole: It's okay. I wish I could have more time to look up vocabulary in the dictionary, so I can understand whether the main ideas I selected were correct.

Nicole stated that her interpretation skill increased after the concept mapping activity by which she could "understand the main ideas of the text." However, Nicole pointed out that her interpretation skill was affected by her limited English proficiency by saying "I wish I could have more time to look up vocabulary in the dictionary, so I can understand whether the main ideas I selected were correct." The same problem happened to Cindy who stated that she could identify the main ideas of the text through the concept mapping activity, but she could not interpret the text well due to her English-speaking deficiency in paraphrasing the text. Cindy stated that if she could restate the text in her native language, she would not have this problem. The results showed that the concept mapping activity was beneficial for the development of the interpretation skill when language was not a barrier.

The analysis skill was associated with the concept mapping activity for the same reason that the concept mapping activity stimulated the students to locate main text ideas and find relevant and concrete examples to illustrate the main ideas. For example, John stated, "While I was creating the concept map, I was looking for relevant ideas and examples to support the main ideas of each paragraph." The actions of identifying the main ideas and relevant examples involved in the concept mapping activity enabled John to practice the analysis skill of distinguishing the general text information from concrete text ideas, and recognizing the text structures.

Explanation refers to presenting the results of your reasoning in a clear way by telling someone how you comprehend the reading, giving reasons for accepting or rejecting what the author said. The four students perceived that the concept mapping activity was related to the explanation skill because the concept mapping activity allowed them to identify the main text information, and especially the activity helped organize the text information. For example, Nick

in Excerpt 6 described how the concept mapping activity supported him to organize the text information.

Excerpt 6

1. P: Let's look at the question, "I can explain to others how I can comprehend the text." You selected "agree." Why?
2. Nick: Because I think after drawing the concept map, I could see which concepts were related. If I can see how concepts were connected, I can tell how I comprehend the text.
3. P: How did you see these concepts were connected from the concept mapping activity?
4. Nick: Using those connecting lines. After I wrote down the main points, I started building the connections among them.
5. P: So, the connecting lines were helpful.
6. Nick: Yes, because listing the main ideas would make the information look fragmented. It is hard to explain to others. These connecting lines were just like clues to help me explain.

Nick indicated that the concept mapping activity was useful for the explanation skill, because he could see "how concepts were connected" in the text after he built the relationships between concepts in the concept mapping activity. The linking lines became useful resources in the concept map for him to organize "fragmented" text information into a logical knowledge structure so that he could better recall the text and provide explanations to others.

### *Inference Skill for the Low-directed Group*

Nicole, Nick, and John agreed that the concept mapping activity was related to the inference skill because the activity allowed them to identify the elements they needed to draw reasonable inferences. For example, Nicole provided the following responses when asked about the relationship between the inference skill and the concept mapping activity.

Excerpt 7

1. P: Let's look at the question, "I can make reasonable inferences without reading the rest of the text." You selected "agree". Why?
2. Nicole: Because I had listed some main ideas of the reading. So, based on these main points, I could predict what the author might say in the text. But the prediction might not be 100 percent correct. The author may have his own perspectives, and I have mine. So, my concept map would look different and my prediction might not be correct.

Nicole stated that in the concept mapping activity she had "listed some main ideas of the reading", and that main ideas served as useful information to infer what the author might say next. However, she was not sure about the accuracy of the inferences by saying her prediction might be different from the author's, because she said that each person might has his or her own unique interpretation of the text. For her, making inferences seemed a critical thinking skill relying on personal unique interpretation of the text and possibly varying from one person to another.

***Evaluation Skill for the Low-directed Group***

John, Cindy, and Nicole indicated that the concept mapping activity had little to do with their evaluation skills. John provided the following reasons for why he assigned lower scores on his evaluation skill after engaging in the concept mapping activity.

Excerpt 8

1. P: Can you tell me why you selected "neutral" on the Question, "I can raise questions or objectives when reading something which is weak in an argument"?
2. John: Because when drawing the concept map, I was able to find out the important ideas of the text. But, to raise questions about the text, I would read the text again.
3. P: So, the concept map was only useful for you to identify the main points of the text?
4. John: Yes, and some examples.

John stated that the concept mapping activity was merely a process of identifying the main points of the reading text. The activity could not help him evaluate the text information. To evaluate the text, he would have to review the text to detect the weak arguments in the text. Echoing John, the instructor in Excerpt 9 pointed out why evaluation skill was not related to the concept mapping activity.

Excerpt 9

1. P: I found the students seemed to see the concept mapping activity as not related to the evaluation skill. Do you know why?

2. Course instructor: I think when the students were creating the concept maps, they just wanted to transform the text information, the main ideas, into a diagram. But they did not try to judge the relationship between the concepts. They did not have such training. And I think most students just handed in their concepts once they finished it. They often put unrelated concepts together.

The instructor stated that the concept mapping activity for the students was a way to "transform what they know about the text" into a node-link diagram by writing down the main ideas and examples in the concept maps. Once the students wrote down enough the text information which they perceived important in the maps, they would hand in their concept maps immediately without reviewing their concept maps to identify concepts which were not well supported or connected. However, it was found that the students often put unrelated concepts together, which showed that the students were copying and pasting the main ideas from the text without engaging in the process of evaluation in the concept mapping activity.

***Keys to Develop the Evaluation skill for the Low-directed Group***

Nick was the only student who appreciated the usefulness of the concept mapping activity for his evaluation skill. A unique characteristic differentiating Nick from those, who perceived the evaluation skill and the concept mapping activity as unrelated, was that Nick would review his concept map and assess the logical strength of the connections between nodes in the concept map. He provided the following responses when asked to describe his feeling about the concept mapping activity for the evaluation skill.

Excerpt 10

1. P: How did you feel about the concept mapping activity for the critical thinking skills?
2. Nick: It's helpful. Without doing the activity, I was used to reading each word in the text very carefully. After creating the map, I can get an overall picture of the text.
3. P: What are other benefits of the concept mapping activity?
4. Nick: I think because while I was reading, I agreed with everything the author said. But, after drawing the concept map, I found there were some arguments in the text that were not very strong.
5. P: Why can drawing the concept map help you find the weak arguments in the text?
6. Nick: I created the map based on the text. But when I read the concept map again, I found some connections between the nodes in the map were not strong.

Nick stated that when reading an article without creating a concept map, he simply followed the author's logic and agreed with everything the author said. However, after creating his concept map, he could identify some weak arguments in the text from reviewing the connections between the nodes in his concept map. When reading his concept map again, he generated an idea that "why the author put these concepts together." He "spent so much time understanding the logics of the author," trying to revise his original concept map to make the connections between concepts stronger. This demonstrated that Nick was engaged in the evaluation process in which he analyzed the author's purpose and perspective in the text to understand how they affect the text. Reviewing the concept map was a significant learning behavior that stimulated his evaluation skill. A possible explanation of this was the

metacognition monitoring ability triggered by reviewing the concept maps, which allowed the students to assess their cognitive knowledge structure.

**Limitations of the High-directed Concept Mapping Activity**

The students encountered a major difficulty in the high-directed concept mapping activity in which they filled in blank nodes and provided linking phrases to define the relationships between concepts in a skeleton concept map. The difficulty was that the skeleton concept map did not allow the students to present their unique knowledge structure of the assigned reading. For example, Zach indicated:

Excerpt 11

1. P: Can you tell me about your concept map?
2. Zach: The map is about green buildings and how to build green buildings and why we need green buildings.
3. P: How did you start the activity?
4. Zach: I finished the reading first. Then, read the text again to find the words [on the vocabulary list]. Then, I put the words in the same paragraph together, determined how they were related, and put them in the blanks.
5. P: Any difficulties?
6. Zach: Yes, I felt some words were related and wanted to put them together in the map. But, I found out these words could not be put together in this map structure. So I felt my thinking was limited by the concept map.

Zach stated that he started filling in empty nodes in a skeleton map by reviewing the text to find the words on the vocabulary list. However, he felt his thinking was limited by the skeleton map, because he did not have the flexibility to put some of keywords together based on his own understanding of the text. He stated, "I felt some words were related and wanted to put them together in the map. But, I found out these words could not be put together in this map structure."

The same problem of the skeleton map occurred again when the students were providing linking phrases in the high-directed concept mapping activity, as shown in Excerpt 12.

Excerpt 12

1. P: Can you tell me why you did not specify most of the connecting lines to show relationships among these nodes?
2. Steve: I spent too much time filling in these blank nodes for a while. I did not know how to fill in these nodes. Too complicated. I just guessed the relationship based on my own understanding. I felt a map like this makes things complicated. There is no way I can know the relationship between these nodes.
3. P: What if you create your own map?
4. Steve: That would be much better. Because it is your own concept map, you know what you are drawing, and why you put these two concepts together. But this map created by others, I have no ideas how the map was created like this.

