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THE EFFECT OF CONCEPT MAPPING WITH DIFFERENT LEVELS OF GENERATIVITY AND LEARNERS' SELF-REGULATED LEARNING SKILLS ON KNOWLEDGE ACQUISITION AND REPRESENTATION

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ABSTRACT

The purpose of this study was to investigate the effectiveness of concept mapping strategies with different levels of generativity in terms of knowledge acquisition and knowledge representation. Also, it examined whether or not learners' self-regulated learning (SRL) skills influenced the effectiveness of concept mapping strategies with different levels of generativity. Four research questions were posed: (1) Do concept mapping strategies with different levels of generativity influence factual and conceptual knowledge acquisition? (2) Do different levels of self-regulated learning skills influence factual and conceptual knowledge acquisition? (3) Do different levels of self-regulated learning skills affect the effectiveness of different concept mapping strategies in terms of factual and conceptual knowledge acquisition? (4) Do different levels of self-regulated learning skills influence the knowledge representation of learners who study with a fully learner-generated concept map?

The participants were 285 undergraduate students who enrolled in a 200-level statistics course at a large northeastern university. The independent variables of this study were the levels of self-regulated learning skills and the levels of generativity in concept mapping strategies. The levels of SRL skills were divided into high and low, while the levels of generativity in concept mapping were operationalized in three treatments: Expert-generated concept mapping, partially learner-generated concept mapping, and fully learner-generated concept mapping. Dependent variables were knowledge acquisition (factual and conceptual knowledge), and knowledge representation of concept maps (the proposition quality, overall quality, and the quantity of propositions).

According to the MANOVA results for the first research question, three levels of generativity operationalized in concept mapping strategies produced significantly different levels of effectiveness for knowledge acquisition (F=3.094; p=.016; Wilk's Lambda=.939). Tukey post hoc comparisons showed that the expert-generated concept map group outperformed the partially learner-generated concept map group in factual knowledge, while the expert-generated concept map group outperformed both the partially learner-generated concept map group and the fully learner-generated concept map group in conceptual knowledge. Regarding the second research question, self-regulated learning skills caused significant difference in factual knowledge (F=7.627, p=.006). Regarding the third research question, no significant interaction was found, when using MANOVA, between the levels of generativity in concept mapping and the levels of self-regulated learning skills. However, regression analysis indicated that the higher the participants' self-regulated learning skills, the higher the factual knowledge acquisition score, only for the expert-generated concept map group and partially learner-generated concept map group. Regarding the last research question on knowledge representation, a significant effect of the levels of self-regulated learning skills was found in proposition quality, overall quality, and the quantity of proposition (F=3.004; p=.037; Wilk's Lambda=.880). More specifically, the participants with high self-regulated learning skills scored significantly higher in the overall quality of knowledge representation and the quantity of propositions made in each concept map.

Instructional implications included: (1) When using expert-generated concept maps, learners should be encouraged to actively interact with the given map; (2) When using partially-learner generated concept maps, learners should be guided not to focus only on the fill-in-the-blank activity; (3) When using fully learner-generated concept maps, consider details of procedures as a secondary component; (4)When evaluating fully learner-generated concept maps, use the quality of cross-link as an indicator of high self-regulators.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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Chapter 1

INTRODUCTION

Background

With the increasing volume and availability of information, college students are able to access huge amounts of information to create knowledge. However, access to information does not guarantee meaningful learning, which has been a fundamental concern in education field. According to Ausubel (1963), meaningful learning results when a person consciously and explicitly ties new knowledge to relevant concepts already possessed. In other words, people learn meaningfully by selecting relevant information, organizing information into a coherent structure, and integrating current information with relevant existing knowledge (Mayer, 1984). Generative learning theory, which is the overarching theme of the current study, attempts to explain how an individual mind learns meaningfully.

Generative Learning Theory

In generative learning, learners have an active, participatory role in order to interpret and construct meaning. According to Wittrock (1990) , "[T]he essence of the generative learning model is that the mind, or the brain, is not a passive consumer of information. Instead, it actively constructs its own interpretations and draws inferences from them” (p. 348). Meaning making, he claims, occurs in two ways: The different parts of external information are conceptually woven together in a meaningful way. Alternatively, external information and the learner’s schema are integrated to generate new knowledge. Thus, from an instructional strategies standpoint, Wittrock (1990, 1991) claimed that only those activities that involve the actual creation of relationships and meaning classify as examples of generative learning strategies. That is, well-designed instruction should support learners’ organization and integration of new information into an existing knowledge structure to promote meaningful learning. Considering that the construction of conceptual relationships is the key to knowledge generation, concept mapping has the potential to be one of the more powerful strategies to support the process of meaning-making.

Concept Mapping as a Generative Learning Strategy

Concept mapping is a strategy of displaying text material graphically in a two dimensional, spatial, node-linked network (Novak & Gowin, 1984). Novak’s concept map consists of concepts and linking words, arranged in a hierarchical way. While constructing a map, learners become actively engaged in identifying central ideas and relating them to each other in a meaningful way (Heinz-Fry & Novak, 1990). Eventually, the mapping activity facilitates the discovery of new knowledge, assimilated into prior experience and stored in the long-term memory.

The mechanism of concept mapping has its basis in assimilation theory outlined by Ausubel (1968). He differentiated knowledge acquisition through “rote” learning and “meaningful” learning. Rote learning involves memorizing the material without processing it which allows easily forgetting. Meaningful learning, on the other hand, involves assimilation of new concepts and ideas with the learner’s prior experience (Ausubel, 1968), which is in line with the meaning-making process of generative learning.

Since the early work of Novak, much empirical research tested the effectiveness of concept mapping as a learning strategy. Horton and his colleagues (1993), from meta-analysis of nineteen studies on concept mapping, found that concept mapping had positive effects on both student achievement and attitude. Likewise, a number of other researchers have demonstrated that concept mapping is an effective tool for improving learners’ academic achievement (Gobert & Clement, 1999; Hall et al., 1992; Lambiotte & Dansereau, 1992; Scevak et al., 1993).

More specifically, studies on concept mapping strategies reported different perspectives regarding the usage of concept mapping activities. One perspective focuses on the issue of “who” develops a concept map (Grabowski, 2003), that is, levels of generativity. According to this view, concept maps generated by learners support meaningful construction of knowledge by involving more cognitive generation; whereas concept maps provided by instructors support transmission of an expert’s understanding of knowledge and reduce learners’ cognitive load (Jo, 2001; Lee & Nelson, 2005; Smith & Dwyer, 1995; Wang, 2003). Another perspective focuses on the issue of “the amount and type of support” provided to learners while creating their own concept maps. Some researchers suggested a completion strategy so that learners can fill in the blanks of the given instructional material (Chang *et al.*, 2002; Taricani, 2002; van Merrienboer, 1990; Wang, 2003), whereas Novak and Gowin (1984) outlined detailed step-by-step instruction which enables learners to create their own concept maps freely. In sum, concept mapping strategy has gained acceptance as being effective, in general, by engaging learners more actively with the material, and by flexibility in terms of the levels and types of application.

Problems with Concept Mapping Research

However, regardless of these potential benefits, research findings failed to reach consistent conclusions as to the effect of different uses of concept mapping, such as instructor-provided versus learner-generated, and completion strategy versus generation strategy (Jonassen et al., 1997; Romance & Vitale, 1998). Wang (2003) reported that both a learner-generated mapping group and a completion strategy group outperformed the control group which studied without concept maps, but no significant difference appeared between the learner-generated mapping group and the completion strategy group. Smith and Dwyer (1995) found no significant difference between the instructor-provided and learner-generated mapping groups, while the learner-generated mapping group outperformed the instructor-provided mapping group in the studies by Jo (2001) as well as Lee and Nelson (2005). Two other studies found no significant effects from a learner-generated mapping strategy (Kenny, 1995; Taricani, 2002).

Some possible explanations for the mixed results include a mismatch between the levels of required generativity during the concept mapping process and the expected learning outcome (e.g. the highest generative treatment and immediate recall test), or the difficulty of controlling learners' learning processes (e.g. learners' not following the procedure required for creating concept maps). Most of all, a faulty assumption appears to be that concept mapping strategies work equally well under all conditions, especially for learners who process information differently (Grabowski, 2003). Given that the task of generating a concept map requires higher-order thinking skills throughout the meaning-making process, learners' cognitive capability should be considered a critical factor affecting the effectiveness of concept mapping strategy use. Especially, self-regulated learning skill is one of the influential variables among cognitive capabilities fostering meaningful understanding (Pintrich & De Groot, 1990).

Self-Regulated Learning during Making Meaning

Self-regulated learning is the regulatory process whereby students plan, monitor, control and reflect on their learning to achieve their goals and perform better (Pintrich, 2004). A variety of definitions exist for self-regulated learning, but researchers repeatedly emphasized three components (Brown et al., 1983; Corno & Mandinach, 1983; Pintrich & De Groot, 1990; Zimmerman & Pons, 1986). First, self-regulated learning includes cognitive control for the skills to use cognitive strategies necessary to learn the material. Second, metacognitive control is another component of planning, monitoring, and modifying their cognition, which refers to the awareness and control of thought processes.

Third, self-regulated learning includes motivational control which is the regulation of beliefs and attitudes that affect the use and development of cognitive and metacognitive skills. Theoretically, these skills should play an essential role in a generative learning environment, as Zimmerman (1986) and Wittrock (1990, 1991) agree with each other in that learners should be cognitively, metacognitively, and motivationally active during learning.

Interestingly, most of the research investigating the relationship between concept mapping and self-regulated learning skills considered self-regulation as an outcome variable. For example, Chularut and DeBacker (2003) argued, based on the empirical data, that the benefit of a concept mapping activity extends beyond the achievement to include positive effects on self-regulation. Corno and Mandinach (1983) also stated that using concept mapping strategy can be a powerful means to promote self-regulated learning skills, which would support learners experiencing meaningful learning. Novak (1998) clearly summarized this notion by reporting: “[A]s students gained skill and experience in constructing concept maps, they began to report that they were learning how to learn” (p.27). However, since the concept mapping activity requires high mental effort while making meaning, self-regulated learning skill is reasonably placed as an independent variable to find an interaction between different levels of generativity and learners’ self-regulated learning skill. Those who possess weak self-regulated learning skills are less likely to be able to direct their own learning, and thereby may gain less benefit from generative learning strategies.

Purpose of the Study

The purpose of this study was to investigate the effectiveness of concept mapping strategies with different levels of generativity in terms of knowledge acquisition and knowledge representation. Also, it examined whether or not learners' self-regulated learning skills influenced the effectiveness of concept mapping strategies with different levels of generativity.

Significance of the Study

This study builds upon prior research of various types of concept map use in order to achieve both theoretical and practical goals. Theoretically, the study extends the understanding of generative learning strategies by investigating the learning processes and outcomes of concept mapping activities with different levels of generativity. Also offered is a new perspective of the field of generative learning by introducing learners' self-regulated learning skills as an influential variable for generative process. These implications from the theory provide practical guidelines for the design of generative activities by answering questions such as: "How can I design a concept mapping activity in a meaningful way?" "Given the characteristics of my students, what levels of generativity should I select?" And, "How can I assess students' representation of meaning when using a concept mapping strategy?"

Research Questions and Hypothesis

The purpose of this study was to investigate the effectiveness of concept mapping strategies with different levels of generativity in terms of knowledge acquisition and knowledge representation. Also it examined whether or not learners' self-regulated learning skills influenced the effectiveness of concept mapping strategies with different levels of generativity. The first investigation involves discerning the main effects of the effectiveness of different levels of generativity and learners' self-regulated learning skills on knowledge acquisition. The second investigative aspect is testing for an interaction between different levels of generativity and learners' self-regulated learning skills on knowledge acquisition. Third, a further investigation explores knowledge representations of students with high self-regulated learning skills and low self-regulated learning skills in the fully learner-generated concept map group.

Research questions and corresponding research hypotheses are listed below.

Effect on Knowledge Acquisition

Question 1: Do concept mapping strategies with different levels of generativity (expert-provided, partially learner-generated, and fully learner-generated) influence knowledge acquisition?

Hypothesis 1: Different levels of generativity in concept mapping (expert-provided, partially learner-generated, and fully learner-generated) will influence knowledge acquisition.

Hypothesis 1-1: Learners who study with a fully learner-generated concept map will demonstrate a higher factual knowledge acquisition score than learners who study with an expert-provided concept map.

Hypothesis 1-2: Learners who study with a fully learner-generated concept map will demonstrate a higher factual acquisition score than learners who study with a partially learner-generated concept map.

Hypothesis 1-3: Learners who study with a fully learner-generated concept map will demonstrate a higher conceptual knowledge acquisition score than learners who study with an expert-provided concept map.

Hypothesis 1-4 Learners who study with a fully learner-generated concept map will demonstrate a higher conceptual knowledge acquisition score than learners who study with a partially learner-generated concept map

Question 2: Do different levels of self-regulated learning skills (high vs. low) influence knowledge acquisition?

Hypothesis 2: Different levels of self-regulated learning skills (high vs. low) will influence knowledge acquisition.

Hypothesis 2-1: Learners with high self-regulated learning skills will demonstrate higher factual knowledge acquisition scores than learners with low self-regulated learning skills.

Hypothesis 2-2: Learners with high self-regulated learning skills will demonstrate higher conceptual knowledge acquisition scores than learners with low self-regulated learning skills.

Question 3: Do different levels of self-regulated learning skills (high vs. low) affect the effectiveness of different concept mapping strategies in terms of factual and conceptual knowledge acquisition?

Hypothesis 3: A significant interaction will exist between the levels of generativity in concept mapping and the levels of learners' self-regulated learning skills in terms of knowledge acquisition.

Effect on Knowledge Representation

Question 4: Do different levels of self-regulated learning skills (high vs. low) influence the knowledge representation of learners who study with a fully learner-generated concept map?

Hypothesis 4: Different levels of self-regulated learning skills (high vs. low) will influence the knowledge representation of learners who study with a fully learner-generated concept map.

Hypothesis 4-1: Learners with high self-regulated learning skills will demonstrate higher proposition quality in knowledge representation than learners with low self-regulated learning skills when they study with a fully learner-generated concept map.

Hypothesis 4-2: Learners with high self-regulated learning skills will demonstrate higher overall quality in knowledge representation than learners with low self-regulated learning skills when they study with a fully learner-generated concept map.

Hypothesis 4-3: Learners with high self-regulated learning skills will demonstrate larger quantity of propositions in knowledge representation than learners with low self-regulated learning skills when they study with a fully learner-generated concept map.

Definition of Terms

Generative learning is the process of constructing links between new and old knowledge, and generating a personal understanding of how new ideas fit into an individual's web of known concepts (Wittrock, 1990). Learners actively engage in the process to construct their own interpretations, so called: meaning-making (Grabowski, 1996).

Level of generativity is the degree to which learning with generative learning strategies involves an active generation of meaning (Wittrock, 1992). In this study, three different levels of generativity are operationalized in concept mapping interventions: low-level, mid-level, and high level.

Concept mapping is a graphic strategy of displaying text material in a two-dimensional, spatial, node-linked network. This study follows Novak's concept mapping strategy, represented in a hierarchical way with nodes and links. Links are the existing relationships between the nodes in a two-dimensional layout (Novak & Gowin, 1984).

- *An expert-generated concept map* is a type of concept map with a low level of generativity, constructed by subject matter experts or teachers prior to instruction and provided to learners. In this research, the nodes and links in the expert-generated concept map directly relates to the achievement test items.

- *A partially learner-generated concept map* is a type of concept map with mid-level generativity, mostly constructed by subject matter experts or teachers prior to instruction and provided to learners. However, half of the nodes and linking words are intentionally omitted, while the basic structure of the concept map is presented.
- *A fully learner-generated concept map* is a type of concept map with high-level generativity, constructed by learners from scratch on a blank sheet of paper.

Self-regulated learning is the regulatory process whereby learners plan, monitor, control and reflect on their learning to achieve their goals and perform better (Pintrich, 2004). The main focus of this study is learners' regulation of cognition, metacognition and motivation (Brown et al., 1983; Corno & Mandinach, 1983; Pintrich & De Groot, 1990; Zimmerman, 1986). Regulation of cognition is the control of skills to use cognitive strategies necessary to learn the material; whereas, regulation of metacognition is the control of skills for planning, monitoring, and modifying their cognition. Motivational control is the regulation of beliefs and attitudes that affect the use and development of cognitive and metacognitive skills.

Knowledge acquisition, in this study, is the learning outcome in terms of obtaining factual and conceptual knowledge. *Factual knowledge* is the basic elements learners must know to be acquainted with a discipline or solve problems (Anderson et al., 2000). Specifically or this research, it involves recall or recognition of a single piece of information such as each part of human heart. *Conceptual knowledge* is the interrelationships among the basic elements within a larger structure (Anderson et al., 2000) arising from making associations between words, ideas and labels. Specifically for this research, it involves understanding the complex processes of how each part of the human heart interacts and functions.

Knowledge representations are, in a general sense, carriers of meaning (Markman, 1999), defined as how humans represent information in long-term and working memory (Gagne et al., 1993). This study focuses on the concept map as a type of knowledge representation, which is measured by proposition quality, overall quality, and the quantity of propositions. *Proposition quality* indicates the validity of each proposition which is the least complex structure represented in a concept map (McClure et al., 1999; Ruiz-Primo & Shavelson, 1996), while *overall quality* examines broader judgments regarding the representation of understanding using multiple propositions. *Quantity of propositions* represents the amount of information processed by the learner during concept mapping.

Chapter 2

LITERATURE REVIEW

Introduction

The purpose of this study was to investigate the effectiveness of concept mapping strategies with different levels of generativity in terms of knowledge acquisition and knowledge representation. Also it examined whether or not learners' self-regulated learning skills influenced the effectiveness of concept mapping strategies with different levels of generativity.

This chapter presents Generative Learning Theory and Schema Theory as theoretical backgrounds for the current study. As two major phenomena of interest, concept mapping and self-regulated learning are described in terms of definitions and prior research.

Generative Learning Theory

A Pursuit of Meaningful Learning

Over the years, meaningful leaning has remained a fundamental concern for educational researchers as well as practitioners. According to Ausubel (1963), meaningful learning results when a person consciously and explicitly ties new knowledge to relevant concepts already possessed. In other words, learning occurs meaningfully by selecting relevant information, organizing information into a coherent structure, and integrating current information with relevant existing knowledge (Mayer, 1984). Once stored in long-term memory in association with similar, related pieces of information, the chances of recall increases whenever cued or activated later on. With rote learning, on the other hand, little attempt to make the information meaningful in terms of integration occurs; this results in isolated facts or fragments of information stored in memory.