Steve indicated that he had a hard time providing linking phrases in the skeleton map. He could only "guess" the relationship between nodes in the skeleton map, and ended up with frustration by saying "there is no way I can know the relationship between these nodes." He

stated that he preferred to create his own concept: “Because it is your own concept map, you know what you are drawing, and why you put these two concepts together.” These statements indicated that asking students to define linking phrases in a skeleton map could be confusing, because the skeleton map prevented the students from making links between nodes from personal perspectives.

Another evidence which supported the findings above was the conversation with the course instructor, as shown in Excerpt 13 where she described her observation of the high-directed concept mapping activity.

Excerpt 13

1. P: Can you tell me about the high-directed group?
2. Course instructor: For the high-directed group, the students did not like the activity. I’ve got some feedback from the students. They indicated that they could comprehend the text well. But their problem with the activity was to fill in the blank nodes. They found it difficult to transform what they know about the text into the concept map. They disliked the activity because they felt the map could not represent what they know about the text. Even though you have listed some keywords in the activity, they still found the task difficult.

The instructor stated that she had received several complaints from the students about the high-directed concept mapping activity. The instructor indicated the students “disliked” the high-directed concept mapping activity, because they “found it difficult to transform what they know about the text into the concept map,” and the skeleton map “did not represent what they [the

students] knew about the text." The statement implied that the students had their own preferences to construct concept maps based on their personal experiences and understanding of the text, and they would prefer creating their own concept maps rather than using the skeleton map.

## Relationship Between the Concept Mapping Activity and Critical Thinking Skills for the High-directed Group

Four students were interviewed to interpret the relationships between the high-directed concept mapping activity and the critical thinking skills in terms of interpretation, analysis, evaluation, inference, and explanation. Table 4.18 provides a summary of the interview findings. The students indicated that the high-directed concept mapping activity, where they filled in a skeleton concept map, was related to interpretation, analysis, and explanation skills. However, the students indicated that the high-directed concept mapping activity was not related to evaluation and inference skills.

Table 4.18

*Relationships Between Concept Mapping activities and Critical Thinking Skills for the High-directed group*

| | Interpretation | Analysis | Explanation | Evaluation | Inference |
|---|---|---|---|---|---|
| High-directed activity | Related | Related | Related | Not related | Not related |

### *Interpretation, Analysis, and Explanation Skills for the High-directed Group*

The four students perceived that the high-directed concept mapping activity was related to their interpretation, explanation, and analysis skills due to the vocabulary list provided in the skeleton map. Using the given list, the students could easily identify the main ideas and

examples of the text to "interpret" and "explain" the text to others. For example, Bob stated, "Because the vocabulary list already listed some important ideas of the text with examples. So, after I put these words in the blank nodes, the map was like a summary of the text." Bob also stated that "because of his poor English reading ability," he would not be able to identify the main ideas of the text if the vocabulary list were not provided. Bob's statements indicated the vocabulary list was especially beneficial for students like him who also had lower levels of English proficiency to reduce the uncertainty about the text information. Apart from the interpretation and explanation skills, the vocabulary list was useful for the analysis skill. Steve stated that he had chances to practice the analysis skill while he was analyzing which words in the vocabulary list were the main ideas or examples by reading the article again to locate those words in the text.

Zach was the only student in the interviews who remained neutral about the usefulness of the high-directed concept mapping activity for his explanation and interpretation skills. Zach agreed that the vocabulary list was useful because it gave some clues about the reading text. However, the skeleton concept map structure became an obstacle that prevented him from explaining the text. He provided the following responses when asked how he assigned scores on the critical thinking survey.

Excerpt 14

P: Can you tell me why you selected "neutral" on the question, "I can restate what the author said using different words"?

Zach: I did not select "disagree" because the words listed in the map were helpful to know what the text was talking about. I did not select "agree" because I could interpret

the text very well without concept maps or I could create my own map. This map really confused me. For example, I felt two main ideas were related in the text, but I did not know how to fill them in the map. Because the map structure was different from what I thought.

P: Let's look at the question, "I can explain to others how I can comprehend the text." You selected "Neither agree nor disagree." Why?

Zach: This activity could help me know the main ideas of the text. But if I can draw my own map, I can better explain how I comprehend the text. It was the same problem with this map which I told you earlier.

Zach stated that he was confused with the skeleton concept map, because its map structure was different from the one he constructed in his mind by saying, "I felt these two main ideas were related in the text, but I did not know how to put them in the map." Therefore, he found it difficult to use the skeleton map to explain the text to others. He pointed out that if he could "create his own map", he would gain much more benefit on the explanation skill from the concept mapping activity. Based on the interview with Zach, the most effective concept mapping activity which supported the students' ability to explain what they knew about the text was the low-directed concept mapping activity in which the students could organize the text information based on their own understanding of the text.

### *Inference Skill for the High-directed Group*

Inference refers to drawing reasonable conclusions by identifying relevant information. Bob, Steve, Zach and Bill felt that the high-directed concept mapping activity was not highly related to the inference skill for the following reasons.

Excerpt 15

P: Let's look at the question, "I can make reasonable inferences without reading the rest of the text." You selected "Neither agree nor disagree." Why?

Bob: Because doing the activity only helped me recognize the major points of the text, but not the details. I need to see these details to make inferences about the text.

P: How about the vocabulary list? You mentioned that the vocabulary list gave you the main ideas and examples of the text.

Bob: I could not make inferences about the text using the vocabulary list because these points [in the vocabulary list] were identified by you. I had to find mine.

The first reason was that the vocabulary list provided in the high-directed concept mapping activity did not provide the information the students needed for drawing conclusions. The students agreed with the following comments from Bob: "I could not make inferences about the text using the vocabulary list because these points [in the vocabulary list] were identified by you. I had to find mine." This comment showed that the vocabulary list did not help the students to make inferences about the text. When making an inference, the students preferred to collect the information on their own. The same problem happened to Zach shown in Excerpt 16.

Excerpt 16

P: Let's look at the question, "I can make reasonable inferences without reading the rest of the text." You selected "Neither agree nor disagree." Why?

Zach: It was the same problem with the activity. Because this map was not created by me. I did not feel confident that I understand this map very well. To make the inference, you must fully understand what you draw in the map. Another reason was I think you have your personal understanding of the text and your map could be different. So it is easier to make the inferences based on your own understanding or your own map.

Zach stated he could not make inferences about the text from engaging in the high-directed concept mapping activity, since the activity restrained him in the skeleton map and prevented him from using his own perspective to predict the text information. He was limited to relying on the skeleton map structure and the vocabulary list that was provided in the concept mapping activity to make inferences. However, the problem was he did not feel confident in his understanding of the skeleton concept map, since it was not his own map. Therefore, he could not acquire enough information from the skeleton map to make inferences about the text. Based on the interview with Zach and Bob, making inferences was a personal knowledge construction process in which the students combined what they perceived as important in the reading with what they already knew about the reading to draw conclusions. The low-directed concept mapping which did not restrict students in the given concept map structure might be more suitable than the high-directed concept mapping to develop the inference skill.

### *Evaluation Skill for the High-directed Group*

Evaluation refers to assessing the credibility or the logical strength of information. All four students perceived that the high-directed concept mapping activity was not related to the evaluation, because evaluating the text information required sufficient detailed information from the text, while the concept mapping activity only provided avenues to identify the main points of the text. For example, Steve indicated that he could detect the weak arguments in the text and raise questions. But, the evaluation skill was not related to the concept mapping activity. Engaging in the concept mapping activity only gave him a general scope of the text in terms of the main ideas and the text structure. In order to judge whether the arguments in the text were true or not, he needed to read through the text carefully to assess the arguments and examples which the author proposed to support the main ideas. The results corresponded to the students in the low-directed concept mapping activity, who indicated that the concept mapping activity was not related to the evaluation skill since it was merely a process of identifying main points of the reading text.

## Summary of the Relationship Between the Concept Mapping Activity and Critical Thinking Skills

This study implemented the low-directed concept mapping activity, where the students constructed their own map, and the high-directed concept mapping activity, where the students filled in a skeleton map, to explore how the students interpreted the relationships between the concept mapping activities and critical thinking skills. For the low-directed concept mapping activity, the activity was beneficial for the development of interpretation, analysis, explanation, and inference skills, mainly because the students used the concept mapping activity to write down the main ideas of the text and add relevant examples. However, the low-directed concept

mapping activity was unrelated to the evaluation skill, because the students were merely copying and pasting the main ideas of the text in the concept maps without evaluating the logical strength of the main ideas of the text. Asking the students to review and re-examine their concepts could be a way to enhance the evaluation skill.

For the high-directed concept mapping activity, this study found that the vocabulary list in was beneficial for the students to interpret, explain, and analyze the text information. However, the skeleton concept map was an obstacle which prevented the students from using their own perspectives to evaluate the text and make inferences. In the next chapter, this study will compare and contrast the results of this study with that of previous research and explain the rationale of the research findings. Suggestions for future research and future teaching practices are also addressed in the following chapter.

# CHAPTER 5

# DISCUSSION AND CONCLUSIONS

The purpose of this study was three-fold. First, this study aimed to explore the differences in critical thinking skill development between high-directed and low-directed concept mapping activities in the context of a high school in Taiwan. Second, this study investigated high school students' interpretations of the relationship between concept mapping activities and critical thinking. Third, this study examined the correlation between critical thinking skills and the Novak and Gowin's concept map assessment rubric. This chapter was organized based on the three research purposes.

## Correlation between Novak and Gowin's concept map assessment rubric and students' critical thinking skills

Using Pearson correlation, this study found that the example was the only element in Novak and Gowin's rubric related to the critical thinking skills in Task 2. The students who obtained higher example scores demonstrated higher interpretation and analysis skills. However, the correlation between the example scores and the interpretation skill had become not significant in Task 3. Further, the example scores had become negatively correlated with critical thinking skills, although the negative correlation was not significant statistically. The possible explanation for the inconsistency in the correlation between Tasks 2 and 3 was that the sample size in Task 2 (N = 23) and Task 3 (N = 12) was too small. Goodwin and Leech (2006) indicted

that when a sample size is below 30, the correlations would be substantially affected by any changes in scores. Therefore, due to the small sample size Tasks 2 and 3 could not produce consistent and valid correlations between Novak and Gowin's concept map assessment rubric and critical thinking skills. Further studies with a sample size of participants above 30 should be conducted in the future.

The interviews were used to confirm the Pearson correlation results and provide deeper explanation of the relationship between Novak and Gowin's concept map assessment rubric and critical thinking skills. The interviews, corresponding to the correlation result, showed that examples in Novak and Gowin's concept map assessment rubric was related to the analysis skill. In this study, the students indicated that when adding examples in the concept map, they utilized the analysis skill to differentiate the main ideas from the subordinate ideas and examples in the text.

The interviews did not support previous research showing that the hierarchy and the cross-link in Novak and Gowin's rubric could reflect analysis and evaluation skills (e.g., Abel & Martha Freeze, 2006; Senita, 2008). In other words, this study found that the hierarchy and the cross-link in Novak and Gowin's concept map assessment rubric were not related to analysis and evaluation skills. The reason was the students engaged in concept mapping as a summarizing activity to increase their reading comprehension. During the concept mapping activity, the students focused on duplicating the phrases or sentences which they perceived as important text ideas and examples and wrote them down in the concept map. The students did not have incentives to expand the hierarchical structure of their concept maps or to cross-link the hierarchical structures because the students felt that "the concept mapping activity was just about listing the main ideas of the text." Therefore, the students constructed their concept maps with

simply one or two levels of hierarchy, and they did not use crosslinks to show the connections between one segment of the hierarchy and another segment (see Figure 5.1 as an example of students' concept maps). Thus, hierarchy and cross-links were not valid elements to measure students' critical thinking skills.

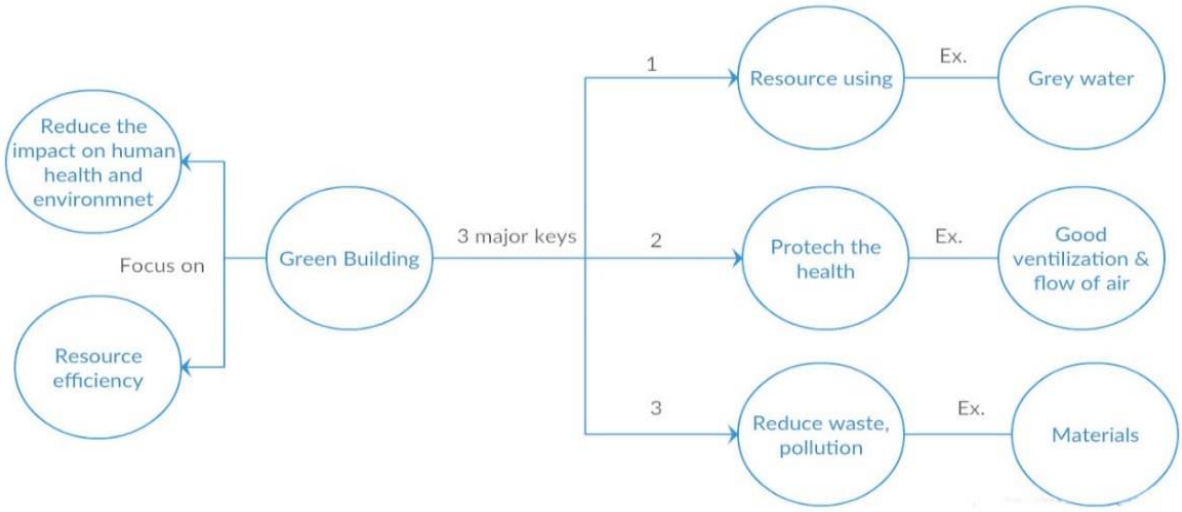



*Figure 5.1* An example of students' concept maps

Another finding was that propositions in Novak and Gowin's concept map rubric might be related to explanation skill. The propositions refer to the linking lines and words used to describe the relationships between nodes in a concept map. During an interview with Nick, he indicated that by using the linking lines and phrases, he could clearly explain how he comprehended the text. The linking lines between concepts and the linking phrases above lines enabled him to recognize the relationships between concepts in a cogent way, and therefore he could better explain the text to others. The results corresponded to Hsu's (2004) study, which examined whether concept maps can promote college students' critical thinking and problem-

solving skills in a nursing school. She found that the propositions of concept maps distinguished high-level critical thinkers from low-level critical thinkers.

**Differences in critical thinking skill development between the high-directed and low-directed concept mapping groups**

The Task 2 MANOVA results (N = 43) were used to discuss the differences in critical thinking skill development between the high-directed and low-directed concept mapping groups, since the sample size of Task 3 (N = 23) was not large enough to generate effective results of a MANOVA which required at least 40 samples (Faul et al., 2013). The Task 2 results showed that there was a significant difference in critical thinking skill development between the high-directed and low-directed concept mapping groups. The results corresponded to previous research (Ruiz-Primo & Shavelson, 1996) arguing that different concept mapping activities would produce different learning outcomes.

As relatively few studies have examined the learning effects of the high-directed group and low-directed group upon critical thinking skill development, this study discussed Task 2 results with previous research which compared the high-directed and low-directed concept mapping activities on different learning outcomes: biology (Chang, Sung & Chen (2001), physics (Korganci, Miron, Dafinei, & Antohe, 2014), problem-solving performance (Lee & Nelson, 2005), and reading comprehension (Soleimani & Nabizadeh, 2012). The Task 2 results of this study are contradictory to previous research showing that the high-directed group demonstrated higher scores than the low-directed group. These previous studies argued that the high-directed group generated better learning outcomes because the skeleton map provided students with a partial structure for learning content and reduced their cognitive load. Lee and

Nelson's (2005) is the sole study which is consistent with the Task 2 results showing the low-directed group who constructed their own map demonstrated better learning outcomes. In Lee and Nelson's (2005) study, students were assigned, based on prior knowledge, to use generative or completed concept maps. The students using the generative map constructed their own map entirely, while the students using the completed map were given a ready-made concept map. All the students took a problem-solving performance test after the concept mapping activity. The students who constructed their own map outperformed the groups using the completed map in problem solving.

This study found that the high-directed group scored higher when the task focused on content knowledge and conceptual understanding of the topic on subjects. For example, Chang et al. (2001) and Korganci et al. (2014) indicated that the high-directed group had better performances in the tests of content knowledge regrading biology and physics. In addition, this study found that the high-directed group obtained lower critical thinking scores when the task focused on high-order thinking skill training such as critical thinking skills. Therefore, this study concluded that the low-directed concept mapping activity was better for critical thinking skill training, while the high-directed concept mapping activity could be used to support the students to absorb conceptual knowledge.

**Using different concept mapping activities to develop students' critical thinking skills**

This study contributed to the literature by identifying which concept mapping activities (high-directed or low-directed) are better to develop students' critical thinking skills in terms of interpretation, analysis, explanation, evaluation, and inference.