Generative Learning: Definitions and Processes

In Generative Learning Theory, the cognitive process of creating ties between information and existing knowledge is explicitly underscored. Wittrock (1974b), the founder of the Generative Learning Theory, defined learning as “a process of generating semantic and distinctive idiosyncratic associations between stimuli and stored information” (p. 89) . Therefore, learning is a generative process by nature (Wittrock, 1974a). More specifically, he assumed that, in generative learning, the learners become the sources of everything, such as plans, intentions, goals, ideas, memories, strategies, and emotions, which actively attend to, select, and construct meaning from stimuli and knowledge from experience (Wittrock, 1990). Based on this assumption, he claimed that the essence of the Generative Learning Theory is that the human mind is not a passive consumer of incoming information (Wittrock, 1990, 1992; Wittrock & Alesandrini, 1990).

Rather, it actively makes its own meanings of information and draws inferences from them.

Meaning making occurs in two ways: The different parts of external information are conceptually woven together in a meaningful way. And, alternatively, external information and the learner's existing schema are integrated to generate new knowledge. As a result, generation can induce assimilative learning, so called, schema fitting, as well as accommodative learning which is a construction of new schemata (Wittrock, 1990). Notably, the relationships and connections created by learners facilitate meaningful learning because learners generate the relationships and connections themselves.

Wittrock's (1990, 1991, 1992) model of generative learning consists of four major processes: attention, motivation, memory (knowledge and preconceptions), and generation. To illustrate, generative learning begins with learners' voluntary and selective attention to events. Once attention is paid, learners' interest is activated, which results in motivation. Motivated learners are not only able to take control and responsibility for being active in learning, but also able to manage their preconceptions, knowledge and belief. Finally, with all these three processes, learners relate individual events and ideas to their own knowledge and experience. These four processes attempt to explain how learners process information through external and internal learning conditions, and actively generate meaning from it (Grabowski, 2003).

Generative Learning Strategies

One of the values of generative learning is that the theory extends to modeling teaching to provide instructional implications (Grabowski, 2003; Kourilsky et al., 1996; Wittrock, 1985, 1991; Wittrock & Alesandrini, 1990; Wittrock & Carter, 1975). According to Wittrock (1991, 1992), only those activities that involve the actual creation of relationships and meaning are appropriately classified as examples of generative learning strategies. In other words, a learning strategy is generative when it provides an opportunity for the learner to restructure or manipulate the information presented, either by organizational or integrated relationships, and to construct personal meaning. This claim originated from his definition of teaching: “the process of leading learners to use their generative processes to construct meaning and plans of action” (p. 531). Thus, well-designed instruction should support learners’ organizing and integrating new information into their existing knowledge structures to promote meaningful learning.

Studies investigating the viability of the generative learning strategies have occurred for the last three decades, following a series of studies by Wittrock and his colleagues in mathematics (Wittrock, 1974a), science (Osborne & Wittrock, 1983), and reading comprehension (Doctorow et al., 1978; Linden & Wittrock, 1981; Wittrock & Alesandrini, 1990). Grabowski (2003) analyzed thirty-six studies dealing with a variety of generative strategies, and categorized them as simple coding strategies (e.g. underlining, note-taking, creating questions), complex coding strategies (e.g. creating headings, summaries, concept maps), integration strategies (e.g. analogies, creating examples), and metacognitive training. She concluded that, in general, results have shown increased gains in learning when the learner is an active participant in the learning process, and when instruction includes activities that help make connections between information and between information and the learner's prior knowledge. Grabowski's findings support the claim made by Wittrock.

Implications for the Current Study

Based on an understanding of Generative Learning Theory, the following implications apply to the current study:

- The key to meaningful learning is to generate the relations among the parts of given information as well as among the information and learners' prior knowledge.
- Learning strategies' design should support learners' generation process.
- Learners' control of motivation and metacognition influence the generation process.
- Empirical studies support the effectiveness of generative learning strategies.

Schema Theory

Schema: Definitions and Processes

The notion of the schema is traced back to a 1932 book by Bartlett, *Remembering* (Schmidt, 1975). The idea, at that time, was that in order to perceive and classify a set of stimuli correctly into a category, one does not need to have previously experienced the exact same stimuli. Instead, the past experience related to these stimuli will be activated, help interpretation and categorization of the incoming stimuli, and abstract a concept to be stored in memory (Bartlett, 1932). In other words, he claimed that human memory takes the form of schema which provides a mental framework for understanding and remembering information (Bartlett, 1932, 1958). Since then, many other terms have been used to depict similar constructs, including frames (Minsky), scripts (Schank and Abelson), and story grammars (Rumelhart, Mandler and Johnson).

More clearly, a schema is “a data structure for representing the generic concepts stored in memory” (Rumelhart, 1980, p. 34). Jonassen and his colleagues described Schema Theory with more focus on the interrelationships among schemas (Jonassen *et al.*, 1993). A schema for an object or event consists of attributes or slots that illustrate that object or event. These slots contain relationships to other schemas. Therefore the interrelationships created among schemas give meaning to an individual schema.

A schema is dynamic (Rumelhart, 1980). An existing schema is continuously modified as an individual acquires new input, and sometimes, a new schema is constructed. Three processes have been proposed to account for the modification and construction of a schema: accretion, tuning, and restructuring (Rumelhart, 1980; Rumelhart & Norman, 1978). Accretion occurs by filling the slots either by encoding experiences as attributes of a schema or by connecting existing schemas and new schemas. A schema is tuned to meet specific needs or become more consistent with experience. When new experiences occur that cannot be explained, a new schema is induced by restructuring and reconceptualizing the existing schema. Hence, in a sense, how people acquire schema is equal to how people learn (Jonassen et al., 1993).

Schema Theory and Generative Learning Theory

Commonalities between Generative Learning Theory and Schema Theory are found with respect to their basic assumptions. First, both theories assume that knowledge is organized semantically. The gist of Generative Learning Theory is the creation of connections among multiple information sources, as well as between information and the learner's prior knowledge. Likewise, Schema Theory emphasizes the development of a network of interrelated concepts, that is, schema, as well as the interaction between new and existing schema. Second, both theories consider learners as active participants during learning. A learner in a generative learning environment is supposed to selectively attend to the given information, to control the whole process, and to generate meaningful relationships. An individual mind, according to Schema Theory, is also responsible for the processes of accretion, tuning, restructuring of an individual's own schema. All in all, schemas are the knowledge units that are manipulated in generative learning (Grabowski, 2003).

Although these two theories complement each other well (Wittrock, 1991), a fundamental difference remains regarding the purpose of their theories. Schema Theory is a *descriptive* model since it illustrates how information is represented in memory and how stored knowledge plays a role in learning. On the other hand, Generative Learning Theory involves a *functional* aspect which focuses on the cognitive processes that learners use to comprehend concepts, and on the instructional procedures useful for meaningful learning (Kourilsky et al., 1996; Wittrock, 1990), which points to practical applications. That is, descriptive models focus on the process of retrieving and storing information with a concentration of research on the memory structures; whereas, functional models focus not only on the processes of learning, but also on the functions of each process in order to provide implications to practitioners.

Implications for the Current Study

Based on an understanding of Schema Theory, the following implications apply to the current study:

- The process of learning is the process of creating linkages.
- Knowledge is represented semantically, which is fluid in response to inputs.
- A schema is a basic unit to be manipulated in generative learning.
- Prior knowledge is a variable to be considered.

Concept Mapping

Concept Mapping and Learning

The mechanism of concept mapping has its origins in the argument made by Ausubel (1963, 1978), who differentiates “rote” learning and “meaningful” learning. Rote learning involves memorizing material without processing it and it is easily forgotten, since the information is stored in an unconnected fashion. Meaningful learning, on the other hand, involves assimilation of new concepts and ideas with the learner’s prior experience, which is in line with the meaning-making process of generative learning and with the schema induced process of Schema Theory. Novak and his colleagues were particularly interested in how to promote meaningful learning (Novak et al., 1983; Novak & Gowin, 1984).

According to Novak and Gowin (1984), a concept map is “a schematic device for representing a set of concept meanings embedded in a framework of propositions” (p.15). Concept maps are more commonly defined as strategies for displaying text material graphically in a two dimensional, spatial, node-link network (Novak & Gowin, 1984). Novak’s concept map consists of concepts and linking words which represent the hierarchical structure of knowledge in propositional statements that illustrate the relationships among the concepts (Novak, 1981).

Concept maps consist of three important characteristics: hierarchy, proposition, and cross-link (Jonassen et al., 1993; Novak, 1990, 1998; Novak & Cañas, 2006). (1) Due to the hierarchical arrangement, the most inclusive, general concepts are located at the top of the map, while less inclusive, subordinate concepts appear below. (2) A concept map consists of multiple propositions interwoven with each other; a proposition is “a statement that contains two or more concepts connected using linking words or phrases to form a meaningful statement” (Novak & Cañas, 2006, p.1). (3) Concept maps encourage the inclusion of cross-links, which are relationships or links between concepts in different segments or domains of the concept map. Cross-links are often considered to be “creative leaps” (Novak & Cañas, 2006, p.2).

Concept mapping, as a learning strategy, realizes the spirit of the theories mentioned earlier. First, concept mapping activities facilitate learners’ identification, clarification, and organization of the abstract concepts and the generation of relationships among incoming information. Second, concept mapping activities support learners’ redefinition and restructuring of their existing schemas by creating overt connections between new knowledge and prior knowledge. Learners are guided to the discovery of new knowledge, which is eventually assimilated into prior experience and stored in long-term memory. Third, as required to represent these relationships overtly, learners pay attention to the learning materials and become active participants throughout the learning process. Conversely, the process of constructing a map is intellectually rigorous and challenging (Anderson-Inman & Horney, 1997), since it forces learners to make their understanding more explicit.

Concept Mapping and Knowledge Representations

Given that the concept mapping activity produces an overt illustration of learners' understanding, a concept map is a type of knowledge representation. Knowledge representations are, in a general sense, carriers of meaning (Markman, 1999), defined as how people represent information in long-term and working memory (Gagne et al., 1993). Knowledge representation can take many forms depending on the type of knowledge learned and the cognitive strategy used in acquiring that knowledge. Concept mapping holds its attributes from semantic network representation. According to Markman (1999), a semantic network is a type of representation consisting of nodes which represent concepts and directed links which represent semantic relations between the concepts. Novak and his colleague elaborated the premises of semantic networks by emphasizing hierarchical aspects, propositional statements, and meaningful cross-links, and finally proposed concept mapping activity as a viable learning strategy that can be implemented in any classroom.

The Effectiveness of Concept Mapping

Studies regarding the effectiveness of concept mapping as a learning tool date back to the early 1980s. Since the 12-year span of work by Novak and Musonda (1991) which used concept maps as a research tool to represent learners' science knowledge structures, several studies emerged employing the use of this new representation tool. Novak and Gowin (1984) demonstrated that a group of graduate students found concept maps useful for representing changes in their knowledge structures, over time. These students also indicated that concept maps helped organize and understand new subject matter. Horton and colleagues (1993), from their meta-analysis of nineteen studies on concept mapping, found that concept mapping had positive effects on both student achievement and attitude, although no significant difference appeared for achievement from using teacher-generated concept maps or student-generated concept maps. Based on a comprehensive literature review on concept mapping, O'Donnelle, Dansereau, and Hall (2002) also reported the tendency for students to recall more central ideas when they learned from a concept map than when they learned from text. They noted that those with low verbal ability or low prior knowledge often benefited the most. Likewise, a number of researchers demonstrated that concept mapping is an effective tool to improve learners' academic achievement (Gobert & Clement, 1999; Hall et al., 1992; Lambiotte & Dansereau, 1992; Scevak et al., 1993). More recently, the effectiveness of concept mapping is discussed along various dimensions such as computer-supported application, web-based application, and collaborative concept mapping (Cañas *et al.*, 2005; Chang *et al.*, 2002; Komis *et al.*, 2002; Spector *et al.*, 2005).

Relevant Studies on Concept Mapping

Several studies, selected for review, contain the following two criteria: (1) use of Novakian mapping method, and (2) concern for the level of generativity. First, three studies compared the effectiveness of learner-generated concept maps which have high levels of generativity, and instructor-generated concept maps which have low levels of generativity. Smith and Dwyer (1995) compared the effect of "instructor-prepared" and "learner-generated" concept maps; Jo (2001) investigated the effect of "concept map-as-product" and "concept map-as-process," and Lee and Nelson (2005) also tested the effect of "completed map" and "generative map." Although their treatments all had different labels, the mechanisms behind the treatments were the same: students were given either a ready-made concept map to consult (instructor-prepared, concept map-as-product, completed map) or a blank sheet to create their own concept maps (learner-generated, concept map-as-process, generative map). However, the results are inconsistent. Smith and Dwyer (1995) found insignificant differences between the two concept map groups, concluding that even though concept mapping strategies are physically and procedurally different, they may be functionally identical in terms of facilitating achievement. To the contrary, Jo (2001) found that students in the learner-generated map group significantly outperformed the students in the instructor-generated map group in both free recall and example generation tests. Lee and Nelson (2005) supported Jo's (2001) results in terms of problem-solving tasks, and furthermore, they claimed that students with high prior knowledge in the learner-generated map group scored highest on well-structured problem solving performance.

Other researchers elaborated the level of generativity, and incorporated the idea of completion strategy, also known as "fill-in-the-blank," as a partially learner-generated mapping. The completion strategy, originally proposed by van Merrienboer (Sweller *et al.*, 1998; van Merrienboer, 1990), is a possible solution for overcoming cognitive overload when solving problems. For concept mapping, an instructor-generated map is similar to the complete solution of a problem; whereas, a "fill-in-the-blank" map is problem solving with scaffoldings. Wang (2003) compared the effect of learner-generated concept mapping, concept identifying mapping, and proposition identifying mapping. The last two treatments were considered completion strategies that required students to fill in the missing concepts and propositions respectively. Taricani (2002) had similar treatment groups titled "totally learner-generated concept map and partially learner-generated concept map." The latter group was given a concept map with half of the nodes and links eliminated. Chang and his colleagues (2002) compared three concept mapping techniques: map correction, scaffold fading, and map generation. Learners in map correction used an instructor-generated map with 40% of the concepts and linking words incorrect according to the text content, while learners in scaffolding fading group received a series of concept maps starting from instructor-generated maps, and then "fill-in-the-blank" maps. Finally, learners in map generation received a blank space to generate their own maps. The results from these studies are not consistent, either. Wang

(2003) reported that all three concept mapping groups outperformed the control group which studied without concept mapping, but showed no significant difference between the student-generated mapping group and the completion strategy group. No significant interaction appeared between the levels of prior knowledge and concept mapping treatment types on any of the criterion tests. Taricani (2002) echoed the result of no significant difference between the totally learner-generated concept map group and partially learner-generated map group. She also reported no significant difference on the criterion tests between students who used concept mapping and students who did not use concept mapping. Chang and his colleagues (2002) reported that the map correction group outperformed the scaffold fading group and map generation group in text comprehension and summarization abilities.

Implications for the Current Study

Several implications for the current study exist: First, all of the research described earlier used criterion measures, mostly related to knowledge acquisition to assess the effectiveness of concept mapping (e.g. terminology, identification, comprehension, free recall, example generation and summarization). However, given that the theories behind concept mapping are generative learning and schema, lower-level of knowledge acquisition is not a major concern of concept mapping. Rather, mapping is designed to help learners conceptually “understand” the content by generating relationships among different concepts and refining their schema for the related domain. Along with the criterion measure of conceptual understanding, an evaluation of the quality of a concept map would be meaningful since concept maps themselves represent learners' understanding in a qualitative way.

Second, methodological issues appeared in relation to treatment fidelity. As Grabowski (2003) suggested, mental activity can not be strictly controlled by instruction, no guarantee exists that learners in the learner-generated map group truly followed the suggested procedures to create a map. Wang (2003) delivered comprehensive training on concept mapping prior to the experiment for all the treatment groups, while Taricani (2002) provided "how to create a concept map" and "how to fill-in-the concept map," respectively, for a learner-generated map group and a completion map group. Jo (2001) reported that only the learner-generated map group received relevant training. Although the researchers did not specify the reason why they chose a particular type and scope of training, their practice implies that concept mapping should be accompanied with training and instructor guidance.

Finally, the research findings failed to reach consistent conclusions about the effectiveness of different types of concept mapping strategies especially when viewed from a perspective of level of generativity, although the overall effectiveness of concept mapping is widely accepted. If this is true, the assumption could be that different types of concept mapping strategies are significantly effective under certain circumstances. More specifically, concept mapping strategies might not work equally well under all conditions, especially for learners who process information differently (Grabowski, 2003). Further research needs to be conducted to investigate under what circumstances concept mapping with different levels of generativity are more effective. Such an investigation will help refine the research questions in the area of generative learning as well as concept mapping strategy.

Self-Regulated Learning Skills

Self-Regulation and Learning

Self-regulated learning has become a critical theory in education, since learners have been considered as active participants, rather than passive recipients, throughout the learning process. That is, when learners take charge of their own learning, self-regulation occurs in order to accomplish the learning goal (Schunk, 1996; Zimmerman, 2000). According to Zimmerman (2000), self-regulation refers to "self-generated thoughts, feelings, and actions that are planned and cyclically adopted to the attainment of goals." (p. 14). Thus, self-regulated learning is defined as the regulatory process whereby students plan, monitor, control and reflect on their learning to achieve their goals and perform better (Pintrich, 2004). Put simply, self-regulated learning is a process of understanding and controlling their learning.

A variety of definitions of self-regulated learning exist, but three components are repeatedly emphasized by researchers: cognitive control, metacognitive control, and motivational control (Brown et al., 1983; Corno & Mandinach, 1983; Pintrich & De Groot, 1990; Zimmerman & Pons, 1986). First, cognitive control is the regulation of skills to use cognitive strategies necessary to learn the material. In other words, learners should be able to control the process of selecting and using the various cognitive strategies for memory, learning, reasoning, problem solving, and thinking (Pintrich, 2004). Second, metacognitive control is the regulation of skills for planning, monitoring, and modifying cognition, which refers to the awareness and control of one's thought processes. Although planning and modifying are important sub-components of metacognitive control, self-monitoring is central to success in learning (Butler & Winne, 1995; Pintrich, 2000, 2004). It is claimed that learners have to become aware of and monitor their progress toward their learning goals in order to be able to make any adaptive changes in their learning. Third, motivational control is the regulation of beliefs and attitudes that affect the use and development of cognitive and metacognitive skills. More specifically, regulation of motivation includes the control of goal orientation, self-efficacy, perceptions of task difficulty, task value beliefs, and personal interest in the task (Pintrich & Schunk, 2002; Wolters, 1998).

Researchers typically conceptualize self-regulated learning skills as follows: (1) Each of these three components is a necessary condition for self-regulated learning (Schraw *et al.*, 2006). For example, those who are motivated, but do not possess the necessary metacognitive skills, often fail to achieve high levels of self-regulation, which eventually results in low achievement. (2) Self-regulated learning has properties of both an aptitude and an event (Winne & Perry, 2000). An aptitude describes a relatively enduring attribute of a person that predicts future behavior, whereas an event is a snapshot embedded in a larger series of states unfolding over time. Typically self-regulated learning has been conceptualized as an aptitude that predicts learners' academic performance (Patrick & Middleton, 2002).

The Effectiveness of Self-Regulated Learning Skills

Ample empirical research results claim that self-regulated learning skills constitute a crucial factor for learners' performance (Corno & Mandinach, 1983; Paris & Paris, 2001; Pintrich & De Groot, 1990; Schunk & Zimmerman, 1998; Zimmerman & Pons, 1986). In a study with eighty high school students, Zimmerman and Pons (1986) concluded that students' use of self-regulated learning skills appeared to be highly correlated to their academic performance. Components of self-regulated learning skills included cognitive control and metacognitive control such as goal-setting, planning, seeking information, self-monitoring, self-evaluation, organizing, rehearsing, and memorizing. Pintrich and De Groot (1990) also reported significant relationships between motivational orientation, metacognition, and classroom academic performance for 173 seventh graders. Especially, metacognition was one of the best predictors of performance, while intrinsic motivation was strongly correlated with metacognition and cognitive strategy use. These results suggested that learners who set goals, selected strategies, implemented those strategies, and monitored their progress towards their goals have a higher chance of performing better (Pintrich, 2000; Zimmerman, 2000).

Relevant Studies on Self-Regulated Learning Skills

According to Zimmerman (1986), self-regulated learners are behaviorally, motivationally, and metacognitively active participants in their own learning process, which is in accord with Wittrock's claim that learners are active participants in the knowledge generation process. More explicitly, Wittrock (1990, 1991) not only included motivation as a process component of generative learning, but also emphasized that the teaching of metacognitive strategy is key to the success of generative learning. He clearly stated that "Learners need to be aware of and to control their use of generative learning strategies" (Wittrock, 1990, p. 371). Hence, from the theoretical standpoint, generative learning strategies as an overarching theme of the current study closely associates with self-regulated learning.

Interestingly, when considering the concept mapping strategy, most of the research investigating the relationship between concept mapping and self-regulated learning skills considered self-regulation as an outcome variable. For example, Chularut and DeBacker (2003), in a study with 79 ESL students, argued that the benefit of concept mapping activity significantly extends beyond achievement to include positive effects on self-regulation. Based on a discourse analysis from transcribed videotapes in small groups, Cassata and French (2006) reported that, with appropriate adult supports, concept maps are beneficial in facilitating preschoolers' metacognitive control, including planning, evaluation, and correction. Corno and Mandinach (1983) also stated that using concept mapping strategy can be a powerful means to promote self-regulated learning skills, which supports learners experiencing meaningful learning. This notion is clearly summarized by Novak (1998) who stated that: "[A]s students gained skill and experience in constructing concept maps, they began to report that they were learning how to learn" (p. 27).

Implications for the Current Study

An implication for the current study has been drawn from the literature review. Few studies investigate self-regulated learning skills as an input variable for generative learning, specifically concept mapping strategy. To answer Grabowski's (2003) statement, "Concept mapping strategies might not work equally well under all conditions, especially for learners who process information differently," the level of self-regulated learning skills is suggested as an independent variable of the current study with a strong interest in its interaction with the level of generativity of the treatment.

Summary

Generative Learning Theory and Schema Theory provide the fundamental theoretical framework for the current study. Generative Learning Theory emphasizes that the human mind actively generates its own meanings for information and draws inferences from them, rather than passively consuming incoming information (Wittrock, 1990, 1992; Wittrock & Alesandrini, 1990). On the other hand, Schema Theory focuses on the continuous refinement of an existing schema as an individual acquires new input. For the current study, the former provides a functional perspective with instructional implications, while the latter provides a descriptive perspective with an understanding on how people learn (Wittrock, 1991).

Concept mapping and self-regulated learning are the two major phenomena of interest in this study. Concept mapping, holding its origin in the pursuit of meaningful learning, is widely known as one of the generative learning strategies by its realization of the spirit of the two aforementioned theories. However, the process of constructing a map is intellectually rigorous and challenging (Anderson-Inman & Horney, 1997), as it focuses learners' attention on making their understanding more explicit, where the issue of learners' self-regulated learning skills plays a role. Based on a literature review, the level of self-regulated learning skills is a suggested independent variable for the current study with a strong interest in its interaction with the level of generativity of the treatment.

Chapter 3

METHODOLOGY

Introduction

The purpose of this study was to investigate the effectiveness of concept mapping strategies with different levels of generativity in terms of knowledge acquisition and knowledge representation. Also it examined whether or not learners' self-regulated learning skills influenced the effectiveness of concept mapping strategies with different levels of generativity. This chapter describes the research methodology including participants, research design, treatments, measurement instruments, procedures and data analysis for both a pilot and the main study.

Pilot Study

In the fall of 2006, 124 college students participated in a pilot study whose purpose was to test logistical procedures, validate the measurement instruments, and refine the treatment. Also, the following research questions were answered from the pilot study:

1. Do concept mapping strategies with different levels of generativity influence knowledge acquisition?

2. Do different levels of self-regulated learning skills influence knowledge acquisition?
3. Do different levels of self-regulated learning skill affect the effectiveness of concept mapping with different levels of generativity?

These questions are equivalent to the Research Questions 1, 2, and 3 of the current study.

The pilot study adopted a 2 x 3 factorial design with three levels of concept mapping strategies (expert-generated, partially learner-generated, and fully learner-generated mapping) and two levels of self-regulated learning skills (high and low). The dependent variable was knowledge acquisition as measured by the combined factual and conceptual knowledge. The learning material used in the pilot study was expository text with corresponding visual images describing the human heart, which was also the same as the learning material of the current study.

Regarding the concept mapping treatment, the expert-generated concept map group and the partially learner-generated concept map group used the concept maps created by Taricani (2002) without modifications (See Figure 1 and Figure 2). The expert-generated concept map group was asked to “use the given concept map while you are studying;” whereas, the partially learner-generated concept map group was asked to “fill in the blanks while you are studying.” The fully learner-generated concept map group received a blank sheet of paper on which they generated their own concept maps (See Figure 3).

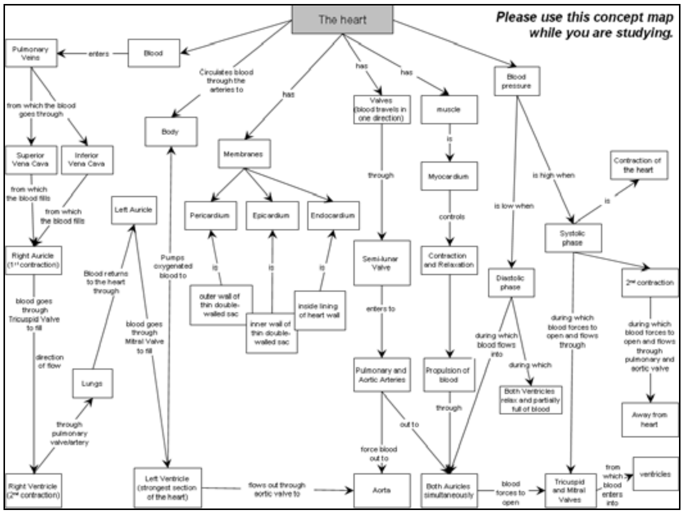


Figure 1. The expert-generated concept map for the pilot study: from Taricani (2002)

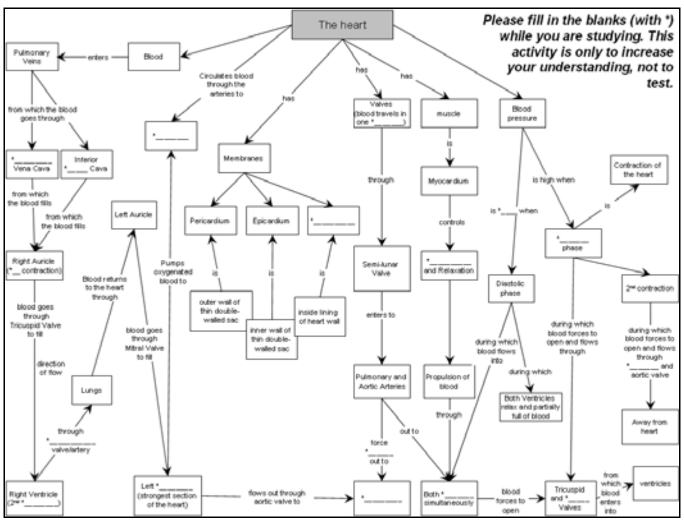


Figure 2. The partially learner-generated concept map for the pilot study: from Taricani (2002)

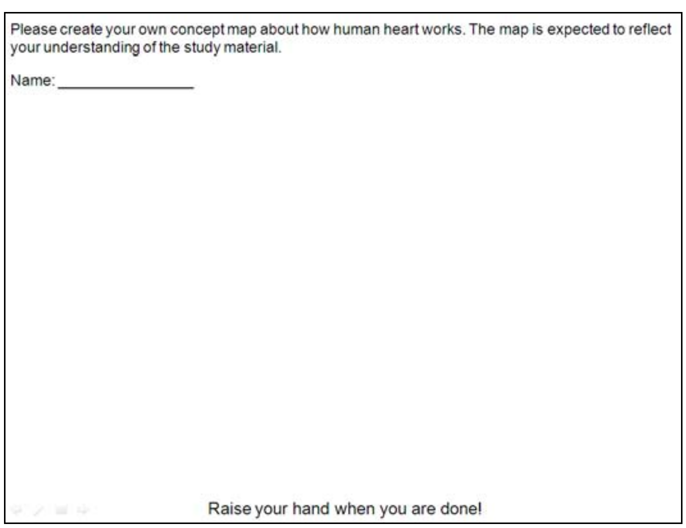


Figure 3. The fully learner-generated concept map for the pilot study

As concept mapping training, all three groups were provided with a two page, paper-based instruction on “How to use/create a concept map,” which described the characteristics, components and procedure for creating concept maps. It also illustrated an example of a concept map.

Means and standard deviations for knowledge acquisition of each treatment group by self-regulated learning skills are shown in Table 1.

Table 1. Means and Standard Deviations for Knowledge Acquisition in the Pilot Study

Generativity in Concept Mapping	Self-regulated Learning Skills	n	Knowledge Acquisition	
			M[a]	SD
Expert-generated Concept Mapping	High	18	22.78	9.40
	Low	22	20.23	8.18
	Total	40	21.38	8.73
Partially Learner-generated Concept Mapping	High	24	24.92	8.43
	Low	17	22.53	8.62
	Total	41	23.93	8.48
Fully Learner-generated Concept Mapping	High	20	31.00	5.77
	Low	23	23.00	9.67
	Total	43	26.72	8.96
Total	High	62	26.26	8.57
	Low	62	21.89	8.82
	Total	124	24.07	8.93

Note a. Maximum score = 40

The results of the two-way ANOVA, shown in Table 2, provided answers to Research Questions 1, 2 and 3. Students’ knowledge acquisition was significantly different between the three levels of generative treatment groups with moderate effect size (Cohen, 1988) (F=4.433; *p*=.014; partial Eta squared=.070). A follow-up pair-wise comparison revealed that the participants in the fully learner-generated concept mapping group significantly outperformed the participants in the expert-generated concept mapping group (mean difference=5.35, *p*=.018). However, no significant differences were found between the expert-generated concept mapping group and the partially learner-generated concept mapping group (mean difference=2.55, *p*=.365), or between the partially learner-generated concept mapping group and the fully learner-generated concept mapping group (mean difference=2.79, *p*=.287).

Table 2. Two-way ANOVA for Knowledge Acquisition in the Pilot Study

Source	df	Type III SS	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[a]
Treatment	2	632.385	316.192	4.433	.014	.070	.753
SRL Skills	1	567.450	567.450	7.955	.006	.063	.799
Interaction	2	212.819	106.409	1.492	.229	.025	.313
Error	118	8417.043	71.331				

Note a. Computed using alpha = .05
Note b. R Squared = .143 (Adjusted R Squared = .106)

Regarding self-regulated learning skills, students with high self-regulated learning skills significantly outperformed those with low self-regulated learning skills (F=7.955; *p*=.006; partial Eta squared=.063).

No significant interaction between the levels of generativity in concept mapping strategies by self-regulated learning skills (F=1.492, *p*=.229) appeared, although the pattern of means showed a promising trend among the six groups (See Figure 4).

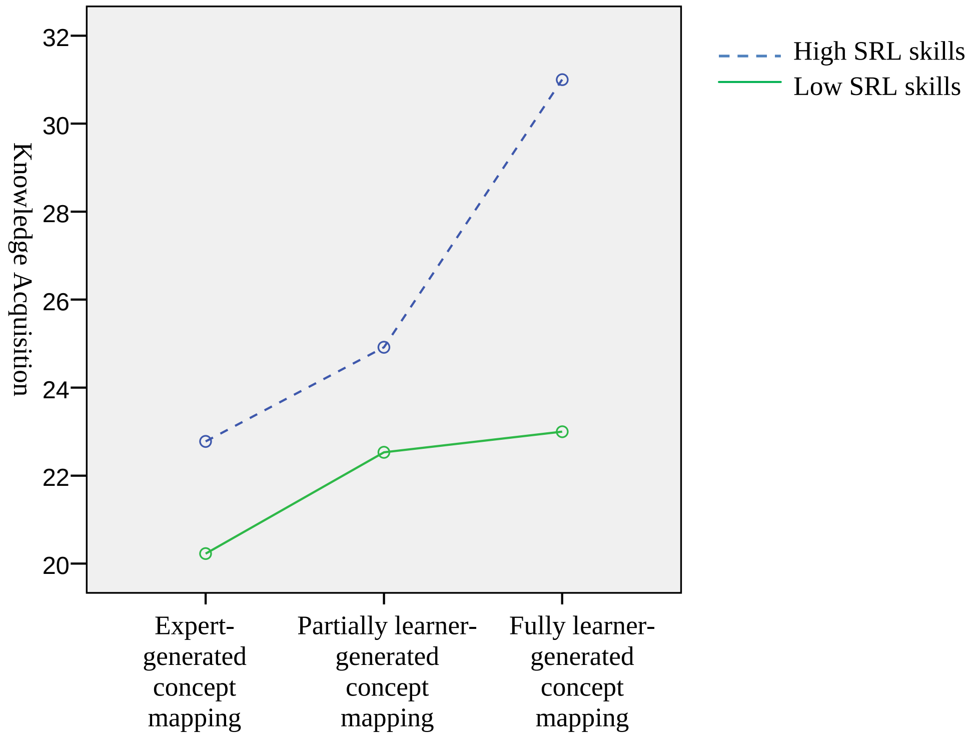


Figure 4. Profile plot of treatment by self-regulated learning skills of the pilot study

During the pilot study, no logistics problems were found with the research implementation procedures, and the measurement instruments were validated in terms of reliability.

Regarding refinement of the treatment, the following changes have been made based on the "lessons-learned" from the pilot study, and the theoretical implications. First, the level of generativity was increased for the expert-generated concept map group and the partially learner-generated concept map group by "encouraging" learners to modify the given map as they wished. In the pilot study, approximately 20% of the participants in the expert-generated and the partially learner-generated map group took their own notes on the given maps, although there was no prompt asking them to do so.

This action implied that some of the participants were willing to do more than just review or fill in the blanks. Second, concept mapping training was strengthened to equalize learners' entry skill level regarding the concept mapping activity. The concept maps generated by the pilot study participants varied significantly in terms of the types as well as quality of the maps. In the pilot, some participants drew a mind map or simple tree structure, which suggested that not all of the participants understood how to create a concept map in the way Novak defined. Therefore, more structure was given to the practice activity in order to support participants learning the attributes of Novak's concept maps better. Third, the expert-generated concept map and the partially learner-generated concept map were modified to follow the Novakian concept maps. More effort was made to generate propositions with linking words and directions, to consider the hierarchies of broader and narrower concepts, and to provide cross-links. Changes in concept mapping training and the treatments were made consistently toward the attributes of Novak's concept maps, which were also operationalized in the evaluation rubric in knowledge representation.

In addition, because students with high self-regulated learning skills in the fully learner-generated concept map group significantly outperformed the other five groups, an additional research question related to the quality of "knowledge representation" was added.

All in all, the pilot study not only enabled the researcher to achieve the intended purposes but also further informed the process and results of concept mapping as a generative learning activity.

Participants

The participants were 285 undergraduate students who enrolled in a 200-level statistics course at a large northeastern university. They were recruited during two consecutive semesters, fall 2007 (n=132) and spring 2008 (n=153), of the same course with the same instructor and the same content. The number of possible participants in the fall 2007 semester was 150 and 243 in the spring 2008 semester, totaling 393. Participants from the fall 2007 semester participated in the research in December 2007, while participants from the spring 2008 semester participated in February 2008. Although they were recruited from different semesters, no group difference due to differing semesters was expected since similar conditions existed.

Since the statistics course is a general education course, participants' majors and backgrounds varied from sociology to engineering, and from freshmen to seniors. They participated voluntarily, and received extra points for participation from their course instructor.

Research Design

Variables and Design

The independent variables of this study were self-regulated learning skills (SRL skills) and the generativity in concept mapping strategies. The levels of SRL skills were divided into high and low, while the levels of generativity in concept mapping were operationalized in three different treatments. Consequently, six groups formed: (a) high

SRL skills/expert-generated concept map group, (b) high SRL skills/partially learner-generated concept map group, (c) high SRL skills/fully learner-generated concept map group, (d) low SRL skills/expert-generated concept map group, (e) low SRL skills/partially learner-generated concept map group, (f) low SRL skills/fully learner-generated concept map group (See Table 3).

Dependent variables were knowledge acquisition in terms of factual and conceptual knowledge, and knowledge representation.

Table 3. Research Design with Two Factors

		Levels of Generativity in Concept Mapping Strategies		
		Expert-generated Concept Mapping	Partially Learner-generated Concept Mapping	Fully Learner-generated Concept Mapping
Self-regulated Learning Skills	High	(a)	(b)	(c)
	Low	(d)	(e)	(f)

This study employed two different research designs to answer different research questions. In order to investigate Research Questions 1, 2 and 3, a 2 x 3 factorial design was employed, and knowledge acquisition of Groups (a) through (f) was compared. Regarding Research Question 4, a 1 x 2 design analyzed the knowledge representation of Groups (c) and (f).

Materials

Learning Material on Human Heart

The learning material used in this study contained an approximately 1,900-word expository text with corresponding visual images describing the human heart, including its parts, locations and functions. The original paper-based booklet, developed by Dwyer (1978), was reformatted into web-based, self-paced learning materials with 21 screens (See Figure 5). This content was selected because of the complexity of the material. The hierarchy of cardiac parts and sub-parts, and the flow of blood circulation during systolic and diastolic phases lent itself well to locating nodes and links and meaningful relationships among them. Also, the content provided reliable and valid criterion measures for identification, terminology, and comprehension (Dwyer, 1978).