**Interpretation, analysis and explanation skills**

Both the high-directed and low-directed concept mapping activities were helpful for interpretation, analysis, and explanation skills. For the high-directed activity, the vocabulary list served as a reference for the students, especially those who had lower English reading proficiency, to easily locate the main ideas of the text. These results align with Schau, Mattern, Zeilik, Teague, and Weber (2001), who found that the high-directed concept mapping activity was particularly beneficial for students with a lower level of communication skills. For the low-directed activity, the concept mapping activity stimulated the students to identify the main ideas of the text and locate examples to illustrate the main ideas, which helped the students conceptualize and summarize the text information. These results are consistent with prior research (Khodadady & Ghanizadeh, 2011), suggesting that the main feature of the concept mapping activity was to enable the students to locate main ideas and distinguish main ideas from examples.

The explanation skill was slightly different from the interpretation and analysis skills. It required the students to select major text ideas, and also asked the students to figure out rhetorical functions such as cause-effect between major ideas. The concept mapping activities enhanced the students' explanation skill by engaging them in linking the concepts with lines and providing linking phrases to specify the relationship between concepts. As Nick stated, he relied so much on the linking lines and linking phrases to explain to others how he comprehended the text. The linking lines and phrases between nodes enabled him to recognize and recall the relationships between the main ideas. Without these linking lines, the map could only provide fragmented information about the text. The linking lines and phrases between nodes in the map

create a holistic picture of the text by which the students can recognize the relationships between text ideas and improve their explanation skills.

**Inference skill**

The low-directed concept mapping activity was more effective than the high-directed concept mapping activity in developing the inference skill for the following reasons. First, inference was a critical thinking skill which the students needed full autonomy to collect the information which they felt was important and organize the information in a way which they felt was meaningful. In other words, making inferences required the students to apply and build upon their unique knowledge structures to draw conclusions. However, the students were unable to do so in the high-directed concept mapping activity in which the skeleton concept map prevented the students from building their knowledge structure to inference the text. For example, Zach indicated that he could not make correct inferences about the text using the vocabulary list and the skeleton map structure in the high-directed activity, because he had his own understanding of the text and might create a concept map different from the skeleton map in terms of the map structure. He must collect relevant text information by himself and create his own concept map by which he could use his personal knowledge structure to make inferences. Such findings corresponded to Chang et al (2001) indicating that the students disliked the high-directed mapping activity because the skeleton map in the activity did not allow them to reveal their creativity and individual knowledge structure. The problem of the skeleton concept map for the inference skill was exacerbated when the students could not figure out the relationships between blank nodes in the skeleton map. Failing to identify the relationships of the skeleton map became

an obstacle for the students to make inferences about the text in the high-directed concept mapping activity.

**Evaluation skill**

This study found that evaluation was the critical thinking skill which neither the high-directed nor the low-directed concept mapping activities could effectively enhance. These results align with Lee et al. (2013) and Maneval et al. (2011) who found that the concept mapping activities did not enhance the evaluation skill. However, they did not account for why the students did not improve their evaluation skills with concept mapping activities.

This study identified two possible reasons for why the concept mapping activities did not enhance the evaluation skill. The first reason was that the students mainly used the concept mapping activity to summarize the major points of the text, and thus did not include much text information that would be useful for them to evaluate the text. Previous research (e.g., Asan, 2007; Cañas, Hill, Carff & Suri, 2003; Oliver, 2009) similarly found that concept maps are mainly used as advanced organizers to present an overview of information sources to help students, especially beginners, better understand learning content through deductive or inductive reasoning. As this study found, the students did not want to add too much text information in concept maps, even though the information might be useful for the evaluation of the text. It was because they wanted to keep the concept maps clear and concise enough to easily visualize the main points of the text.

The second reason was that the students did not re-examine their concept maps after they created their maps, which has not been addressed in the literature. This study found that examining the hierarchal structures or the propositions of concept maps was a critical step for the

students to practice the evaluation skill in the concept mapping activity. Among the students participating in the interviews, Nick was the sole student who indicated that the concept mapping activity was related to the evaluation skill. He stated that before the concept mapping activity, he agreed with everything the author said in the article. He drew the concept map simply based on the relationships embedded in passages. However, he was able to evaluate the logical strength of text information and detect weak arguments when reviewing his map. He started analyzing and evaluating the text information based on his own knowledge and from different angles. Further evidence was seen from the students who perceived the concept mapping activity as unrelated to the evaluation skill. The common feature of these interviews was the idea that the concept mapping activity for them was to transform what they know about the text into a visual figure. As the teacher stated, most students drew their maps by listing keywords or main points of text information, and then submitted their maps. They did not review their maps from their own viewpoints to see if some concepts should be removed or added because of logical problems. All these results suggest that examining the concept map is necessary for the development of the evaluation skill in the concept mapping activity.

## Conclusions

This study investigated the relationship between Novak and Gowin's concept map assessment rubric and critical thinking skills in terms of interpretation, analysis, explanation, inference, and evaluation. However, due to the small samples, the Pearson correlation did not provide consistent and valid results. The interviews were used as alterative data to discuss the correlation between Novak and Gowin's rubric and critical thinking skill, and suggested that the

examples in the concept map were related to the analysis and interpretation skills, and the propositions in the concept map were related to the explanation skill.

In addition, this study examined the difference in the five critical thinking skills between the high-directed and low-directed groups. This study found that the low-directed group obtained significantly higher inference, interpretation, analysis, evaluation, and explanation scores than the high-directed group, and concluded that the use of different concept mapping activities has impact on the learning outcomes. Both the high-directed and low-directed concept mapping activity was beneficial for the development of the three critical thinking skills: explanation, analysis, and interpretation. The low-directed mapping activity was useful for the development of the inference skill. Neither the low-directed nor the high-directed mapping activity could effectively enhance the evaluation, which required the students to re-examine their concept maps. Based on the findings, this study provides pedagogical implications and suggestions for future research.

## Implications for Teaching Practice

Concept mapping activities have been used to improve students' learning outcomes in various subjects and higher order skills. In teaching practice, concept mapping is mainly divided into high-directed and low-directed concept mapping activities. This study provides teachers with some suggestions for the use of the two activities.

First, teachers may decide which concept mapping activities to use based on teaching objectives. The high-directed concept mapping activity is recommended when teaching objectives involve the interpretation, analysis, and explanation of learning content. Teachers may use the high-directed concept mapping activity when they want to help students comprehend and

absorb content knowledge of certain topics. When students become more sophisticated in their content knowledge, teachers may use the low-directed concept mapping activity to teach students to apply the knowledge which they have already learned. The low-directed concept mapping activity is better for teaching objectives which involve high-order thinking abilities such as evaluation and inference, rather than the memorization or interpretation of learning content.

Second, teachers may ask students to review and revise concept maps after students generate their first concept maps. Reviewing concept maps can stimulate students' evaluation skill to justify weak points in their concept maps. An instructional activity is proposed here for teachers to engage students in reviewing their concept maps. The instructional activity comprises the phases of (a) creating, (b) reviewing, and (c) revising concept maps. In the first phase, teachers assign students learning content (e.g., articles, videos) as stimuli to create concept maps. Students may start building their concept maps based on the main points of the learning content and expand their maps by adding detailed information. After finishing their maps, students proceed to the reviewing phase by sharing concepts with others. In the reviewing phase, students explain their concept maps to peers and ask for peer feedback on their concept maps. When providing peer feedback, students may raise questions or explain their rational of the idea in the map with which they agree or disagree. Students are forbidden to leave comments including generic praise or short phrases like "I agree" "I like it" or "Nice job." After receiving peer feedback, students move to the revising phase in which they revise their concept maps based on peer feedback. The three phases could be supported with online concept mapping tools which allow students to share concept maps and leave comments on concept maps without time and space constraints.

Third, teachers may encourage students to describe the nature of the relationships between concepts in the map, as it can help students better recognize the rhetorical functions between text ideas and enhance their explanation skills. Training must be provided ahead of time, especially for students who are not used to specifying the nature of the relationships between concepts in concept maps. In the training, teachers should avoid using a skeleton concept map, that is, a teacher-generated concept map with a pre-determined hierarchical structure. The skeleton map may constrain students' thinking and prevent them from identifying the relationships between concepts available and interesting to them. Low-directed concept maps are recommended. Teachers may use a think-aloud approach for demonstrations. Teachers can verbalize their thinking while defining the relationships between concepts in the map. Or teachers can teach students to look for contextual clues such as transition words to identify the relationships between concepts. In order not to overwhelm students, teachers may ask students to describe at least 10 relationships which they feel are the most useful and important to reduce their cognitive loads.

## Limitations of the Study

This study has several limitations. First, the Person correlation were unable to produce consistent and valid results to show the correlation between Novak and Gowin's concept map assessment rubric and critical thinking skills due to the small samples. The interviews were used to discuss the relationship between Novak and Gowin's rubric and critical thinking skills. Future research is suggested to examine the correlation using the Pearson correlation with sample size above 30.

Another limitation was the selection of the students for interviews. This study interviewed 8 students whose concept map scores were not consistent with their critical thinking survey scores. The inconsistency was calculated by subtracting the individual student's critical thinking survey scores from his or her own concept map scores. The top 10 students' inconsistency scores were ranked in order within each of the high-directed and low-directed groups. However, only 4 students from each of the groups gave permission for interviews. Nevertheless, the interview data were meaningful and helpful to answer the research questions.

The last limitation was the difficulty of the texts assigned for the students to draw concept maps about. The reading texts were selected by the instructor, indicating the texts had been used in her class and were not difficult for her students to comprehend. However, the interviews showed that some students still had reading difficulty with the texts because of their small vocabulary size. They indicated that they could perform much better in drawing concept maps if they could look up unknown vocabulary in the dictionary. It could be a loss that I did not ask students if the selected texts were too difficult for them to draw concept maps before this research.

## Suggestions for Future Research

Based on the results of this study, the following research topics were proposed to investigate in the future.

- ***An automated concept map rubric for critical thinking assessment***. The results showed that the example and proposition could be the elements in Novak and Gowin's concept map assessment rubric related to critical thinking skills. Therefore, Novak and Gowin's concept

map assessment rubric had little relationship with critical thinking skills. Future studies may delve into the development of a new concept map rubric for critical thinking skills assessment and examine its validity and reliability. An automatic scoring system then could be developed based on the rubric to assess students' critical thinking skills. In addition, it was also important to know that concept map rubrics should be used for the low-directed concept mapping task where students can represent their individual understanding and the connectedness of understanding of the domain knowledge.

- ***Enhancing the evaluation skill through the revision of concept maps***. This study found that examining the hierarchal structures or the propositions of concept maps may be a critical step for students to practice the evaluation skill in the concept mapping activity. Future studies may investigate how to support students as they review and revise their own concept maps to enhance the evaluation skill. One possible method is to pair up students and ask students to provide feedback on each other's concept map. Based on the peer feedback, the students may or may not revise their concept maps. Researchers may explore what peer feedback may emerge to effectively help students discover the problem of their maps and make further revisions. After identifying the effective peer feedback, an automated feedback system could be developed to enhance students' evaluation skill.
- ***Students' beliefs about the concept mapping activities in different contexts***. This study was conducted in a high school in Taiwan to explore how students interpret the relationships between the concept mapping activities and the critical thinking skills. However, students from different cultural or educational contexts may have different interpretations of the concept mapping activities and critical thinking skills. It would be interesting to implement a similar research design in different contexts and compare the research results. For

example, future research may conduct similar research at a college level to explore how college students may react differently from senior high school students to the use of the concept mapping activity to develop critical thinking skills.

REFERENCES

Abel, W. M., & Martha Freeze, M. S. N. (2006). Evaluation of concept mapping in an associate degree nursing program. *Journal of Nursing Education*, *45*(9), 356-364.

Afamasaga-Fuata'i, K. (2008). Students' Conceptual Understanding and Critical Thinking: A Case for Concept Maps and Vee-Diagrams in Mathematics Problem Solving. *Australian Mathematics Teacher*, *64*(2), 8-17.

Anohina-Naumeca, A. (2014). Finding factors influencing students' preferences to concept mapping tasks: literature review. *Procedia-Social and Behavioral Sciences*, *128*, 105-110.

Astleitner, H. (2002). Teaching critical thinking online. *Journal of Instructional Psychology*, *29*(2), 53-76.

Asan, A. (2007). Concept mapping in science class: A case study of fifth grade students. *Journal of Educational Technology & Society*, *10*(1), 186-195.

Attride-Stirling, J. (2001). Thematic networks: an analytic tool for qualitative research. *Qualitative research*, *1*(3), 385-405.

Ausubel, D. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart & Winston.

Baugh, N. G., & Mellott, K. G. (1998). Clinical concept mapping as preparation for student nurses' clinical experiences. *Journal of Nursing Education*, *37*(6), 253-256.

Bixler, G. M., Brown, A., Way, D., Ledford, C., & Mahan, J. D. (2015). Collaborative concept mapping and critical thinking in fourth-year medical students. *Clinical pediatrics*, *54*(9), 833-839.

Bray, J. H., & Maxwell, S. E. (1985). *Multivariate analysis of variance*. Beverly Hills, CA: Sage.

Cañas, A. J., Hill, G., Lott, J., & Suri, N. (2003). *Permissions and access control in concept mappingaptools (IHMC concept mappingapTools Technical Report 2003-03).* Pensacola, FL: Institute for Human and Machine Cognition.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.).Hillsdale, NJ: Lawrence Earlbaum Associates.

Chang, K. E., Sung, Y. T, & Chen, S. F. (2001). Learning through computer-based concept mapping with scaffolding aid. *Journal of Computer-Assisted Learning*, *17*(1), 21-33.

Daley, B. J. (1996). Concept maps: Linking nursing theory to clinical nursing practice. *Journal of Continuing Education in Nursing, 27*(1), 17-27.

Daley, B. J., Shaw, C. R., Balistrieri, T., Glasenapp, I., & Placentine, L. (1999). Concept maps: A strategy to teach and evaluate critical thinking. *Journal of Nursing Education, 38*, 42-47.

Duran, M., & Sendag, S. (2012). A preliminary investigation into critical thinking skills of urban high school students: Role of an IT/STEM program. *Creative Education*, *3*(02), 241-250.

Ennis, R. H. (1993). Critical thinking assessment. *Theory into practice*, *32*(3), 179-186.

Facione, P.A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction*. Research findings and recommendations. ERIC Document Reproduction Service No. ED315423.f

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2013). *G*Power Version 3.1.7 [computer software]*. *Uiversität Kiel, Germany*. Retrieved from http://www.psycho.uni-uesseldorf.de/abteilungen/aap/gpower3/download-and-register

Flumerfelt, S., & Green, G. (2013). Using lean in the flipped classroom for at risk students. *Educational Technology and Society, 16*(1), 356-366.

Goodwin, L. D., & Leech, N. L. (2006). Understanding correlation: Factors that affect the size of r. *The Journal of Experimental Education*, *74*(3), 249-266.

Harris, C., & Zha, S. (2013). Concept mapping: A critical thinking technique. *Education*, *134*(2), 207-211.

Hsu, L. L. (2004). Developing concept maps from problem-based learning scenario discussions. *Journal of Advanced Nursing*, *48*(5), 510-518.

Huang, Y. C., Chen, H. H., Yeh, M. L., & Chung, Y. C. (2012). Case studies combined with or without concept maps improve critical thinking in hospital-based nurses: A randomized-controlled trial. *International journal of nursing studies*, *49*(6), 747-754.

Hughes, W., Lavery, J., & Doran, K. (2010). *Critical thinking: An introduction to the basic skills* (6th ed.). Peterborough, Ontario: Broadview Press.

Jie, z., Yuhong, J., & Yuang, Y. (2015). The Investigation on Critical Thinking Ability in EFL Reading Class. *English Language Teaching*, *8*(1), 83-94.

Kathol, D. D., Geiger, M. L., & Hartig, J. L. (1998). Clinical correlation map: A tool for linking theory and practice. *Nurse Educator*, *23*, 31-34.

Khodadady, E., & Ghanizadeh, A. (2011). The impact of concept mapping on EFL learners' critical thinking ability. *English Language Teaching*, *4*(4), 49-60.

Kinchin, I. M., Hay, D. B., & Adams, A. (2000). How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational research*, *42*(1), 43-57.

Ko (2014). *The effect of the integration of critical thinking into English teaching on senior high school.* Unpublished master's thesis, National Taiwan Normal University, Taiwan, R.O.C

Korganci, N., Miron, C., Dafinei, A., & Antohe, S. (2014). Comparison of generating concept maps and using concept maps on students achievement. In *The International Scientific Conference eLearning and Software for Education* (Vol. 2, p. 287). National Defence University.

Lauzon, A. (1992). Integrating computer instruction with computer conferencing: An evaluation of a model for designing online education. *American Journal of Distance Education, 6*(2), 32-46.

Lee, W., Chiang, C. H., Liao, I. C., Lee, M. L., Chen, S. L., & Liang, T. (2013). The longitudinal effect of concept map teaching on critical thinking of nursing students. *Nurse education today, 33*(10), 1219-1223.