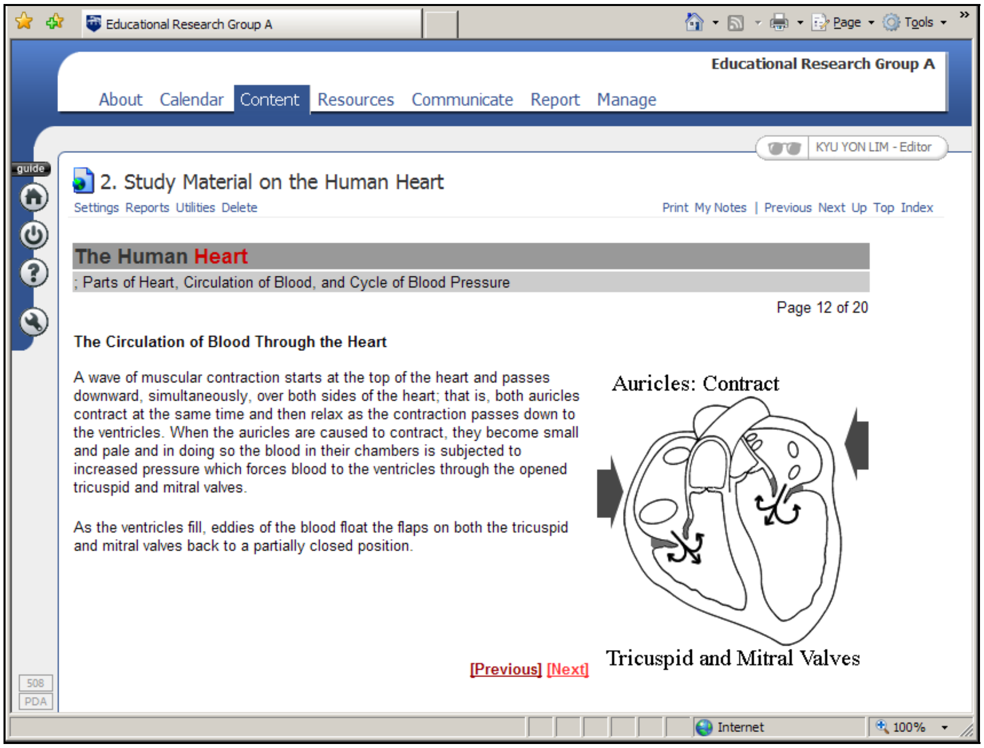


Figure 5. Sample screen of the learning material

Concept Mapping Training

To promote and equalize participants' understanding of concept maps, a 10-15 minute online training session was provided immediately before the participants started the treatments. Training materials with 5 screens consisted of three sections: 1) What is a concept map? 2) How to create a concept map? And, 3) Let's try! (See Figure 6; See Appendix D for the full training material). The first two parts included a general illustration of concept maps with sample images, while the last part included a passage and a blank paper so participants could actually generate a simple concept map of the given passage. The passage, "Graphical and numerical summaries of quantitative variables," was selected from a statistics course handout, since learners were already familiar with the content. This allowed learners to focus on concept mapping practice itself without unnecessary cognitive overload caused by unfamiliar content.

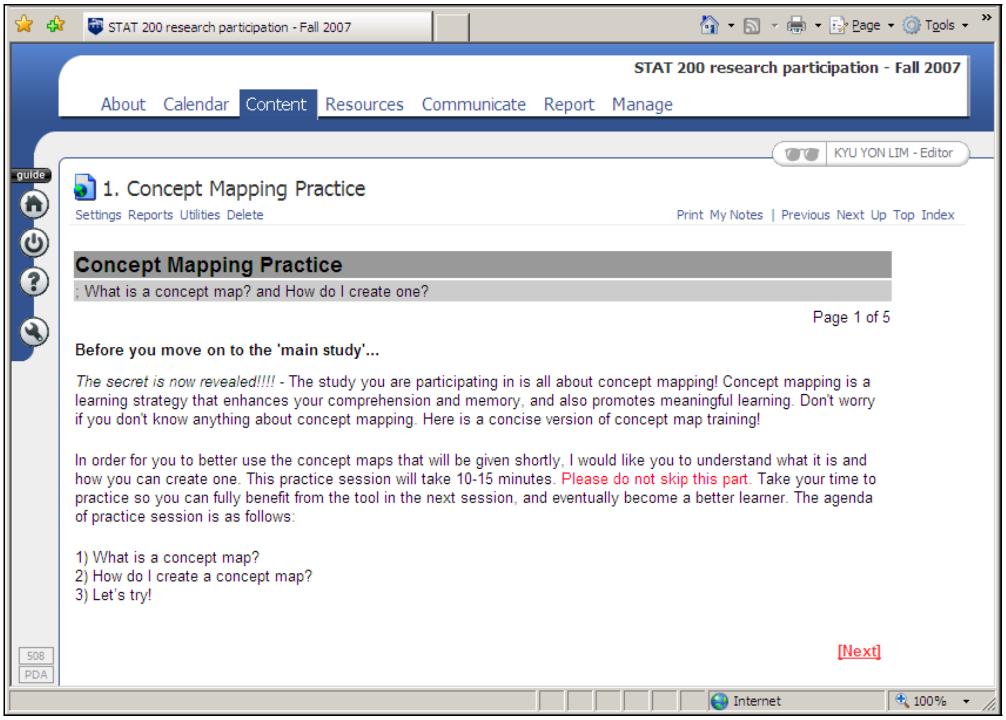


Figure 6. Sample screen of the training material

The training occurred online for the following reasons: 1) Training for the multiple experiment sessions would be exactly the same. 2) Computer management systems permit tracking of each participant's page hits and learning time. 3) Online training is logistically more convenient, since experiments can start without waiting for late-comers. 4) Training and the main treatment used the same delivery method (online learning material and paper-based concept mapping treatments) so learners could become accustomed to the mode of learning.

Treatments

Three types of concept mapping activities were designed to operationalize the different levels of generativity, that is, the degree to which learning with concept mapping involves active generation of meaning (Wittrock, 1992). In this study, each treatment consisted of 1) paper-based concept mapping tools and 2) corresponding written instructions, allowing learners to work with these treatments while studying the online learning material.

Treatment 1: Expert-Generated Concept Mapping

A paper-based concept map constructed by an expert prior to the instruction was used for the expert-generated concept map group, requiring the lowest level of generativity (See Appendix A for the treatment packet). Learners who study with this treatment are asked to consult, review, or study the product of someone else's cognitive efforts, rather than overtly represent their knowledge. The expert-generated concept map, initially adopted from the study by Taricani (2002), and modified to reflect the attributes suggested by Novak (1984), specifically included concepts, linking words, and directions between a pair of concepts. Important or more general concepts occupied a top-most position, and cross-links connected multiple concepts under different sub-domains. Concepts in the map were selected with the knowledge acquisition test in mind.

The corresponding written instruction stated, "While you are studying the material, you are encouraged to refer to the given concept map to enhance your understanding of the human heart." Learners were also encouraged to make changes on the given concept map if appropriate by the written instruction which stated, “You are encouraged to modify this map, if you think necessary, by adding, removing, or relocating the components. Please do whatever you’d like with the map!” These instructions were included in the top corner of the concept map as a reminder. This added feature was expected to provide learners with an opportunity to give a thoughtful review of the ready-made structure of the given concept map, which facilitates generative learning.

Treatment 2: Partially Learner-Generated Concept Mapping

The partially learner-generated concept mapping treatment used a paper-based concept map in which half of the concepts and/or linking words had been randomly eliminated for a “fill-in-the-blanks” activity (See Appendix B for the treatment packet). Nodes and linking words were intentionally omitted from the expert-generated concept map in order to incorporate a mid-level generativity. Learners in this treatment group generated their own meaning to some degree with the completion activity, and were encouraged to modify the given concept map as they wished.

The corresponding written instructions stated, “You are encouraged to modify this map, if you think necessary, by adding, removing, or relocating the components. Please do whatever you’d like with the map!” This was the exact same statement given to the expert-generated concept map group to facilitate generative learning.

Treatment 3: Fully Learner-Generated Concept Mapping

Lastly, the fully learner-generated concept mapping treatment consisted of a blank sheet of paper on which learners demonstrated their understanding by creating their own concept maps (See Appendix C for the treatment packet). In this treatment which required the highest level of generativity, concept maps were constructed entirely by learners who were expected to organize and integrate given information, and represent it in an overt way.

The corresponding written instructions included a brief step-by-step guideline added to the corner of the blank paper in order to remind learners of Novak's (1984) suggested procedure for creating concept maps.

Measurement Instruments

Three instruments were used to measure self-regulated learning skills, knowledge acquisition, and knowledge representation.

Self-Regulated Learning Skills

The Motivated Strategies for Learning Questionnaire (MSLQ) measured participants' self-regulated learning skills (Pintrich & De Groot, 1990). In order to fit the needs of the current study, sub-scales related to: 1) cognitive strategy use (rehearsal, organization, elaboration, critical thinking), 2) metacognition, and 3) motivation (extrinsic, intrinsic) were selected. Some of the items were slightly restated: The phrase, "in this class/course," was revised as "when studied this material," since the current research was conducted outside of the "class" or "course" environment. The revised questionnaire consisted of 39 items with a seven point Likert-type scale ranging from 1 (not at all true of me) to 7 (very true of me). Sample items are: "When I'm reading I stop once in a while and go over what I have read." And, "I ask myself questions to make sure I know the material I have been studying" (See Appendix E for the entire questionnaire items).

The highest possible score was 7 and the lowest possible score was 1, based on the mean score of 39 items of each participant. The higher the score, the higher the level of self-regulated learning skills.

According to the result of the pilot study, Cronbach's alphas for the revised scales were high, demonstrating good internal consistency (See Table 4).

Table 4. Measurement Instruments

Constructs			# of items	Scales	Reliability[a] (α)
Self-regulated learning skill	Cognitive strategy use	Rehearsal	4	Likert-type	.757
		Elaboration	6		.736
		Organization	4		.585
		Critical Thinking	5		.809
	Metacognition		12		.734
	Motivation	Intrinsic	4		.702
		Extrinsic	4		.762
					.881
Knowledge Acquisition	Factual		20	Multiple choice	.817
	Conceptual		20		.833
					.910

Note a. Reliability is calculated based on the data from the pilot study (n=124).

Knowledge Acquisition

In order to assess students' acquisition of knowledge, a 40-item, multiple-choice test was adopted from Dwyer (1978) (See Appendix F). Knowledge acquisition was measured in two ways: factual and conceptual knowledge. The first half of the test related to students' factual knowledge of specific terms and definitions relevant to the material. A sample test item is:

The ______ is (are) the strongest section(s) of the heart.

a. Left ventricle b. Aorta c. Septum d. Right ventricle e. Tendons

The second half of the test covered students' conceptual knowledge of the human heart, its parts and their interrelationships as a system. A sample test item is:

When the tricuspid and mitral valves are forced shut, in what position is the pulmonary valve?

a. Closed b. Beginning to open c. Open d. Beginning to close

The highest possible score for factual knowledge and conceptual knowledge was 20, respectively. The reliability of the knowledge acquisition test scores in the pilot test was 0.91, using Cronbach's alpha. Specifically, the alpha of factual knowledge test scores was .817, while the alpha of conceptual knowledge test scores was .833 (See Table 4).

Knowledge Representation

Knowledge representation of the fully learner-generated concept map group, referred as Group (c) and (f) in Table 3, was measured in terms of (1) proposition quality, (2) overall quality of concept maps, and (3) the quantity of propositions covered in each concept map. That is, more than a one-dimensional scoring system was required to evaluate the concept maps adequately, accommodating the diversity and flexibility of students' self-created outcomes (Rice *et al.*, 1998; Yin *et al.*, 2005). As a result, each concept map received two scores for quality: proposition quality based on the relational scoring rubric, and overall quality based on the holistic scoring rubric. In addition, the quantity of propositions in each map was also counted as a third criterion.

Proposition Quality. Relational scoring method was used to measure the adequacy of each proposition which is the least complex structure but the most fundamental elements represented in a concept map (McClure et al., 1999; Ruiz-Primo & Shavelson, 1996). For this research, the details of the relational scoring method have been adopted and modified from the study by McClure, Sonak, and Suen (1999). The separate propositions of each map were evaluated according to the scoring protocol in Table 5. The scores for each proposition were summed, then divided by the maximum possible score derived from the expert map, which was 124, and then multiplied by 5: (sum of proposition scores/124) x 5. The reason for the multiplication by 5 was to put the relational scores and holistic scores on the same scale: 5 as the highest possible score. Propositions presented in the expert-generated map were used as a guide, not a criterion.

Table 5. Scoring Rubric of Knowledge Representation

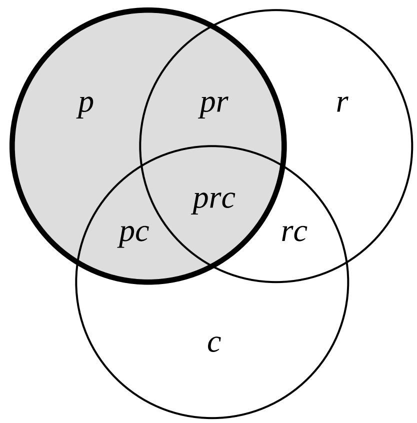
Construct	Method	Protocols
Proposition quality	Relational scoring for each proposition	(0 points) No or invalid relation between concepts (1 points) Valid relationship between the concepts but the linking word is invalid (2 points) Valid relationship and linking word between the concepts but the direction of the arrow does not indicate the appropriate relationship (3 points) Valid relationship with linking word and arrows
Overall quality	Holistic scoring for the entire concept map	(1 points) An attempt is made but limited understanding is found. (2 points) The map represents a partial understanding of the material with little amount of substantial relationships between concepts. Neither hierarchies nor cross-links are found. (3 points) The map represents a partial understanding of the material with small amount of substantial relationships between concepts. Hierarchies are found to some degree but no cross-links are found. (4 points) The map represents a fair amount of understanding of the material with substantial relationships between concepts. Some hierarchies and cross-links are found. (5 points) The map represents a full amount of understanding of the material with substantial relationships between concepts. Some hierarchies and cross-links are found.
Quantity of propositions	The number of propositions in each concept map	Summation of the number of valid propositions in each concept map.

Overall Quality. Holistic scoring method was used to measure overall quality of each concept map because it supports broader judgments regarding the quality of product by endorsing a single score. This assessment of the learner's overall understanding of the learning material was added in order to complement the bottom-up approach of relational scoring. The protocol measuring the overall quality appears in Table 5. Since learners generated concept maps based on the instruction of Novak and Gowin (1984), and in order to achieve the congruency of assessment, this protocol incorporated the components emphasized in Novak and Gowin's concept map, especially the hierarchies and cross-links. The highest possible score was also 5.

Quantity of Propositions. Counting the total number of valid propositions was used to measure the quantity of propositions, which represents the amount of information processed by the learner. Given that there was no limitation in the number of concepts and linking words used in fully-learner generated concept maps, there was no maximum score in the quantity of proposition.

Since the relational scoring rubric on proposition quality and the holistic scoring rubric on overall quality were modified for this study, the reliability and validity of the concept map scores was tested. Thirty fully learner-generated concept maps from the pilot study were used as sample concept maps. Two raters selected were graduate students in the College of Education. One of them was familiar with the human heart material, while the other was not. Regarding rater training, the two raters thoroughly reviewed the learning material, shared their ideas for the scoring rubrics, and then they each evaluated three concept maps in order to verify agreement between the two. Rater training continued until the gap between the two raters reduced to adjacent points (±1 point). After the training, each rater scored thirty concept maps using the relational scoring rubric on proposition quality and the holistic scoring rubric on overall quality in order to assess reliability and validity.

Reliability. A generalizability coefficient was calculated for each scoring method. In general, the reliability reported in concept mapping studies is in the form of inter-rater reliabilities using percent agreement, Pearson's r, or Spearman's rho (Rice et al., 1998; Ruiz-Primo & Shavelson, 1996). However, these techniques, based on classical test theory, do not recognize that multiple sources of error may operate in a measurement. Classical test theory provide a decomposition of the observed score into a true score and with only one type of error (Gruijter & Kamp, 2003). On the other hand, generalizability theory provides models and methods to disentangle multiple sources of error and manage them in a systematic way (Brennan, 2000). In this study, rubric and rater were sources of error, called facets. Thus, a *two-facet, fully-crossed design* was adopted to conduct a G-study, as illustrated by the Venn diagram in Figure 7. Given that the use of scoring rubric in this study was intended for the relative model, the error variances related only to the student factor (*p, pr, pc, prc*) were considered for calculating the generalizability coefficient. The implicit universe of admissible observations was 30 students evaluated by 2 raters on their knowledge representation using relational and holistic scoring methods. The object of measurement was knowledge representation of 30 students.



p (person: students) x *r* (rater) x *c* (criteria: rubric)

Figure 7. Venn diagram for the two-facet, fully-crossed design model

As a Decision-Study, four different generalizability coefficients were computed to examine how the coefficients varied depending on the number of raters and the number of scoring rubrics (holistic scoring rubric and relational scoring rubric). In other words, four different coefficients were calculated to answer the question of "How much different are coefficients when using only one scoring rubric and when using two scoring rubrics?" and also "How much different are coefficients when using only one rater and when using two raters?" GENOVA software produced generalizability coefficients as reported in Table 6.

Table 6. Generalizability Coefficients of Scoring Rubrics

	1 rater	2 raters
1 scoring rubric	.76060	.81105
2 scoring rubrics	.85029	.88823

According to the results, the generalizability coefficient was .88823 if 2 raters use 2 scoring rubrics, while .85029 if 1 rater uses 2 scoring rubrics. The result indicated that 2 raters were not needed to acquire sufficient generalizabiliy. Therefore, the decision was made to use 1 rater and 2 scoring rubrics to finalize the generalizability coefficient of .85029, demonstrating high reliability of the scoring rubric.

Validity. As evidence of concurrent validity, each of the proposition quality scores and the overall quality scores of the fully learner-generated maps was compared to the similarity scores to the expert-generated map. Similarity scores were calculated based on the convergence score: “the proportion of accurate propositions in the student’s map out of total possible valid propositions in the criterion map” (Ruiz-Primo *et al.*, 2001, p.365).The lowest possible similarity score was 0 and the highest possible proportion was 100. The Pearson product moment correlation was then computed to compare the scoring rubric-based scores with the similarity scores. Pearson’s r for proposition quality scores was .728 and overall quality scores .685, demonstrating satisfactory concurrent validity.

The reliability and validity of the quantity of proposition scores, the third measure of the knowledge representation, was not tested since the measure was based on number counting.

Procedures

Prior to the Intervention

A personal classroom visit initiated recruiting participants. During the visit, students reviewed the Informed Consent (Appendix G) and received a list of computer lab time slots they could select to accommodate their schedules. Those volunteers were randomly assigned to one of the three concept mapping treatment groups by a random number generator in advance of their coming to the lab. A week before the computer lab session, participants received an email asking to log on to the research web site and respond to the MSLQ. They were able to finish the MSLQ anytime anywhere, prior to their coming to the computer lab to minimize a fatigue effect during the intervention.

During the Intervention

When participants arrived at the computer lab, they registered, received an instruction sheet of the procedures which corresponded to the assigned treatment groups (See Appendix A~C), along with a blank paper for the concept mapping training activity. Participants began their sessions independently once seated in a designated area. This reduced distraction among different treatment groups. First, participants logged onto the research web site, and read the "Read-me-first!" page which described the research procedure. Second, they studied the concept mapping training material and created a simple concept map as a practice. As soon as they finished the practice concept map, they raised their hand so the researcher could collect the practice map and hand out the paper-based concept mapping tool in accordance with the treatment assignment. Third, participants studied the human heart material with a given concept mapping tool in a self-paced manner. Fourth, after finishing the given treatment, participants raised their hands so the researcher could collect the concept mapping outcome. At this point, each participant received the written access code to the test page individually to proceed to the post-knowledge test.

Participants recruited from the fall 2007 semester and from the spring 2008 semester went through the exact same procedure. However, an open-ended survey requesting responses to their learning experience regarding concept mapping (Appendix H) was added to the end of the experiment only for participants from the spring 2008 semester.

Data Analysis

Preliminary Analysis

A preliminary analysis achieved two purposes: Examining the possible differences between participants recruited in the fall 2007 semester and the spring 2008 semester, and identifying participants with high and low self-regulated learning skills. First, in order to examine the differences between the participants from the fall 2007 and the spring 2008 semester, T-test was applied for group comparison. If the differences due to semester in self-regulated learning skills and knowledge acquisition appeared to be insignificant, these two groups would be considered as identical and merged as one participant group. Second, descriptive statistics for self-regulated learning skills allowed dividing the participants into the two groups: high and low. For each treatment level, one-third of the participants in the higher end were specified as high self-regulators, while one-third of the participants in the lower end were specified as low self-regulators. Participants who scored mid-level of self-regulated learning skill were included only for the preliminary analysis and follow-up analysis, and removed for the main analysis.

Descriptive Statistics

After merging semesters and identifying the levels of self-regulated learning skills, means and standard deviations of dependent variables were calculated.

Effect of Generativity and Self-regulated Learning Skills on Knowledge Acquisition

To investigate the main effect of the levels of generativity in concept mapping and the levels of self-regulated learning skills as well as the interaction effect between those two on factual and conceptual knowledge, two-way MANOVA was run. Multivariate analysis tested the effect of independent variables in combination with dependent variables, since relationships among dependent variables were expected. To justify the use of MANOVA, assumptions - normality of dependant variables, homogeneity of variances, and relationship between dependant variables- were tested. In addition, to follow-up the interaction effect, a multiple linear regression was used to further understand the results.

Effect of Generativity and Self-regulated Learning Skills on Knowledge Representation

One-way MANOVA answered Research Question 4 by comparing knowledge representation between the high self-regulated learning skill group and the low self-regulated learning skill group. Dependent variables were the proposition quality, overall quality, and the quantity of propositions. MANOVA test assumptions were also examined.

Chapter 4

RESULTS

Introduction

The purpose of this study was to investigate the effectiveness of concept mapping strategies with different levels of generativity in terms of knowledge acquisition and knowledge representation. It also examined whether or not learners' self-regulated learning skills influenced the effectiveness of concept mapping strategies with different levels of generativity. This chapter reports the results of statistical analysis in order to answer the research questions proposed in Chapter 1.

Preliminary Analysis

Combining Semesters

Given that data were collected from two different semesters, the data collected from the fall 2007 semester and the data collected from the spring 2008 semester were compared to determine whether they could be merged.

First, participants from the two different semesters were compared using t-tests. The results showed no significant differences between semesters in terms of self-regulated learning skills ($t = -1.317$, $p = .189$), factual knowledge ($t = -.853$, $p = .395$), or conceptual knowledge ($t = -.408$, $p = .683$) (See Table 7).

Table 7. T-test Results for Groups by Semester

Semester	n	M	SD	t	df	*p*
			Self-regulated Learning Skills			
Fa 07	132	4.70	.67	-1.317	283	.189
Sp 08	153	4.80	.60			
			Factual Knowledge			
Fa 07	132	10.83	4.09	-.853	283	.395
Sp 08	153	11.25	4.36			
			Conceptual Knowledge			
Fa 07	132	9.91	4.17	-.408	283	.683
Sp 08	153	10.12	4.41			

Table 8. T-test Results for Groups of Levels of Generativity by Semester

Generativity in Concept Mapping	Semester	n	M	SD	t	df	*p*
			Self-regulated Learning Skills				
Expert-generated Map	Fa 07	44	4.63	.70	-1.096	93	.276
	Sp 08	51	4.78	.63			
Partially Learner-generated Map	Fa 07	44	4.74	.66	-.183	94	.855
	Sp 08	52	4.76	.65			
Fully Learner-generated Map	Fa 07	44	4.73	.67	-1.031	92	.305
	Sp 08	50	4.86	.50			
			Factual Knowledge				
Expert-generated Map	Fa 07	44	11.70	4.52	-.936	93	.352
	Sp 08	51	12.57	4.46			
Partially Learner-generated Map	Fa 07	44	9.95	3.31	-.036	94	.972
	Sp 08	52	9.98	3.84			
Fully Learner-generated Map	Fa 07	44	10.82	4.24	-.468	92	.641
	Sp 08	50	11.24	4.46			
			Conceptual Knowledge				
Expert-generated Map	Fa 07	44	10.95	4.85	-.323	93	.747
	Sp 08	51	11.27	4.78			
Partially Learner-generated Map	Fa 07	44	9.34	3.38	.613	94	.541
	Sp 08	52	8.87	4.10			
Fully Learner-generated Map	Fa 07	44	9.43	4.03	-.964	92	.337
	Sp 08	50	10.24	4.07			

Second, as a further comparison, another t-test examined whether or not participants under the same treatment from different semesters were equivalent. Table 8 shows the comparison of semesters under each treatment level, and reports that none of the pairs were significantly different.

Therefore, participants assigned to the expert-generated concept map group from two different semesters merged as one treatment group. As such, participants in the partially learner-generated concept map group from two semesters merged as one treatment group, and participants in the fully learner-generated map group from two semesters were merged as well. After combining semesters, the numbers of participants for each treatment level were 95, 96, and 94 respectively. Means and standard deviations of each treatment level in self-regulated learning skills, factual knowledge and conceptual knowledge are also as shown in Table 9.

Table 9. Means and Standard Deviations by Levels of Generativity (Semester merged)

Generativity in Concept Mapping	n	M	SD
Self-regulated Learning Skills			
Expert-generated Map	95	4.71	.66
Partially Learner-generated Map	96	4.75	.65
Fully Learner-generated Map	94	4.80	.59
Total	285	4.75	.63
Factual Knowledge			
Expert-generated Map	95	12.17	4.48
Partially Learner-generated Map	96	9.97	3.58
Fully Learner-generated Map	94	11.04	4.34
Total	285	11.06	4.24
Conceptual Knowledge			
Expert-generated Map	95	11.13	4.79
Partially Learner-generated Map	96	9.08	3.77
Fully Learner-generated Map	94	9.86	4.05
Total	285	10.02	4.30

Identifying High and Low Levels of Self-Regulated Learning Skills

In order to identify participants with high and low self-regulated learning skills, students who scored in either the upper one-third or the lower one-third among the participants in each treatment levels were defined as having high or low self-regulated learning skills. Discarding the middle one-third minimized misclassification of high versus low. As a result, out of 285 participants, 201 students formed six groups with three levels of generativity in concept mapping treatments by two levels of self-regulated learning skills. Eighty-four students with mid-level scores in self-regulated learning skills were excluded from the analysis.

Based on the categorizing, the overall mean score of high self-regulated learning skill group was 5.37; whereas, the overall mean score of low self-regulated learning skill group was 4.08. The numbers of participants and descriptive results of self-regulated learning skills for each treatment level appear in Table 10.

Table 10. Means and Standard Deviations of Self-regulated Learning Skills

Generativity in Concept Mapping	Self-regulated Learning Skills	n	M	SD
Expert-generated Map	High	33	5.38	.38
	Low	32	4.00	.41
	Total	65	4.74	.81
Partially Learner-generated Map	High	33	5.43	.32
	Low	33	4.05	.40
	Total	66	4.78	.78
Fully Learner-generated Map	High	36	5.32	.24
	Low	34	4.18	.45
	Total	70	4.75	.68
Total	High	102	5.37	.32
	Low	99	4.08	.42
	Total	201	4.74	.75

Descriptive Statistics

After combining semesters and identifying high and low levels of self-regulated learning skills, descriptive statistics of dependent variables were analyzed. Table 11 present the means and standard deviations of the factual and conceptual knowledge acquisition examined by the levels of generativity in concept mapping and the levels of self-regulated learning skills.

Table 11. Means and Standard Deviations of Knowledge Acquisition

Generativity in Concept Mapping	Self-regulated Learning Skills	n	M	SD
	Factual Knowledge			
Expert-generated Map	High	33	12.91	4.20
	Low	32	10.63	4.77
	Total	65	11.78	4.58
Partially Learner-generated Map	High	33	11.00	3.35
	Low	33	8.85	3.39
	Total	66	9.92	3.52
Fully Learner-generated Map	High	36	11.03	4.67
	Low	34	10.61	4.26
	Total	70	10.83	4.45
Total	High	102	11.63	4.18
	Low	99	10.03	4.20
	Total	201	10.84	4.26
	Conceptual Knowledge			
Expert-generated Map	High	33	11.97	4.87
	Low	32	10.41	4.50
	Total	65	11.20	4.70
Partially Learner-generated Map	High	33	9.15	3.78
	Low	33	8.39	3.77
	Total	66	8.77	3.76
Fully Learner-generated Map	High	36	9.72	3.98
	Low	34	9.32	3.46
	Total	70	9.53	3.72
Total	High	102	10.26	4.36
	Low	99	9.36	3.95
	Total	201	9.82	4.18

For the seventy participants who studied with the fully learner-generated concept mapping, the means and standard deviations of the knowledge representation appear in Table 12.

Table 12. Means and Standard Deviations of Knowledge Representation

Generativity in Concept Mapping	Self-regulated Learning Skills	N	Mean	SD
	Proposition Quality			
	High	36	2.65	1.095
	Low	34	2.17	.883
	Total	70	2.42	1.018
	Overall Quality			
	High	36	3.03	.941
Fully Learner-generated Map	Low	34	2.53	.662
	Total	70	2.79	.849
	Quantity of Propositions			
	High	36	31.84	9.353
	Low	34	25.68	8.267
	Total	70	28.70	9.241

Effects on Knowledge Acquisition

Regarding the effects of the levels of generativity in concept mapping and the levels of self-regulated learning skills on knowledge acquisition, the following research hypotheses were raised in this study:

	Effects of Generativity on Knowledge Acquisition
Hypothesis 1:	Different levels of generativity in concept mapping (expert-provided, partially learner-generated, and fully learner-generated) will influence knowledge acquisition.
Hypothesis 1-1:	Learners who study with a fully learner-generated concept map will demonstrate a higher factual knowledge acquisition score than learners who study with an expert-provided concept map.
Hypothesis 1-2:	Learners who study with a fully learner-generated concept map will demonstrate a higher factual knowledge acquisition score than learners who study with a partially learner-generated concept map.
Hypothesis 1-3:	Learners who study with a fully learner-generated concept map will demonstrate a higher conceptual knowledge acquisition score than learners who study with an expert-provided concept map.
Hypothesis 1-4:	Learners who study with a fully learner-generated concept map will demonstrate a higher conceptual knowledge acquisition score than learners who study with a partially learner-generated concept map.
	Effects of Self-regulated Learning Skills on Knowledge Acquisition
Hypothesis 2:	Different levels of self-regulated learning skills (high vs. low) will influence knowledge acquisition.
Hypothesis 2-1:	Learners with high self-regulated learning skills will demonstrate higher factual knowledge acquisition scores than learners with low self-regulated learning skills.
Hypothesis 2-2:	Learners with high self-regulated learning skills will demonstrate higher conceptual knowledge acquisition scores than learners with low self-regulated learning skills.
	Interaction on Knowledge Acquisition
Hypothesis 3:	Significant interaction will exist between the levels of generativity in concept mapping and the levels of learners' self-regulated learning skills in terms of knowledge acquisition.

As a process of collecting evidence to support research hypotheses, two-way MANOVAs were run to determine the existence of any statistically significant differences in knowledge acquisition.

Test Assumptions

Three assumptions for MANOVA were tested: Correlation between factual knowledge and conceptual knowledge, homogeneity of groups, and normality of dependent variables.

Correlation between Dependent Variables. The correlation between factual knowledge and conceptual knowledge is reported in Table 13. Since the Pearson's correlation coefficient is statistically significant yet lower than .90 (r =.714, *p* =.000), the use of multivariate analysis is justified without concern for a multicollinearity issue (Brace *et al.*, 2006).

Table 13. Correlation between Factual and Conceptual Knowledge

Dependent Variable		Factual Knowledge	Conceptual Knowledge
Factual Knowledge	Pearson's r	1	.714**
	Sig. (2-tailed)		.000
	N	201	201
Conceptual Knowledge	Pearson's r	.714**	1
	Sig. (2-tailed)	.000	
	N	201	201

** $p < .01$

Homogeneity of Groups. Testing of homogeneity of variances among groups used Levene's test of equality of error variances. Levene's tests indicated that the error variances were equal among groups in conceptual knowledge at .05 alpha level, but not in factual knowledge (see Table 14). Since the *p* value was .047 in factual knowledge, approaching the .05 level, the test results were double checked based on the suggestion by Field (2005). The assumption of homogeneity was met, since the resulting value of the highest SD^2 divided by the lowest SD^2 was 1.98, which was less than two.

Table 14. Levene's Homogeneity Test on Factual and Conceptual Knowledge

Dependent Variable	F	df1	df2	*p*
Factual Knowledge	2.293	5	195	.047
Conceptual Knowledge	1.960	5	195	.086

Normality of Dependent Variables. Normality of dependent variables was examined using z-score of skewness and graphical representations.

Z-score of skewness was calculated by subtracting mean of distribution and dividing by the standard deviation of distribution: $Z_{skewness}$ = (Skewness statistics – 0) / Standard Error of Skewness (Field, 2005). As presented in Table 15, the z-scores of both factual and conceptual knowledge were less than 1.96, which meets the assumption of normal distribution.

Table 15. Skewness of Factual and Conceptual Knowledge

Dependent Variable	Skewness	Std. Error of Skewness	Converted z-score
Factual Knowledge	.326	.172	1.895
Conceptual Knowledge	.200	.172	1.163

Also, graphical representations of histograms and box plots were investigated as recommended by APA (Wilkinson & Task Force on Statistical Inference, 1999). Figure 8 and Figure 9 show that both dependent variables were within the range of a normal distribution.

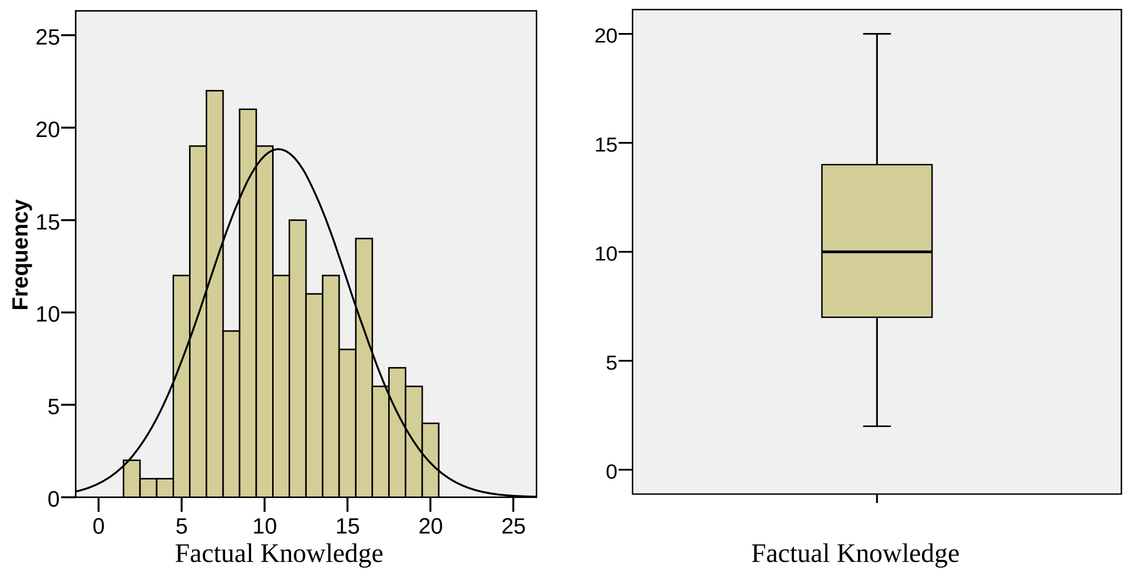


Figure 8. Histogram and Box Plot of Factual Knowledge

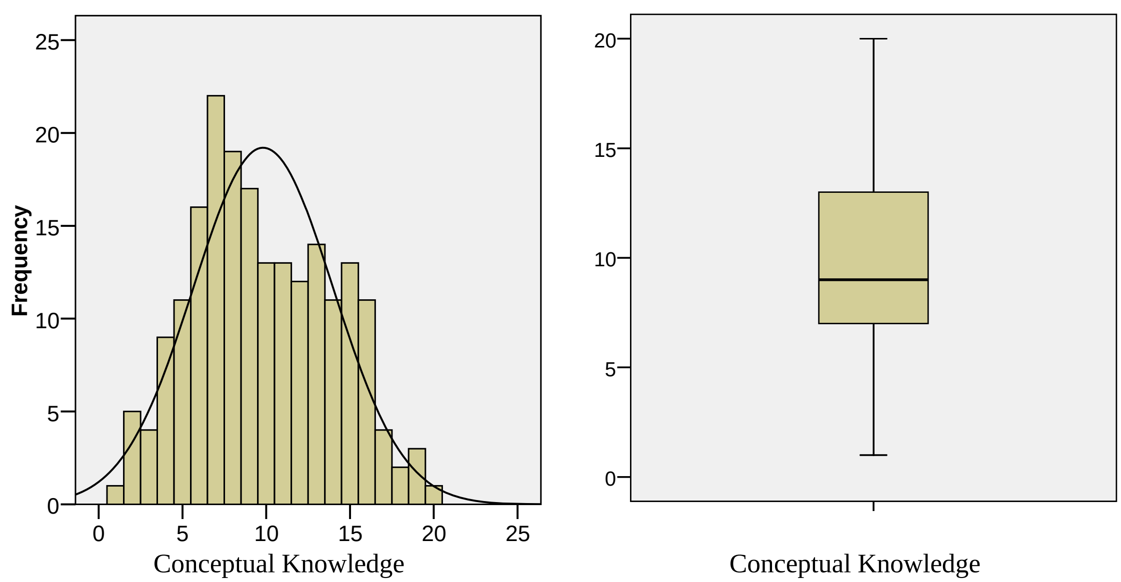


Figure 9. Histogram and box plot of conceptual knowledge

Therefore, all of the three assumptions for the use of MANOVA were met.