Lee, Y., & Nelson, D. W. (2005). Viewing or visualising—which concept map strategy works best on problem-solving performance? *British Journal of Educational Technology, 36*(2), 193-203.

Liu, P. L., Chen, C. J., & Chang, Y. J. (2010). Effects of a computer-assisted concept mapping learning strategy on EFL college students' English reading comprehension. *Computers & Education, 54(*2), 436-445.

Maneval, R. E., Filburn, M. J., Deringer, S. O., & Lum, G. D. (2011). Concept mapping: Does it improve critical thinking ability in practical nursing students? *Nursing education perspectives, 32*(4), 229-233.

McClure, J. R., Sonak, B., & Suen, H. K. (1999). Concept map assessment of classroom learning: Reliability, validity, and logistical practicality. *Journal of research in science teaching, 36*(4), 475-492.

McMullen, M. A., & MuMullen, W. F. (2009). Examining patterns of change in the critical thinking skills of graduate nursing students. *Journal of Nursing Education*, *48*(6), 310-318.

MOE (2002). *Principles of nine-year integrated curriculum designs*. Taipei: Ministry of Education.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn.* New York: Cambridge University Press.

Novak, J. D., & Canas, A. J. (2008). *The theory underlying concept maps and how to construct and use them.* (No. Technical Report IHMC concept mappingapTools 2006-01 Rev 01-2008). Florida Institute for Human and Machine Cognition. Retrieved from. http://conceptmappingap.ihmc.us/Publications/ResearchPapers/TheoryUnderlying ConceptMaps.pdf.

Oliver, K. (2009). An investigation of concept mapping to improve the reading comprehension of science texts. *Journal of Science Education and Technology*, *18*(5), 402-414.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage.

Paulus, T., Lester, J. & Dempster, P. (2014). Digital tools for qualitative research. London, UK: Sage Publications

Rotherham, A. J., & Willingham, D. T. (2010). "21st-Century" Skills. *American Educator*, 17-20.

Ruiz-Primo, M. A. & Shavelson, R. J. (1996). Problems and Issues in the Use of Concept Maps in Science Assessment. J*ournal of Research in Science Teaching*, *33*(6), 569-600.

Ruiz-Primo, M. A., Schultz, S. E., Li, M., & Shavelson, R. J. (1998). *Comparison of the reliability and validity of scores from two concept-mapping techniques*. Paper 24 presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Ruiz-Primo, M.A., (2004). *Examining concept maps as an assessment tool.* Concept Maps: Theory, Methodology, Technology. Paper presented at the Proceedings of the First International Conference on Concept Mapping, Pamplona, Spain.

Ruiz-Primo, M. A., Schultz, S. E., Li, M., & Shavelson, R. J. (2001). Comparison of the reliability and validity of scores from two concept-mapping techniques. *Journal of Research in Science Teaching*, *38*(2), 260-278.

Rosen, Y., & Tager, M. (2014). Making student thinking visible through a concept map in computer-based assessment of critical thinking. *Journal of Educational Computing Research*, *50*(2), 249-270.

Schau, C., Mattern, N., Zeilik, M., Teague, K.W., & Weber, R.J. (2001). Select-and-fill-in concept map scores as a measure of students' connected understanding of science. *Educational and Psychological Measurement*, 61(1), 136-158.

Seidman, I. (2006). *Interviewing as qualitative research: A guide for researchers in education and the social sciences* (3rd ed.). New York, NY: Teachers College Press.

Senita, J. (2008). The use of concept maps to evaluate critical thinking in the clinical setting. *Teaching and learning in nursing*, *3*(1), 6-10.

Soleimani, H., & Nabizadeh, F. (2012). The effect of learner constructed, fill in the map concept Map technique, and summarizing strategy on Iranian pre-university students' reading comprehension. *English Language Teaching*, *5*(9), 78-87.

Staib, S. (2003). Teaching and measuring critical thinking. *Journal of nursing education*, *42*(11), 498-508.

Shihab, I. A. (2011). Reading as Critical Thinking. *Asian Social Science*, *7*(8), 56-366.

Wheeler, L. A., & Collins, S. K. (2003). The influence of concept mapping on critical thinking in baccalaureate nursing students. *Journal of professional nursing*, *19*(6), 339-346.

Wilgis, M., & McConnell, J. (2008). During a Hospital Orientation Program. *The journal of continuing education in Nursing*, *39*(3), 119-126.

Yin, Y., Vanides, J., Ruiz-Primo, M. A., Ayala, C. C., & Shavelson, R. J. (2005). Comparison of two concept-mapping techniques: Implications for scoring, interpretation, and use. *Journal of Research in Science teaching*, *42*(2), 166-184.

Yang, S. C., & Lin, W. C. (2004). The relationship among creative. critical thinking and thinking styles in Taiwan high school students. J*ournal of Instructional Psychology, 31*(1), 33-45.

Yang, Y. T. C., & Wu, W. C. I. (2012). Digital storytelling for enhancing student academic achievement, critical thinking, and learning motivation: A year-long experimental study. *Computers & Education*, *59*(2), 339-352.

Yeh (2002). Analysis of high-order thinking abilities and instructional design. *Journal of general education, 1*, 75-101.

Zhou, J., Jiang, Y., & Yao, Y. (2015). The Investigation on Critical Thinking Ability in EFL Reading Class. *English Language Teaching*, *8*(1), 83-87.

APPENDICES

# APPENDIX A: IRB APPROVAL PROTOCOL

Phone 706-542-3199

The University of Georgia

Office of the Vice President for Research
*Institutional Review Board*

**APPROVAL OF PROTOCOL**

November 21, 2016

Dear Michael Orey:

On 8/15/2016, the IRB reviewed the following submission:

| | |
|---|---|
| Type of Review: | Modification |
| Title of Study: | Improving and Assessing Students' CT through Concept Mapping and Concept Maps |
| Investigator: | Michael Orey |
| IRB ID: | MOD00003874 |
| Funding: | None |
| Grant ID: | None |

The IRB approved the protocol from 11/21/2016.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

Sincerely,

Dr. Gerald E. Crites, MD, MEd
University of Georgia
Institutional Review Board Chairperson

310 East Campus Rd, Tucker Hall Room 212 ◆ Athens, Georgia 30602
An Equal Opportunity/Affirmative Action Institution

## APPENDIX B: ASSENT LETTER FOR STUDENTS

2016/11/17

Dear students:

I am a doctoral candidate in the Department of Career and Information Studies at The University of Georgia. I invite you to participate in a research study entitled Improving and Assessing Students' critical thinking through Concept Mapping and Concept Maps that is being conducted. The purpose of this study is investigate how to improve and assess students' critical thinking. This study is being conducted under the supervision of Dr. Michael Orey, Principal Investigator.

In this class, you will create concept maps based on the readings as class activities. If you choose to participate, you will share your concept maps with the researcher via html links to analyze. The links will be retained by me for a whole semester. The links will be removed after data collection is complete. If you choose to participate, you will also fill out a critical thinking survey, which should only take about 20-30 minutes. After filling out the critical thinking survey, you may be selected to have interviews with me. The interview will take about 20-30 minutes via Skype or Google Hangout to learn more about your experience with concept mapping. The instructor will help set up the equipment for interviews in the classroom, and leave you alone in the classroom. If you are selected to predicate in the interview, you will be asked whether you allow me to record and analyze the interview data

Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled. If you decide to stop or withdraw from the study, the concept maps and the surveys collected from you up to the point of your withdrawal will be kept as part of the study and may continue to be analyzed. Your decision to participate or not will have no bearing on your grades or class standing.

All your concept maps and critical surveys are confidential. Only I will have access to your concept maps and critical thinking surveys. The privacy and the confidentiality of the data will be only used in the study and protected by the researcher carefully. The results of the research study may be published, but your name or any identifying information will not be used. In fact, the published results will be presented in summary form only.

With your participation, the findings from this project may provide information on how students can develop critical thinking through concept maps. In addition, this research will provide a coherent line of argument from educational practice to educational evaluation that to date has been missing from many research and development papers. There are no known risks or discomforts associated with this research.

If you have any questions about this research project, please feel free to call me at 1-701-201-1116 or send an e-mail to pattseng@uga.edu. Questions or concerns about your rights as a

research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, telephone (706) 542-3199; email address irb@uga.edu.

By signing and returning this assent letter, you are agreeing to participate in the above described research project.

Sign_____ Date._____ Thank you for your consideration!