Multivariate Analysis

Results of the two-way MANOVA are shown in Table 16. The effect of the levels of generativity and self-regulated learning skills were statistically significant at the .05 alpha level.

Table 16. Multivariate Test (Wilks' Lambda Test) in Knowledge Acquisition

Effect	Wilks' Lambda	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Observed Power
Levels of Generatvity	.939	3.094*	4	388.000	.016	.031	.811
Self-Regulated Learning Skills	.961	3.918*	2	194.000	.021	.039	.701
Interaction	.985	.742	4	388.000	.564	.008	.239

* $p < .05$

Univariate Analysis

Since multivariate analysis reported significant effects, a follow-up univariate analysis of each individual dependent variable was conducted. The results are shown in Table 17.

Table 17. Test of Between Subject Effects in Knowledge Acquisition

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Levels of Generativity	Factual K.[a]	111.21	2	55.604	3.239*	.041	.032	.612
	Conceptual K.[b]	200.17	2	100.083	6.036*	.003	.058	.880
Self-Regulated Learning Skills	Factual K.	130.93	1	130.925	7.627*	.006	.038	.785
	Conceptual K.	41.24	1	41.243	2.487	.116	.013	.348
Interaction	Factual K.	37.37	2	18.685	1.088	.339	.011	.239
	Conceptual K.	11.88	2	5.939	.358	.699	.004	.107
Error	Factual K.	3347.47	195	17.167				
	Conceptual K.	3233.47	195	16.582				
Total	Factual K.	27247.00	201					
	Conceptual K.	22874.00	201					
Corrected Total	Factual K.	3624.91	200					
	Conceptual K.	3487.55	200					

* p< .05

a. R Squared = .077 (Adjusted R Squared = .053)

b. R Squared = .073 (Adjusted R Squared = .049)

Testing of the Hypotheses

Nine research hypotheses regarding the effects of generativity, the effects of self-regulated learning skills, and the effects of interaction on knowledge acquisition were tested based on the multivariate and univariate analysis results in Table 16 and Table 17.

Effects of Generativity on Knowledge Acquisition (Research Question 1; Research Hypothesis 1, 1-1, 1-2, 1-3, and 1-4). The multivariate analysis indicated a significant effect of the levels of generativity, operationalized in concept mapping strategies of expert-generated concept mapping, partially learner-generated concept mapping, and fully learner-generated concept mapping on knowledge acquisition at .05 alpha level: F = 3.094; *p* = .016; Wilk’s Lambda = .939.

According to the univariate analysis, the effect of the levels of generativity is statistically significant for both dependent variables at .05 alpha level (Factual knowledge: F = 3.239, *p* = .041; Conceptual knowledge: F = 6.036, *p* = .003).

To investigate the difference between three levels of generativity in concept mapping further, Tukey post hoc comparisons were run for both factual and conceptual knowledge (See Table 18 and Table 19).

Table 18. Tukey Pairwise Comparison for Factual Knowledge

Levels of Generativity		Mean Difference[a] (I-J)	Std. Error	Sig.	95% Confidence Interval	
I	J				Lower bound	Upper Bound
Expert-generated	Partially Learner-generated	1.86*	.724	.029	.15	3.57
Expert-generated	Fully Learner-generated	.96	.714	.375	-.73	2.64
Partially Learner-generated	Fully Learner-generated	-.90	.711	.413	-2.58	.77

* P < .05
a. Based on observed means

Table 19. Tukey Pairwise Comparison for Conceptual Knowledge

Levels of Generativity		Mean Difference[a] (I-J)	Std. Error	Sig.	95% Confidence Interval	
I	J				Lower bound	Upper Bound
Expert-generated	Partially Learner-generated	2.43*	.712	.002	.75	4.11
Expert-generated	Fully Learner-generated	1.67*	.701	.047	.01	3.33
Partially Learner-generated	Fully Learner-generated	-.76	.699	.526	-2.41	.89

* P < .05
a. Based on observed means

The analysis showed that the expert-generated concept map group scored significantly higher than the partially learner-generated concept map group in factual knowledge (Mean difference = 1.86, p = .029). Regarding conceptual knowledge, the expert-generated concept map group scored significantly higher than the partially learner-generated concept map group (Mean difference = 2.43, p = .002) and the fully learner-generated concept map group (Mean difference = 1.67, p = .047).

A line graph in Figure 10 visually represents the mean difference between groups. In both factual and conceptual knowledge, there was no significant difference between the partially learner-generated concept map group and the fully learner-generated concept map group.

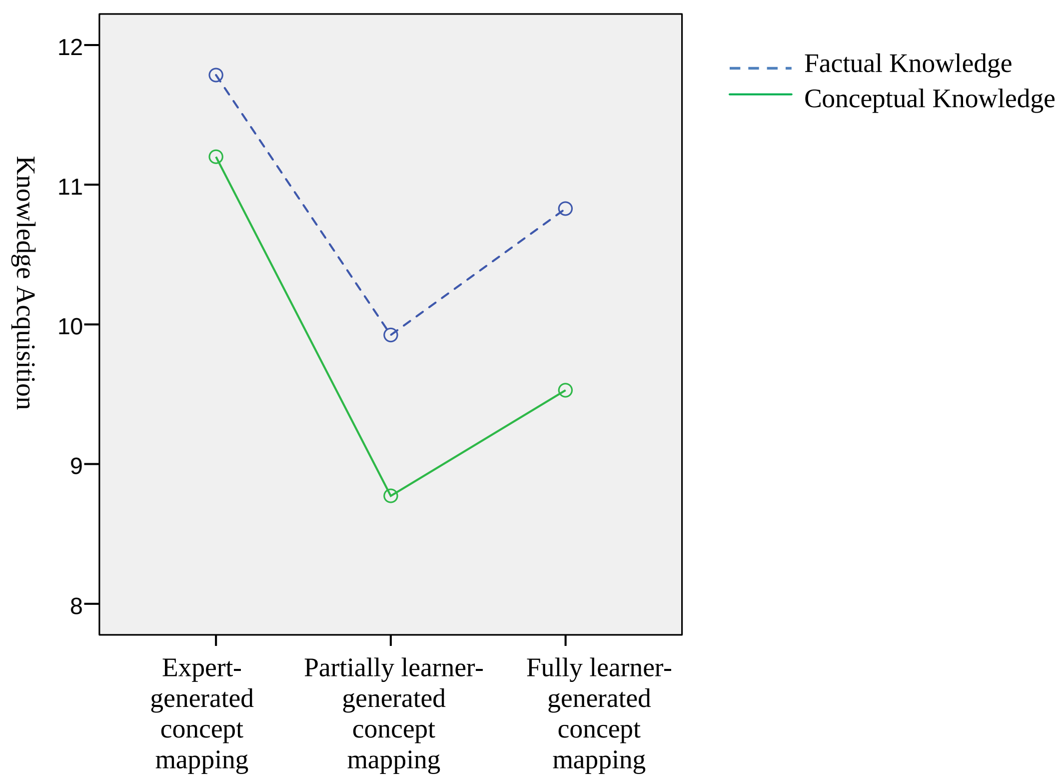


Figure 10. Line graph for knowledge acquisition of 3 treatment groups

Based on the multivariate analysis and univariate analysis, the research hypothesis 1 was supported, meaning that there was a significant difference in factual and conceptual knowledge acquisition among the students who studied with different concept mapping tools. However, Tukey post hoc comparisons failed to support the research hypotheses 1-1, 1-2, 1-3, and 1-4. That is, the results showed different patterns compared to the original predictions, although there was an effect of the concept mapping treatment.

Effects of Self-regulated Learning Skills on Knowledge Acquisition (Research Question 2; Research Hypothesis 2-1 and 2-2). According to the multivariate analysis in Table 16, the effect of self-regulated learning skills was statistically significant at the .05 alpha level: F = 3.918; p = .021; Wilk's Lambda = .961.

Univariate analysis showed that the effect of self-regulated learning skills was statistically significant only on factual knowledge at .05 alpha level (F = 7.627, p = .006). Overall, the participants with high self-regulated learning skills performed significantly better than the participants with low self-regulated learning skills for factual knowledge. However, they performed similarly for conceptual knowledge.

Based on the multivariate analysis, the research hypothesis 2 was supported. Specifically, the research hypothesis 2-1 on the effects of self-regulated learning skills on factual knowledge was supported by the univariate analysis, but the research hypothesis 2-2 on the effects of self-regulated learning skills on conceptual knowledge was not supported.

Effects of Interaction on Knowledge Acquisition (Research Question 3). MANOVA showed no significant interaction effect between the levels of generativity in concept mapping and the levels of learners' self-regulated learning skills at the .05 alpha level, F = .742; *p* = .564; Wilk's Lambda = .985 (See Table 16). Therefore, the research hypothesis 3 was not supported.

However, Figure 11 indicates a tendency for participants with high self-regulated learning skills and low self-regulated learning skills to perform differently in factual knowledge when they studied with expert-generated concept mapping and partially learner generated concept mapping treatments.

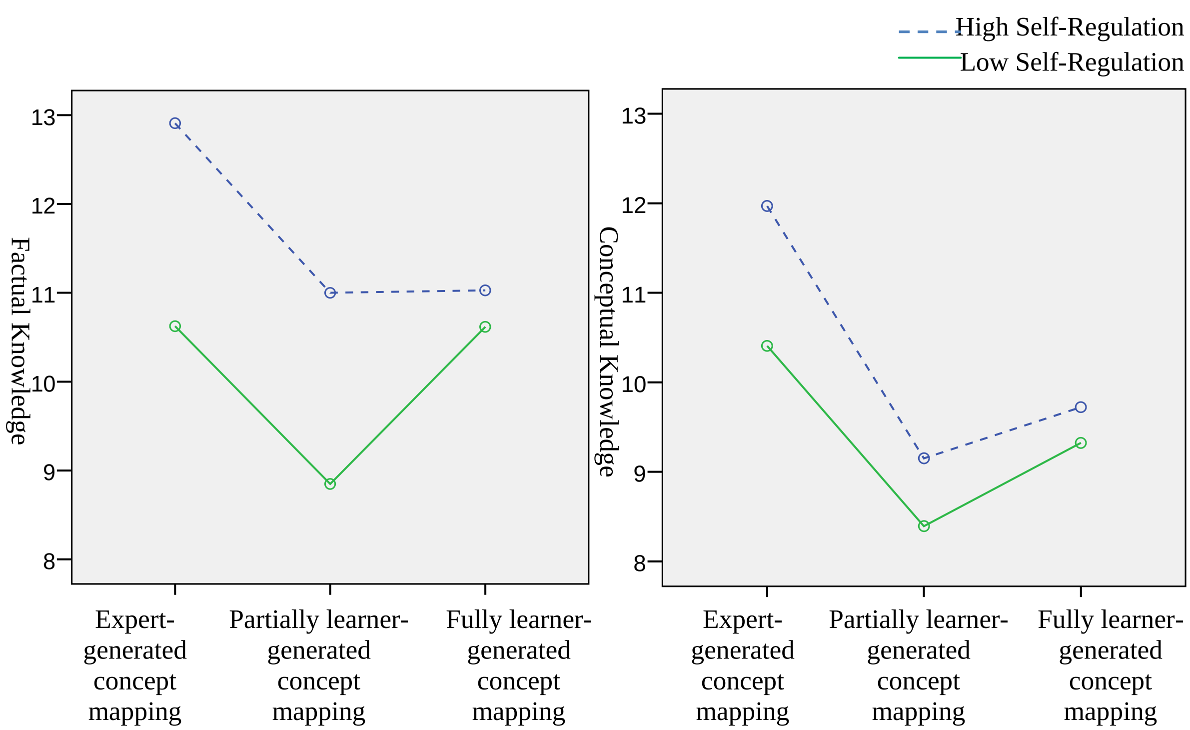


Figure 11. Line graph for knowledge acquisition by the levels of SRL skills

Separate T-test results support this tendency with regard to factual knowledge (See Table 20). Participants with high self-regulated learning skills significantly outperformed participants with low self-regulated learning skills when they studied with expert-generated concept maps (t = 2.060, *p* = .044) and partially learner generated concept maps (t = 2.591, *p* = .012), but not with fully learner-generated concept maps.

Table 20. T-test Results for Groups by High and Low SRL Skills

Levels of Generativity	Self-regulated Learning Skills	n	M	SD	t	df	*p*
Expert-generated map	High	33	12.91	4.201	2.060*	63	.044
	Low	32	10.63	4.730			
Partially learner-generated map	High	33	11.00	3.354	2.591*	64	.012
	Low	33	8.85	3.392			
Fully learner-generated map	High	36	11.03	4.669	.383	68	.703
	Low	34	10.62	4.257			

* P < .05

Exploratory Analysis on the Effects of Interaction on Knowledge Acquisition. Although the omnibus multivariate analysis results reported no significant interaction between the two independent variables at the .05 alpha level, group comparisons between participants with high self-regulated learning skills and low self-regulated learning skills in Table 20 imply a chance of interaction, which avoided detection due to the low observed power in MANOVA (observed power = .239) . Therefore, as an exploratory analysis, a double check of the possible interaction effect was conducted using a multiple linear regression of the original scores of self-regulated learning skills. By using a multiple regression, an interaction between the levels of self-regulated learning skills (continuous variable) and the levels of generativity (categorical variable) was examined without loss of power due to dichotomization (Cohen, 1983; Cohen *et al.*, 2003).

Table 21 shows the regression results from the levels of generativity (dummy coded categorical variable) and the levels of self-regulated learning skills (centered continuous variable). The entire data set from 285 participants was used for regression analysis instead of only the 201 participants who were identified as either one-third of each extreme in the multivariate analysis. Model 1 represents the effect of the levels of generativity and self-regulated learning skills, while Model 2 represents the effect of the interaction in addition to the levels of generativity and self-regulated learning skills.

Table 21. Multiple Regression Results for Interaction between Treatment Levels and SRL Skills in Factual Knowledge

Model	R	R^2	Adjusted R^2	Std. Error	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	.283[a]	.080	.070	4.083	.080	8.151	3	281	.000
2	.310[b]	.096	.080	4.063	.016	2.437	2	279	.089

a Predictors: (Constant), dummies for the levels of generativity, SRL skills
b Predictors: (Constant), dummies for the levels of generativity, SRL skills, interaction terms
c Dependent Variable: Factual Knowledge

Table 22. Multiple Regression Results for Interaction between Treatment Levels and SRL Skills in Conceptual Knowledge

Model	R	R^2	Adjusted R^2	Std. Error	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
1	.228[a]	.052	.042	4.204	.052	5.141	3	281	.002
2	.242[b]	.058	.042	4.205	.006	.941	2	279	.391

a Predictors: (Constant), dummies for the levels of generativity, SRL skills
b Predictors: (Constant), dummies for the levels of generativity, SRL skills, interaction terms
c Dependent Variable: Conceptual Knowledge

According to the multiple regression analysis, the unique contribution of interaction between the levels of generativity and the levels of self-regulated learning skills in factual knowledge was not significant at the .05 alpha level (F change = 2.437; Sig. F Change = .089). No significant interaction in conceptual knowledge appeared (See Table 22).

As a further analysis, the slopes predicting factual knowledge acquisition from the level of self-regulated learning skills in each of the three treatment levels are shown in Figure 12.

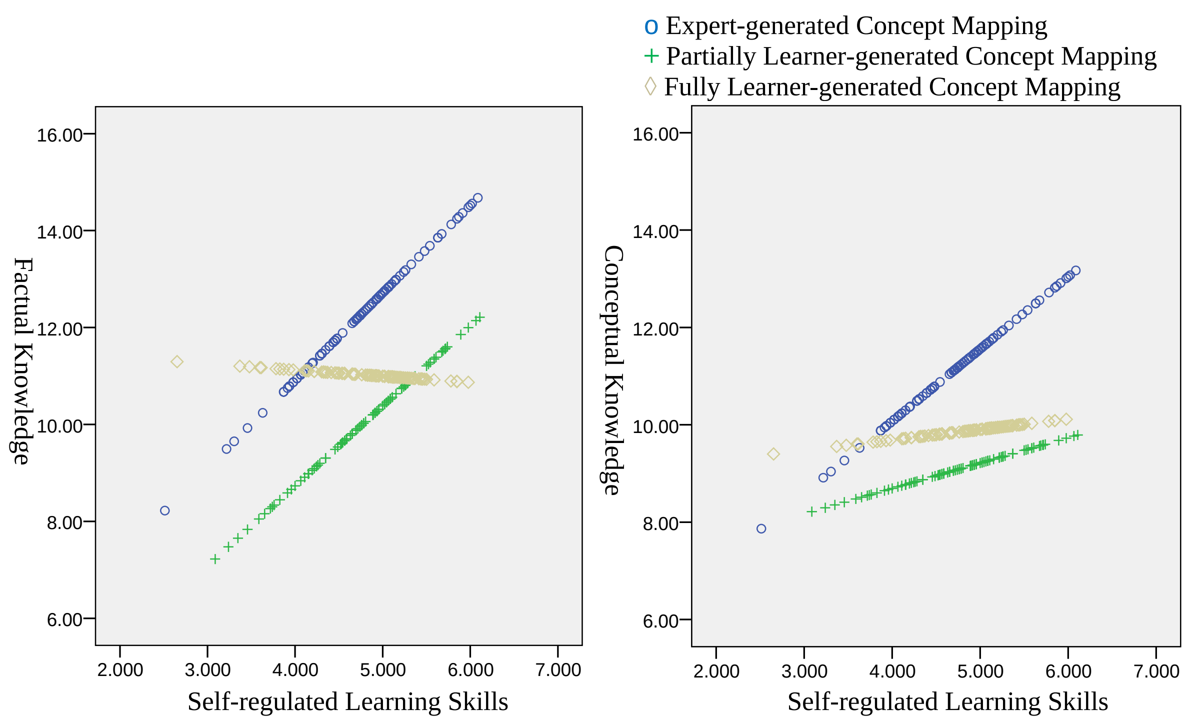


Figure 12. Slopes of knowledge acquisition on SRL skills for 3 treatment levels

Among these slopes in factual knowledge, the slope of expert-generated concept mapping group and the slope of partially learner-generated concept mapping group were significantly different from zero as shown in Table 23 (Expert-generated map group: t =

2.802, *p* = .006; Partially learner-generated map group: t = 3.050, *p* = .003). In other words, the higher the participants' self-regulated learning skills, the higher the factual knowledge acquisition score. This occurred only when participants studied with expert-generated concept maps and partially learner-generated concept maps.

Table 23. Linear Regression Coefficient of Factual Knowledge on SRL Skills

Treatment Groups	Model	Unstandardized Coefficients		t	Sig.
		B	Std. Error		
Expert-generated Concept Mapping	(Constant)	12.188	.444	27.442	.000
	SRL skills	1.890	.674	2.802*	.006
Partially Learner-generated Concept Mapping	(Constant)	9.921	.351	28.269	.000
	SRL skills	1.651	.541	3.050*	.003
Fully Learner-generated Concept Mapping	(Constant)	11.050	.455	24.305	.000
	SRL skills	-.088	.773	-.114	.910

a Predictors: (Constant), SRL skills
b Dependent Variable: Factual Knowledge
* p < .05

Regarding conceptual knowledge, only the slope of the expert-generated concept mapping group were significantly different from zero (t = 2.020, *p* = .046) (See Table 24).

Table 24. Linear Regression Coefficient of Conceptual Knowledge on SRL Skills

Treatment Groups	Model	Unstandardized Coefficients		t	Sig.
		B	Std. Error		
Expert-generated Concept Mapping	(Constant)	11.141	.484	23.038	.000
	SRL skills	1.484	.734	2.020*	.046
Partially Learner-generated Concept Mapping	(Constant)	9.068	.386	23.487	.000
	SRL skills	.521	.595	.875	.384
Fully Learner-generated Concept Mapping	(Constant)	9.844	.424	9.844	.424
	SRL skills	.214	.721	.214	.721

a Predictors: (Constant), SRL skills
b Dependent Variable: Conceptual Knowledge
* p < .05

Based on the exploratory analysis on the effects of interaction in relation to the research hypothesis 3, multiple regression analysis showed that the unique contribution of interaction between the levels of generativity and the levels of self-regulated learning skills was not significance at .05 alpha level (F change = 2.437; Sig. F Change = .089).

Effects on Knowledge Representation

Regarding the effects of the levels of self-regulated learning skills on knowledge representation in the fully learner-generated concept mapping group, following hypotheses were raised in this study:

Effects of Generativity on Knowledge Representation

Hypothesis 4:	Different levels of self-regulated learning skills (high vs. low) will influence the knowledge representation of learners who study with a fully learner-generated concept map.
Hypothesis 4-1:	Learners with high self-regulated learning skills will demonstrate higher proposition quality in knowledge representation than learners with low self-regulated learning skills when they study with a fully learner-generated concept map.
Hypothesis 4-2:	Learners with high self-regulated learning skills will demonstrate higher overall quality in knowledge representation than learners with low self-regulated learning skills when they study with a fully learner-generated concept map.
Hypothesis 4-3:	Learners with high self-regulated learning skills will demonstrate larger quantity of propositions in knowledge representation than learners with low self-regulated learning skills when they study with a fully learner-generated concept map.

As a process of collecting evidence to support the research hypotheses, one-way MANOVAs were run to determine the existence of any statistically significant differences in knowledge acquisition.

Test Assumptions

Three assumptions for MANOVA were tested: Correlations between dependent variables; homogeneity of groups; and normality of dependent variables.

Correlation between Dependent Variables. Table 25 reports the correlation between proposition quality, overall quality, and the quantity of propositions. Since the Pearson's correlation coefficient is statistically significant yet lower than .90, the use of multivariate analysis is justified without concern for the multicollinearity issue (Brace *et al.*, 2006).

Table 25. Correlations among Knowledge Representation Scores

Dependent Variable		Proposition Quality	Overall Quality	Quantity of Propositions
Proposition Quality	Pearson's r	1	.795**	.604**
	Sig. (2-tailed)		.000	.000
	N	70	201	70
Overall Quality	Pearson's r	.795**	1	.722**
	Sig. (2-tailed)	.000		.000
	N	70	70	70
Quantity of Propositions	Pearson's r	.604**	.722**	1
	Sig. (2-tailed)	.000	.000	
	N	70	70	70

** $p < .01$

Homogeneity of Groups. Testing of homogeneity of variances among groups used Levene's test of equality of error variances. Levene's tests indicated that the error variances were equal among groups in proposition quality, overall quality, and the quantity of propositions (See Table 26).

Table 26. Levene's Homogeneity Test on Knowledge Representation

Dependent Variable	F	df1	df2	*p*
Proposition Quality	3.350	1	68	.072
Overall Quality	1.085	1	68	.301
Quantity of Propositions	.464	1	68	.498

Normality of Dependent Variables. Examination of normality of dependent variables uses z-score of skewness. Z-score of skewness was calculated by subtracting the mean of distribution and dividing by the standard deviation of distribution, $Z_{skewness}$ = (Skewness statistics – 0) / Standard Error of Skewness (Field, 2005). As presented in Table 27, z-scores of proposition quality, overall quality, and the quantity of propositions are less than 1.96, satisfying the assumption required for normal distribution.

Table 27. Skewness of Knowledge Representation Scores

Dependent Variable	Skewness	Std. Error of Skewness	Converted z-score
Proposition Quality	.517	.287	1.801
Overall Quality	.285	.287	0.993
Quantity of Propositions	.514	.287	1.791

In conclusion, all of the three assumptions for the use of MANOVA were met.

Multivariate Analysis

Results of the one-way MANOVA using Wilks' Lambda test in knowledge representation are shown in Table 28. The effect of self-regulated learning skills was statistically significant at .05 alpha level.

Table 28. Multivariate Test (Wilks' Lambda Test) in Knowledge Representation

Effect	Wilks' Lambda	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Observed Power
Self-Regulated Learning Skills	.880	3.004*	3	66	.037	.120	.683

* $p < .05$

Univariate Analysis

Since multivariate analysis reported significant effects, a follow-up univariate analysis of each individual dependent variable was conducted, and the results are shown in Table 29.

Table 29. Test of Between Subject Effects in Knowledge Representation

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power
Self-Regulated Learning Skills	Proposition Quality [a]	3.91	1	3.91	3.926	.052	.055	.497
	Overall Quality [b]	4.34	1	4.34	6.499*	.013	.087	.710
	Quantity of Propositions [c]	686.97	1	686.97	8.785*	.004	.114	.832
Error	Proposition Quality [a]	67.72	68	.99				
	Overall Quality [b]	45.44	68	.67				
	Quantity of Propositions [c]	5317.33	68	78.20				
Total	Proposition Quality [a]	480.58	70					
	Overall Quality [b]	593.00	70					
	Quantity of Propositions [c]	64469.00	70					
Corrected Total	Proposition Quality [a]	71.63	69					
	Overall Quality [b]	49.79	69					
	Quantity of Propositions [c]	6004.30	69					

* p< .05

a R Squared = .055 (Adjusted R Squared = .041)

b R Squared = .087 (Adjusted R Squared = .074)

c R Squared = .114 (Adjusted R Squared = .101)

Testing of the Hypotheses

The multivariate analysis indicated a significant effect of the levels of self-regulated learning skills on knowledge representation at the .05 alpha level, F = 3.004; *p* = .037; Wilk's Lambda = .880 (See Table 28). Therefore, the research hypothesis 4 was supported.

According to the univariate analysis presented in Table 29, the effect of the levels of self-regulated learning skills was statistically significant at the .05 alpha level for the overall quality of the concept maps (F = 6.499, *p* = .013) and the quantity of propositions (F = 8.785, *p* = .004), but not for the proposition quality. Therefore, the evidence was not sufficient to support the research hypothesis 4-1, while the research hypotheses 4-2 and 4-3 were supported.

Summary

In Chapter 4, thirteen research hypotheses were tested to investigate the effects of the levels of generativity in concept mapping and the levels of self-regulated learning skills on knowledge acquisition and knowledge representation. Table 30 provides a summary of the research hypotheses and corresponding results.

Table 30. Summary of the Results

Research Hypotheses		Results of Data Analysis
Hypothesis 1:	Different levels of generativity in concept mapping (expert-generated: EG, partially learner-generated: PLG, fully learner-generated: FLG) will influence knowledge acquisition.	Research hypothesis 1 was supported
1-1:	FLG > EG on factual knowledge	Research hypotheses 1-1 through 1-4 were not supported. Contrary to the prediction based on the literature review as well as the pilot study results, the evidence collected for this study indicated that the learners who studied with the expert-generated concept map performed better than other groups.
1-2:	FLG > PLG on factual knowledge	
1-3:	FLG > EG on conceptual knowledge	
1-4:	FLG > PLG on conceptual knowledge	

Research Hypotheses		Results of Data Analysis
Hypothesis 2:	Different levels of self-regulated learning skills (high levels of self-regulated learning skills: HSRL, low levels of self-regulated learning skills: LSRL) will influence knowledge acquisition.	Research hypothesis 2 was supported.
2-1:	HSRL > LSRL on factual knowledge	Research hypothesis 2-1 was supported, while the research hypothesis 2-2 was not.
2-2:	HSRL > LSRL on conceptual knowledge	
Hypothesis 3:	Significant interaction will exist between the levels of generativity in concept mapping and the levels of learners' self-regulated learning skills in terms of knowledge acquisition.	Research hypothesis 3 was not supported.
Hypothesis 4:	Different levels of self-regulated learning skills (high levels of self-regulated learning skills: HSRL, low levels of self-regulated learning skills: LSRL) will influence the knowledge representation of learners who study with a fully learner-generated concept map.	Research hypothesis 4 was supported.
4-1:	HSRL > LSRL on proposition quality	Research hypothesis 4-2 and 4-3 were supported, while the research hypothesis 4-1 was not.
4-2:	HSRL > LSRL on overall quality	
4-3:	HSRL > LSRL on quantity of proposition	

Chapter 5

DISCUSSION AND IMPLICATIONS

Introduction

The purpose of this study was to investigate the effectiveness of concept mapping strategies with different levels of generativity in terms of knowledge acquisition and knowledge representation. It also examined if learners' self-regulated learning skills influenced the effectiveness of concept mapping strategies with different levels of generativity.

Summary of Findings

This study posed four research questions: 1. Do concept mapping strategies with different levels of generativity influence factual and conceptual knowledge acquisition? 2. Do different levels of self-regulated learning skills influence factual and conceptual knowledge acquisition? 3. Do different levels of self-regulated learning skills affect the effectiveness of different concept mapping strategies in terms of factual and conceptual knowledge acquisition? 4. Do different levels of self-regulated learning skills influence the knowledge representation of learners who study with a fully learner-generated concept map?

According to the results, the levels of generativity operationalized in concept mapping strategies of expert-generated concept mapping, partially learner-generated concept mapping, and fully learner-generated concept mapping produced different levels of effectiveness for knowledge acquisition (Research Hypothesis 1). The expert-generated concept map group outperformed the partially learner-generated concept map group in factual knowledge, while the expert-generated concept map group outperformed both the partially learner-generated concept map group and the fully learner-generated concept map group in conceptual knowledge.

Self-regulated learning skills caused significant difference in factual knowledge (Research Hypothesis 2). Participants with high self-regulated learning skills scored higher than the participants with low self-regulated learning skills, especially in the expert-generated concept map group and the partially learner-generated concept map group in factual knowledge, and for the expert-generated concept maps in conceptual knowledge.

When using MANOVA, no significant interaction between the levels of generativity and learners’ self-regulated learning skills was found (Research Hypothesis 3). However, regression analysis indicated that the higher the participants’ self-regulated learning skills, the higher the factual knowledge acquisition score, only for the expert-generated concept map group and partially learner-generated concept map group.

Regarding knowledge representation, a significant effect of the levels of self-regulated learning skills was found (Research Hypothesis 4). More specifically, the participants with high self-regulated learning skills scored significantly higher than the participants with low self-regulated learning skills in the overall quality of knowledge representation and the quantity of propositions made in each concept map.

Discussion of the Findings

Generativity and Knowledge Acquisition

An instructional activity is generative when it provides an opportunity for the learner to restructure or manipulate the information presented, and to construct personal meaning. In this study, the levels of generativity in concept mapping, that is, the degree to which learning involves active generation of meaning (Wittrock, 1992), is operationalized as three different treatments: Expert-generated concept mapping with the lowest level of generativity, partially learner-generated concept mapping with the medium level of generativity, and fully learner-generated concept mapping with the highest level of generativity. The study results of these different levels of generativity provided the information for how differences in generativity levels affect learners' knowledge acquisition.

Effects of Expert-generated Concept Maps and Partially Learner-generated Concept Maps. The expert-generated concept map group performed better than the partially learner-generated concept map group in both factual and conceptual knowledge (See Table 16 and Table 17). The results fail to support the theory of generative learning at first glance, since the partially learner-generated concept mapping activity was designed to facilitate learners' generation of more meanings than the expert-generated concept mapping while studying. According to Wittrock (1990, 1992), meaningful learning occurs when learners actively generate connections among given information, and the cognitive action of filling-in-the-blanks was expected to increase the generation of connections. However, in this study, it was the expert-generated concept mapping with the lowest level of generativity that helped learning.

A possible explanation for this result is easily found from the open-ended student survey. When asked to describe the way they used the given concept maps, the participants from these two groups responded very differently. Some of the participants in the expert-generated concept map group said:

- *"I traced it out as I read along."*
- *"Every time I opened to the next page I found all the information on that page on the map to make sure what I was looking at."*
- *"While reading, go back to the map and follow what I just read."*
- *"I read over all the material posted on the human heart, then I used the map as a reinforcement of everything I read."*

These responses indicate that the students used the concept maps throughout the learning process as supplemental material, although they used various tactics. On the other hand, some of the participants in the partially learner-generated concept map group said:

- *"First I looked over what I would need to find in order to fill in the blanks."*
- *"I found the needed information in each slide and filled it out as I moved along."*
- *"I looked at how many blanks I had to complete in each section. Then I read through the material keeping in mind that I needed to fill in the blanks on the concept map."*

These responses may imply that the participants in the partially learner-generated concept map group focused more on the activity of filling-in-the-blanks itself, rather than understanding material to be learned.

Another evidence of different approaches between these two groups in concept mapping appeared in the collected concept maps. While 61.05% (58 out of 95) of the participants in the expert-generated concept map group added their own notes on the given concept map by adding more concepts and/or new links between existing concepts, only 11.46% (11 out of 96) of the participants in the partially learner-generated concept map group added their own notes. That is, although both groups received the same prompts regarding the modification of the map, the reaction from these groups tends to be quite different. Figure 13 is an example of a modified concept map from the expert-generated concept map group.

Consequently, the completion strategy may have hindered the intended generative activity in this study context. Given that the completion strategy was suggested as a possible solution for overcoming cognitive overload when solving problems (Sweller *et al.*, 1998; van Merrienboer, 1990), more research is needed to investigate whether the reduced cognitive load due to the use of a completion strategy leads to true generative activity.

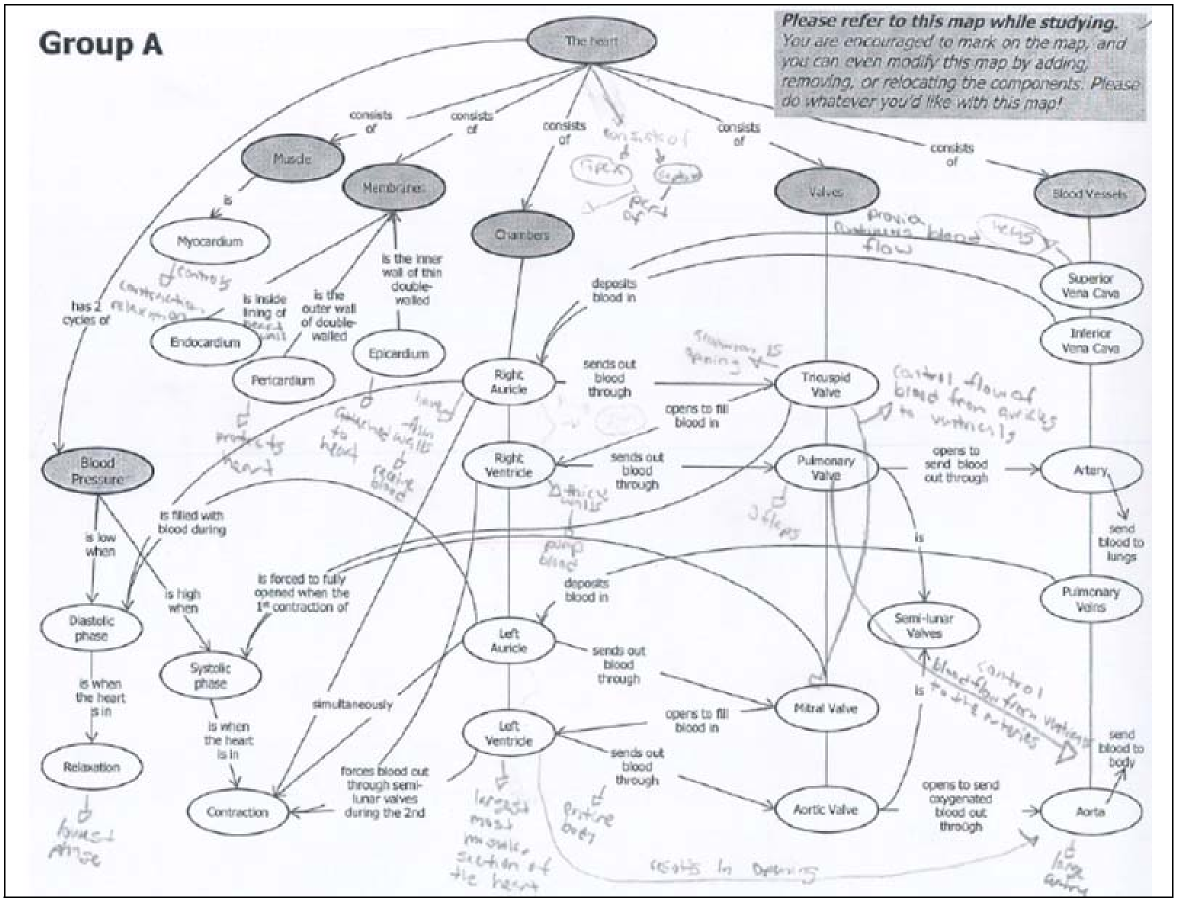


Figure 13. Concept map modified by a participant in the expert-generated concept map group

Effects of Expert-generated Concept Maps and Fully Learner-generated Concept Maps. The results indicated that the fully learner-generated concept map group performed worse than the expert-generated concept map group in conceptual knowledge, which is the opposite of the results in studies of Jo (2001) and Lee and Nelson (2005). Interestingly, the result is also opposite of the pilot study results where the fully learner-generated concept map group significantly outperformed the expert-generated concept map group as presented in Figure 14.