Sincerely, Sheng-Shiang Tseng

## APPENDIX C: PARENTAL PERSMISSION

Dear parents:

I am a doctoral candidate in the Department of Career and Information Studies at The University of Georgia. I invite your child to participate in a research study entitled Improving and Assessing Students' critical thinking through Concept Mapping and Concept Maps that is being conducted. The purpose of this study is investigate how to improve and assess students' critical thinking. This study is being conducted under the supervision of Dr. Michael Orey, Principal Investigator.

In this class, your child create will create concept maps based on the readings as class activities. If your child choose to participate, he or she will share his/her concept maps with me via html links to analyze. The links will be retained by me for a whole semester. The links will be removed after data collection is complete. If your child choose to participate, he or she will also fill out a critical thinking survey, which should only take about 20-30 minutes. After filling a critical thinking survey, your child may be selected to have interviews with me. The interview will take about 20-30 minutes via Skype or Google Hangout to learn more about your child's experience with concept mapping. The instructor will help set up the equipment for interviews in the classroom, and leave your child alone in the classroom. If your child is selected to participate in the interview, he or she will be asked whether he or she allows me to record and analyze the interview data. But, the information he or she share during this interview will be kept confidential.

His or her involvement in the study is voluntary, and s/he may choose not to participate or to stop at any time without penalty or loss of benefits. If s/he decide to stop or withdraw from the study, the concept maps, the surveys, and the interview data collected from you up to the point of your withdrawal will be kept as part of the study and may continue to be analyzed. Your decision to allow your child to participate or not will have no bearing on their grades or class standing.

All your child's concept maps, critical surveys, and the interview data are confidential. Only I will analyze his/her concept maps, critical thinking surveys, and the inteview. The privacy and the confidentiality of the data will be only used in the study and protected by the researcher carefully. The results of the research study may be published, but your child's name or any identifying information will not be used. In fact, the published results will be presented in summary form only.

With your child's participation, the findings from this project may provide information on how students can develop critical thinking through concept maps. In addition, this research will provide a coherent line of argument from educational practice to educational evaluation that to date has been missing from many research and development papers. Both the educational problem and its practice will be well-defined and the tool can be seen as a viable solution that

allows some particular problems to be practiced and discussed. There are no known risks or discomforts associated with this research.

If you have any questions about this research project, please feel free to call me at 1-701-201-1116 or send an e-mail to pattseng@uga.edu. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, telephone (706) 542-3199; email address irb@uga.edu.

By signing and returning this parental permission form, you are agreeing for your child to take part in the above described research project.

Sign_____ Date._____ Thank you for your consideration!

Sincerely, Sheng-Shiang Tseng

## APPENDIX D: CONSENT LETTER FOR THE INSTRUCTOR

Dear Ms. Lai:

I am a doctoral candidate in the Department of Career and Information Studies at The University of Georgia. I invite you to participate in a research study entitled Improving and Assessing Students' critical thinking through Concept Mapping and Concept Maps that is being conducted. The purpose of this study is to investigate how to improve and assess students' critical thinking. This study is being conducted under the supervision of Dr. Michael Orey, Principal Investigator.

In this study, you will use concept maps in your class. If you choose to participate in this research study, you will be also asked to have an individual interview with me nearly the end of this study. The interview aims to learn about your teaching experience with the concept mapping activity. The interview will take about 20-30 minutes via Skype or Google Hangout. All the information you share during this interview will be kept confidential.

Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled. If you decide to stop or withdraw from the study, the interview data collected from you up to the point of your withdrawal will be kept as part of the study and may continue to be analyzed.

Your interview data are confidential. Only I will have access to the data. The privacy and the confidentiality of the data will be only used in the study and protected by the researcher carefully. The results of the research study may be published, but your name or any identifying information will not be used. In fact, the published results will be presented in summary form only.

With your participation, the findings from this project may provide information on how students can develop critical thinking through concept maps. In addition, this research will provide a coherent line of argument from educational practice to educational evaluation that to date has been missing from many research and development papers. There are no known risks or discomforts associated with this research.

If you have any questions about this research project, please feel free to call me at 1-701-201-1116 or send an e-mail to pattseng@uga.edu. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, telephone (706) 542-3199; email address irb@uga.edu. By signing and returning this assent letter, you are agreeing to participate in the above described research project.

Sign_____ Date._____ Thank you for your consideration! Sincerely, Sheng-Shiang Tseng

## APPENDIX E: A SAMPLE SELECTED ARTICLE

Green building

Environmental issues are being talked about everywhere and by everyone. Therefore, it is no surprise that buildings and their construction methods are under the microscope. Green building is a design philosophy that focuses on resource efficiency and reducing the impact a building has on human health and the environment. Few people realize that buildings have their own lifecycles. This includes everything from site selection to eventual removal. By preparing for every step of this lifecycle, green building promotes long-term environmental health.

There are three major keys to green building. The first is the way resources are used not only in creating the building, but also during the use of the building. Reducing energy use can mean solar water heating or simply having more windows to lower the need for electric lights. To reduce the amount of water used, greywater reuse is often an option. Greywater, which comes from places like dishwashers or sinks, can be reused for irrigation or flushing toilets.

The second key in green building is protecting the health of those who will use the building and creating an atmosphere that will encourage productivity. Good ventilation and flow of air in and around a building are important. This can prevent the spread of illness as well as keep the building from being over or under a comfortable temperature. The amount of natural light in a room and the view from the windows also affect the building's internal atmosphere.

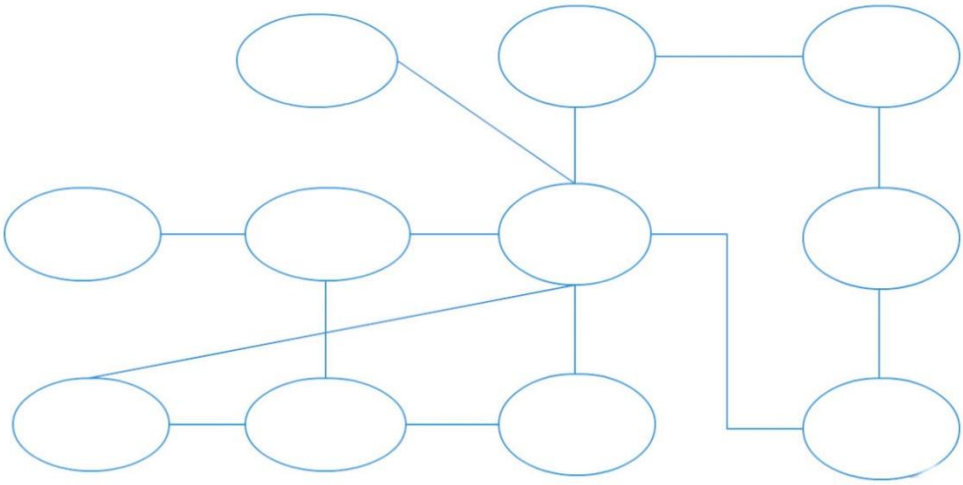
Finally, the third key to green building is reducing waste, pollution, and environmental degradation. As buildings are used, they begin to break down. Constant repairs bring a heavy cost; therefore, materials that can last or those that biodegrade are ideal. In the design and site location stages, the surrounding habitats must be noted. Ideally, a green building will provide a functioning space for humans without interrupting the habitats of species already thriving in them.

More and more countries around the world are choosing to build green. It is likely that this trend will bring about a gradual replacement of older buildings with those that take every aspect of our and the Earth's needs into consideration.

## APPENDIX F: SKELETON MAPS FOR THE TASK 2 AND 3

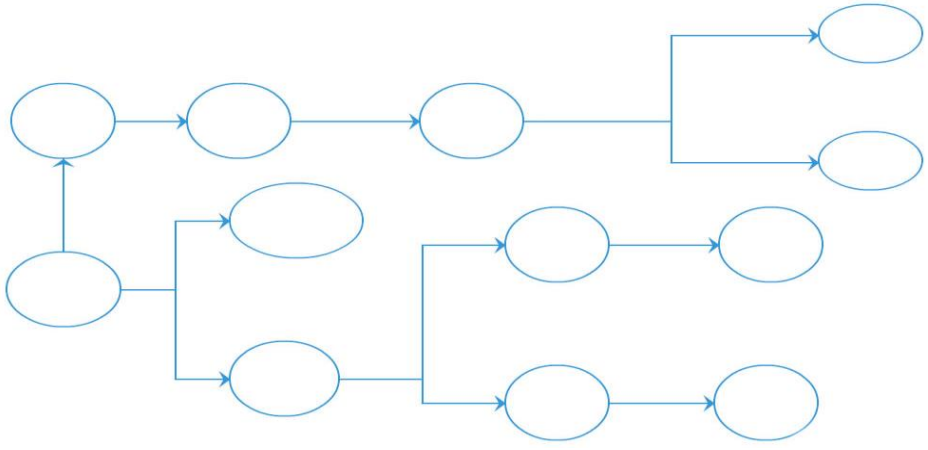
### Task 2

1.Interrupt animals. 2. Old building. 3. Greywater. 4. Productivity. 5. Green Building. 6. Waste energy. 7. Human health.
8. Natural lights. 9. More windows. 10. Environmental problems. 11. Biodegradable materials.



### Task 3

1.Drawback. 2. Deep study. 3. Low grades. 4. Hate schools. 5. Avoid self-esteem issues. 6. Benefits. 7. Slow learners. 8. Peer pressures. 9. Advance learners. 10. Teasing . 11. Academic success. 12. More time to learn



## APPENDIX G: THE CRITICAL THINKING SURVEY

The purpose of this survey is to help you diagnose your critical thinking. There is no incorrect answer. Please circle the number after each statement below according to the degree of your agreement/acceptance of the statement. Each number stands for a different degree in measurement. 5=agree; 4=basically agree; 3=hard to say; 2=not quite agree; 1=disagree. The data of the survey is used for academic research. Only researchers can view the results of the survey. Thanks for your time!

### I. Personal Information

Please write down your responses on the line.
Name: _____ Gender: _____ Year for Learning English:_____

### II. Performance on critical thinking

| **critical thinking skills** | | | | | | |
|---|---|---|---|---|---|---|
| **Interpretation** | 1. I can tell the genre type of the reading text. | 1 | 2 | 3 | 4 | 5 |
| **Inference** | 2. I can identify the elements needed to draw a reasonable conclusion about the text. | 1 | 2 | 3 | 4 | 5 |
| **Interpretation** | 3. I can restate what the author said using different words | 1 | 2 | 3 | 4 | 5 |
| **Inference** | 4. I can predict the main idea of a reading text from the title or subtitles. | 1 | 2 | 3 | 4 | 5 |
| **Analysis** | 5. I can identify the author's mood or attitude. | 1 | 2 | 3 | 4 | 5 |
| **Analysis** | 6. I can distinguish facts from opinion. | 1 | 2 | 3 | 4 | 5 |
| **Evaluation** | 7. I will judge the logical strength of the text. | 1 | 2 | 3 | 4 | 5 |
| **Interpretation** | 8. I decode the text structure of the reading. | 1 | 2 | 3 | 4 | 5 |
| **Interpretation** | 9. I know the writing purpose of the author. | 1 | 2 | 3 | 4 | 5 |
| **Analysis** | 10. I can identify the relationships among paragraphs | 1 | 2 | 3 | 4 | 5 |
| **Analysis** | 11. I can find relevant arguments/supporting ideas to support the main message of the text. | 1 | 2 | 3 | 4 | 5 |
| **Inference** | 12. I can use various clues (e.g. context) to help understand the text. | 1 | 2 | 3 | 4 | 5 |
| **Evaluation** | 13. I can judge the authenticity of the text information based on my knowledge | 1 | 2 | 3 | 4 | 5 |
| **Explanation** | 14. I can express what I feel about the reading. | 1 | 2 | 3 | 4 | 5 |
| **Evaluation** | 15. I can judge whether an argument relies on false or strong assumptions | 1 | 2 | 3 | 4 | 5 |
| **Inference** | 16. I can make reasonable inferences without reading the rest of the text. | 1 | 2 | 3 | 4 | 5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Explanation** | 17. I can find reasonable arguments in the text to support my own view. | 1 | 2 | 3 | 4 | 5 |
| **Interpretation** | 18. I can summarize the main idea of the text after reading. | 1 | 2 | 3 | 4 | 5 |
| **Evaluation** | 19. I can raise questions or objectives when reading something which is weak in an argument. | 1 | 2 | 3 | 4 | 5 |
| **Explanation** | 20. I can explain to others how I can comprehend the text. | 1 | 2 | 3 | 4 | 5 |
| **Explanation** | 21. I can give reasons to for accepting or reject what author said. | 1 | 2 | 3 | 4 | 5 |

**III. Open-ended questions**

1. In your own words, please use one sentence to describe the main message of the text. (Intepretation)
2. Please list 3 ideas that the author used to support the main message of the text (Analysis)
3. Please raise one question or objection which you have about the text. (Evaluation)
4. What do you think the author may say in the next text? (Inference)
5. Can you explain how you identify the main message of the text? (Explanation)

## APPENDIX H: INTERVIEW GUIDE FOR THE STUDENT

Hi, I am Patrick Tseng, a doctoral student at The University of Georgia. Thank you for taking the time to participate in this interview. The purpose of this interview is to learn more about your experience with concept mapping. I will be recording this conversation and our screen interactions. But the information you share during this interview will be kept confidential. We have 30 minutes to talk about your experiences. If I ask anything you do not want to answer, you can skip that question. If you agree to participate in this interview, I will need you to sign the consent form given by your instructor. Before we begin, do I have permission to record our conversation and screen interactions? If you are ready, let's get started. Today is ___. I am interviewing the student John (pseudonym) in the classroom through Skype.

**Topic Domain 1: Concept mapping**

*Lead-off question*

"In the last few weeks, the instructor asked you to create concept maps based on the assigned readings. Now, your concept maps are shown on the screen. Tell me about your map."

Covert categories: [the interviewee's interpretations of concept maps; interviewee's strategies of creating concept maps; interviewee's perceptions of the concept mapping activity; interviewee's problems with the concept mapping activity]

*Possible follow-up questions*

1. Pretend you are teaching me how to create the same concept maps. Can you walk me through it step by step?
2. You have described several steps in creating concept maps. What steps did you find most difficult?
3. What steps did you find most useful and in what aspects?
4. Will you continue to use concept maps in the future?

**Topic Domain 2: Critical thinking surveys and readings**

"Now, I am interested in the surveys you took a few weeks ago. You can also see the surveys on the screen. Because we do not have much time, we will not go through each question item. But I have marked some questions here. Can you tell me how you assigned the scores for these items?"

Covert categories: [The validity of the interviewee's responses to the survey questions; the interviewee's interpretations of the answers to the surrey questions; the interviewee's performances on the sub-categories of critical thinking (analysis, interpretation, inference, explanation, & evaluation)]

*Possible follow-up questions*

1. Okay, you gave high scores on Question #1 - I can tell the genre type of the reading text. Can you tell me the genre of text? How did you identify the genre of the reading text? Pretend you are teaching me.
2. You gave low scores on Question #2 - I can identify the elements needed to draw a reasonable conclusion from the reading. It's okay. I think it is difficult to identify those elements as well. What might make it easier for you to identify the elements of the reading?

## APPENDIX I: THE INTERVIEW GUIDE FOR THE INSTRUCTOR

Hi, I am Patrick Tseng, a doctoral student at The University of Georgia. Thank you for taking the time to participate in this interview. The purpose of this interview is to learn more about your teaching experience with concept mapping. I will be recording this conversation and our screen interactions. But the information you share during this interview will be kept confidential. We have 30 minutes to talk about your experiences. If I ask anything you do not want to answer, you can skip that question. If you agree to participate in this interview, I will need you to sign the consent form given by your instructor. Before we begin, do I have permission to record our conversation and screen interactions? If you are ready, let's get started. Today is ___. I am interviewing the teacher Jessie (pseudonym) in the classroom through Skype.

**Topic Domain 1: Experiences with concept mapping:**

"In your class, we had students do the high-directed and the low-directed concept mapping activities. Can you tell me how you implemented the two concept mapping tasks? Let's begin with the high-directed concept mapping."

Covert categories: [her observations of students' performance on the concept mapping activity; her teaching strategies for the concept mapping activity; her preferences about the concept mapping activity (high vs. low); her suggestions about the concept mapping activity]

*Possible follow-up questions*

1. I see. Can you describe what happened when you assigned the high-directed/low-directed concept mapping task?
2. What worked well?
3. What didn't work well?
4. Would you use the concept mapping activity again? Why or why not?

**Topic Domain 2: Critical thinking surveys and readings**

"We also asked students to fill out a critical thinking survey about the readings. The survey aims to measure students' critical thinking in terms of analysis, interpretation, evaluation, inference, and explanation. Tell me about the survey. How did the students do?

Covert categories: [her definitions of critical thinking; her interpretations of the survey results; her perspectives on ways to improve students' critical thinking]

*Possible follow-up questions*

1. I see. The results indicate that students scored higher or lower in certain categories like analysis and explanations. How would you explain that?
2. You indicated that the concept mapping tasks may be one of the factors. Can you tell me more about that?