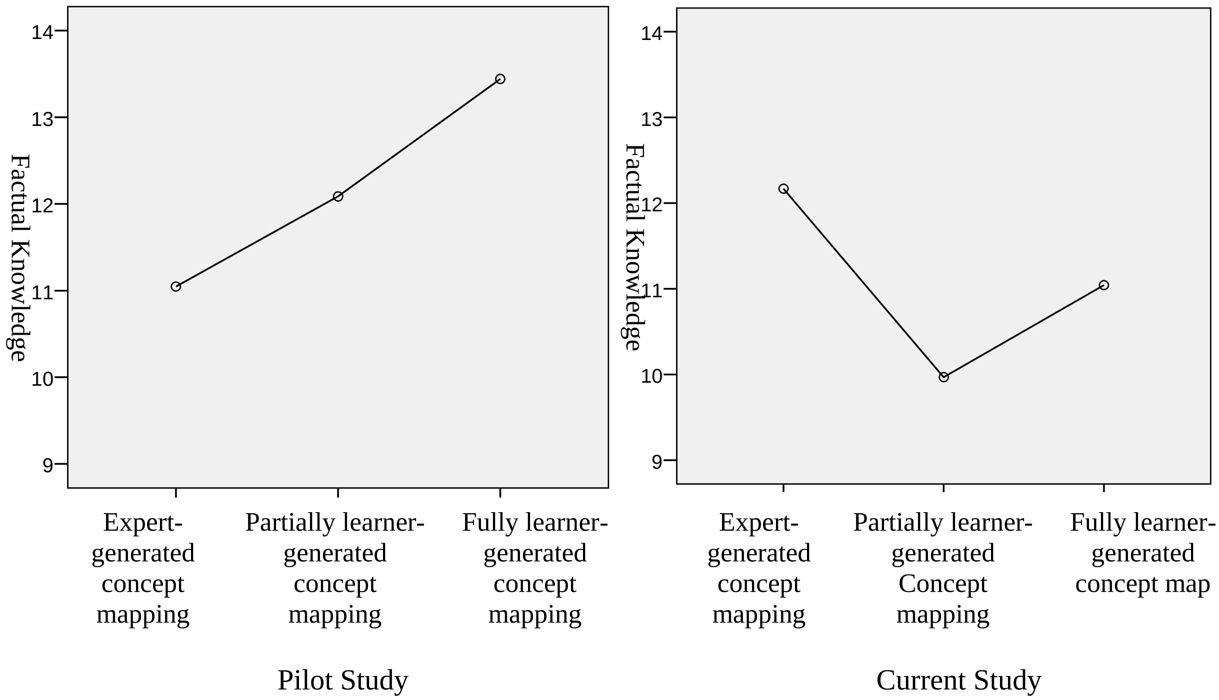


Figure 14. Descriptive comparison of pilot study results and current study results

Considering that the participants of pilot study were recruited from the same two-hundred level statistics course taught by the same instructor, and that the same learning material was provided for the pilot study, the possible explanation for this opposite result is the changes made for the treatments for the current study. As illustrated in Chapter 3, three changes were made after the pilot study: (1) increased generativity in the expert-generated concept map group, (2) increased concept map training across all treatment levels, and (3) increased procedural guidance based on the Novakian concept mapping method in the fully learner-generated concept map group. More specifically, in the current study, the expert-generated concept map group, along with the partially learner-generated concept map group, received the prompt saying, “You are encouraged to modify the given map by adding/removing/relocating the concepts…” which means they were cued to "actively" use the given concept map; whereas, the same treatment group in pilot study was told to "refer to" the given concept map. In conjunction with this added generativity, the strengthened concept mapping training was provided for the current study to increase participants' understanding of concept mapping. That is, they were asked to generate a concept map with 6~7 concepts as an exercise, which might have decreased their feeling overwhelmed when faced with a complex map generated by someone else.

To the contrary, the fully learner-generated concept map group was asked to strictly follow the Novakian method of concept mapping (e.g. linking words, directions, hierarchy, cross-links) in the current study, since many of the concept maps generated in the pilot study did not meet the condition of a concept map defined by Novak. Although this group also received the strengthened training, increased structure in the mapping process might have caused a greater cognitive load in the fully learner-generated concept map group. Put simply, the expert-generated concept map group was encouraged to generate more meaning, although in a covert way, while the fully learner-generated concept map group was asked to follow the instructed rules when generating meanings.

Survey responses from the fully learner-generated concept map group support this inference. When asked to describe challenges related to concept mapping activities, some in the group wrote:

- *"It was hard to find linking words that made sense to the concepts. Sometimes I could not link two concepts together with words even though they should be connected."*
- *"I was focusing on making the map flow in proposition format instead of really understanding the material."*

- *"At times I had difficulty finding the right word to link the different concepts."*

These statements reveal that some of participants were struggling with the mapping procedure, which can be explained by the notion of "extraneous cognitive load" that requires working memory for something irrelevant to schema acquisition (Paas *et al.*, 2003). As a result, added generativity in the expert-generated map group might have helped knowledge acquisition, while added structure – probably less freedom with more cognitive load – in the fully learner-generated map group might have interfered with knowledge acquisition.

Besides, it should be noted that the amount of information provided to the three treatment groups was different due to the research design. The fully-learner generated concept map group did not receive any feedback on their map or reference map before taking the knowledge achievement test. However, the expert-generated concept map groups and the partially learner-generated concept map group benefited from the fully-developed map structure, which incorporated with multiple cross-links generated by the expert. It would be interesting to investigate whether the knowledge acquisition of the fully-learner generated concept map group increase when the reference map or feedback is given prior to taking the test.

Self-regulated Leaning Skills and Knowledge Acquisition

The analysis results showed that the participants with high self-regulated learning skills performed significantly better than the participants with low self-regulated learning skills in factual knowledge, but not in conceptual knowledge (See Table 17). However, the line graphs in Figure 11 shows a descriptive tendency that the mean scores of the high self-regulators are consistently higher than the mean scores of low self-regulators, even for conceptual knowledge.

A noticeable change from the graphs on factual knowledge to the graphs on conceptual knowledge is the difference between the high self-regulators and the low self-regulators in the partially learner-generated concept map group (See Figure 11). In factual knowledge, the mean difference between the high self-regulators and the low self-regulators in the partially learner-generated concept map group was 2.15 (p=.012); whereas, in conceptual knowledge, the mean difference between the high self-regulators and the low self-regulators in the partially learner-generated concept map group was as low as .77 (p=.656). The results indicate that the level of self-regulated learning skills may not play a critical role in conceptual knowledge when study is with partially learner-generated concept mapping as a completion strategy. In other words, when completion strategies are used, a high level of self-regulated learning skills helps learning if learners are required to recall factual knowledge. However, this may not be the case if learners are required to understand the concepts. This result seems to relate to the nature of completion strategy described earlier: even high self-regulators may have tended to focus on filling in the blanks, which might hinder understanding of the material. In fact, the earlier quotes in page 92 related to the way they used the partially learner-generated concept mapping (e.g. *"First I looked over what I would need to find in order to fill in the blanks."*) were made by the participants with high self-regulated learning skills.

Interaction between Generativity and Self-regulated Leaning Skills

The interaction between generativity and self-regulated learning skills was not significant in both factual and conceptual knowledge when using MANOVA (See Table 16). However, the use of original scores in self-regulated learning skills, rather than the use of dichotomized data of the one third of extremes, enabled improving the *p* value from .239 to .089 (See Table 21).

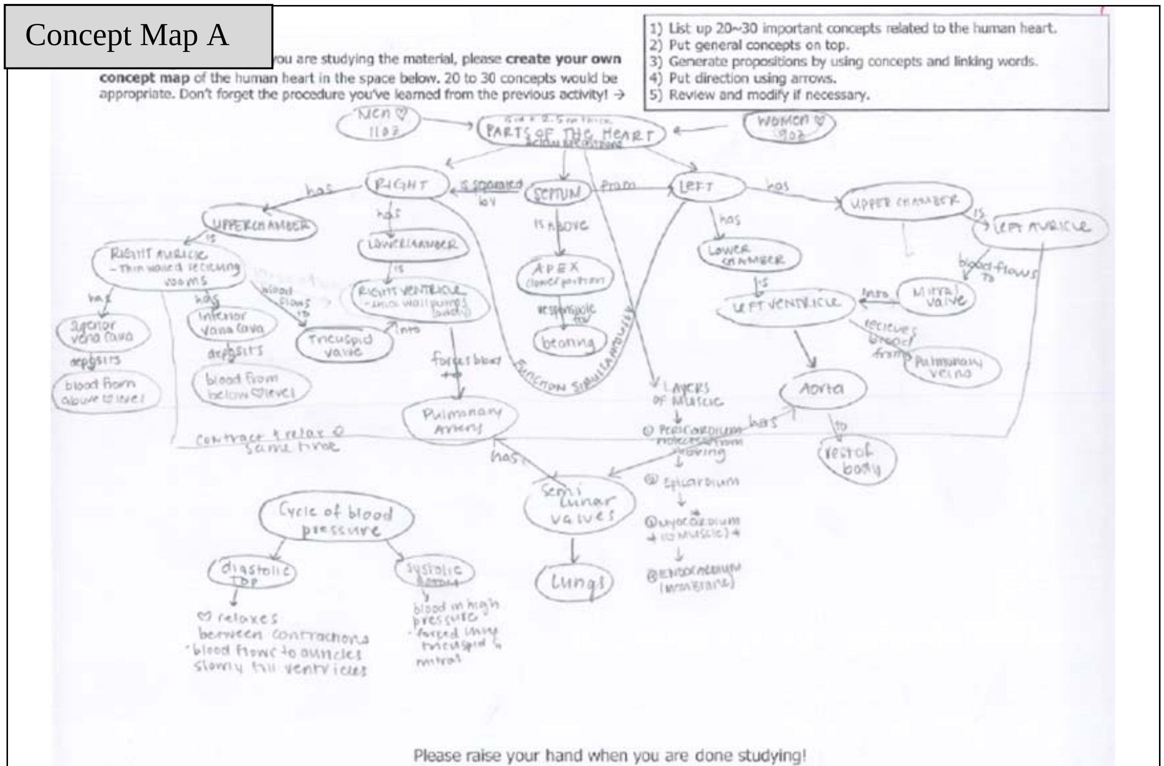
Further analysis revealed that the regression slopes of the fully learner-generated concept map group were not different from zero in both factual and conceptual knowledge (See Figure 12). The results imply that the higher level of self-regulated learning skills does not impact learning outcome in a fully learner-generated concept map environment. Originally, learners with high self-regulated learning skills were expected to perform better in a high level of generative learning environment, since the literature of both self-regulation and generative learning emphasize the same sub-components of motivation, strategy use, and metacognition (Wittrock, 1990, 1991; Zimmerman, 2000).

The discrepancy between the prediction and results could be partly explained by the issue of extraneous cognitive load, mentioned earlier. When an extraneous cognitive load exists, that is, strengthened structures of mapping procedures in this study, learners' cognition is used to handle the extraneous overload, which results in less room for self-regulated learning.

Self-regulated Learning Skills and Knowledge Representation

The participants with high self-regulated learning skills scored significantly higher in 1) overall quality of the concept maps and 2) the quantity of propositions (See Table 29). The latter may be interpreted that the high self-regulators are able to handle more information. The former, on the other hand, has an interesting implication. Since the criteria of overall quality was based on the amount of understanding in line with “hierarchy” and “cross-links,” this result implies that the high self-regulators generated better hierarchies as well as more cross-links compared to the low self-regulators.

In fact, during the evaluation of concept maps, a difference in concept maps between high self-regulators and low self-regulators emerged in terms of cross-links and linearity. Figure 15 presents two concept maps generated by the participants, one by high self-regulator and the other by low-self-regulator. Concept Map A has links between concepts located far from each other, which represents cross-links; whereas, Concept Map B does not include this type of link. Instead it looks quite linear within each sub-domain. According to the Schema Theory, the participant who created Concept Map A is likely to have more and/or stronger connections between concepts, which leads to the capability of handling more interrelationships among schemas (Jonassen *et al.*, 1993; Rumelhart, 1980). The more relationships are handled, the more concepts and propositions are generated and accommodated in one’s schema.



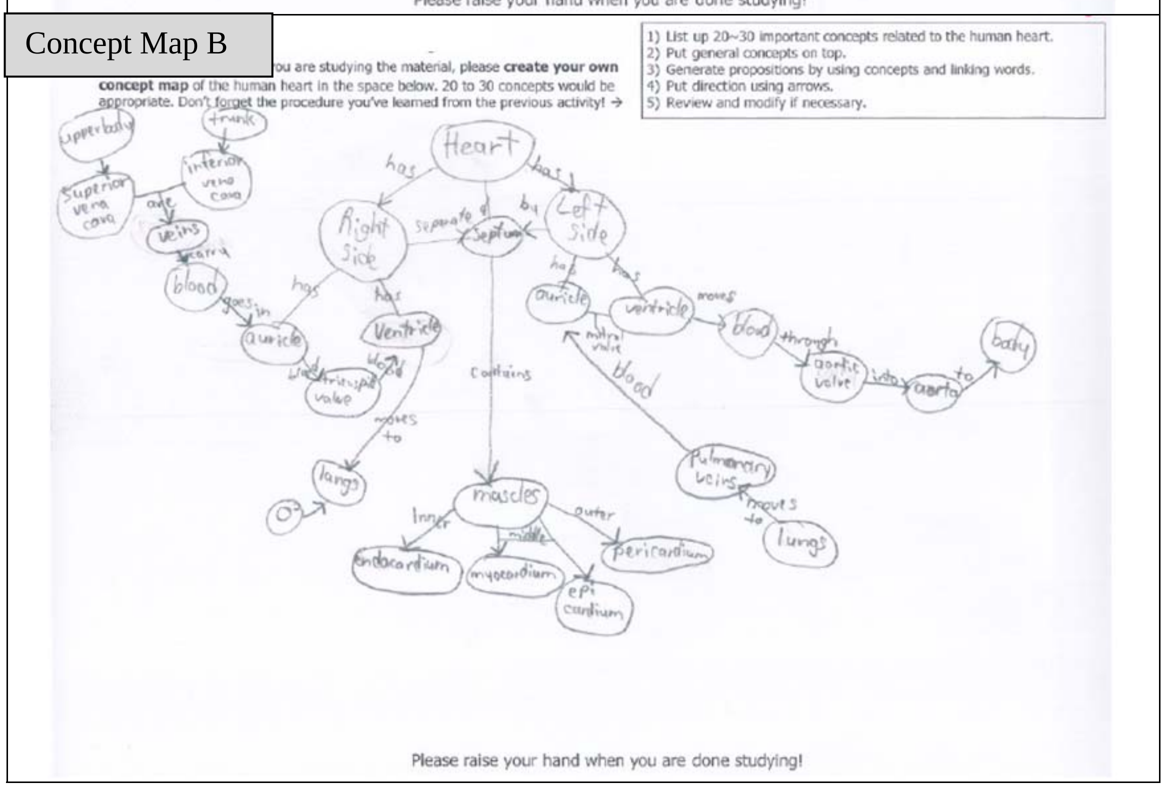


Figure 15. Concept maps generated by a high self-regulator and a low self-regulator

Knowledge Acquisition and Knowledge Representation

Although not raised as a research question in this study, the earlier findings provoked a question of "Is there any relationships between knowledge acquisition and knowledge representation in the fully learner-generated concept map group?" The Pearson's r among the sub-components of knowledge acquisition and the sub-components of knowledge representation revealed that factual knowledge and conceptual knowledge scores have moderate or weak correlations with knowledge representation measures (See Table 31). Given that self-regulated learning skills significantly impacts knowledge acquisition as well as representation, it would be meaningful to investigate the interrelationships among self-regulation, knowledge acquisition and representation.

Table 31. Correlations between Knowledge Acquisition and Knowledge Representation

Variables		Knowledge Acquisition		Knowledge Representation		
		Factual Knowledge	Conceptual Knowledge	Overall Quality	Proposition Quality	Quantity of Propositions
Factual Knowledge	Pearson's r	1	.687**	.342**	.287*	.336**
	Sig. (2-tailed)		.000	.004	.016	.004
	N	70	70	70	70	70
Conceptual Knowledge	Pearson's r	.687**	1	.276*	.316**	.378**
	Sig. (2-tailed)	.000		.021	.008	.001
	N	70	70	70	70	70
Overall Quality	Pearson's r	.342**	.276*	1	.795**	.708**
	Sig. (2-tailed)	.004	.021		.000	.000
	N	70	70	70	70	70
Proposition Quality	Pearson's r	.287*	.316**	.795**	1	.592**
	Sig. (2-tailed)	.016	.008	.000		.000
	N	70	70	70	70	70
Quantity of Propositions	Pearson's r	.336**	.378**	.708**	.592**	1
	Sig. (2-tailed)	.004	.001	.000	.000	
	N	70	70	70	70	70

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

Implications for Instructional Design

The findings of this study provide answers to the questions raised in Chapter 1.

"How can I design a concept mapping activity in a meaningful way?"

- Expert-generated concept mapping is the most effective method to improve knowledge acquisition. However, when using expert-generated concept maps, learners should be encouraged to actively interact with the given map by adding their own thoughts rather than just passively refer to the given information.
- When using partially-learner generated concept mapping, the instructor should guide learners to use the entire map so they can benefit from the expert-generated structure. Filling-in-the-blanks activity should be considered as a part of learning activity, not the whole.
- When using fully learner-generated concept mapping, details of procedures such as putting linking words and directions could be considered as a secondary component of concept mapping so learners think more. In other words, learners should be allowed to "utilize" the mapping technique rather than limit their capability within the pre-defined procedure.
- When the expected outcome is factual knowledge, either expert-generated concept mapping or fully-learner generated concept mapping could be used, if the suggestions described above are followed. However, when the expected outcome is conceptual knowledge, expert-generated concept mapping has

been shown to be more effective in that learners benefit from the expert's full understanding of the material. In order to maximize the advantage of expert-generated maps, learners should be encouraged to actively interact with the given map.

"Given the characteristics of my students, what levels of generativity should I select?"

- When learners are high self-regulators, completion strategy should be avoided for conceptual knowledge acquisition. Instead, using expert-generated concept mapping for both factual and conceptual knowledge acquisition is recommended.
- When learners are low self-regulators, it is important to use concept maps in an appropriate ways as described above regardless of the type of concept maps.

"How can I assess students' representation of meaning when using a concept mapping strategy?"

- When evaluating fully learner-generated concept maps, the cross-link, which are the relationships or links between concepts in different segments or domains of the concept map (also known as "Creative leaps"), is one of the indicators of high self-regulators.

Recommendations for Future Research

Based on the discussion of the results, the following recommendations are posed for future research.

- Use of Structural Equational Modeling is suggested for building the model to predict the impact of the levels of generativity and the levels of self-regulated learning skills on knowledge representation and knowledge acquisition. Sub-components of self-regulated learning skills, treatment levels, and demographic information are considered predictors, and knowledge representation is considered a mediator to knowledge acquisition.
- Study of retaining and transferring knowledge is suggested. It is meaningful to investigate if the degree of retention and transfer is different when using concept maps with different levels of generativity.
- In-depth examination of each of the three self-regulated learning components (cognitive strategy use, metacognition, motivation) is suggested. Such research will shed light on the interaction between the three different generativity levels in concept mapping and the three sub-components of self-regulated learning skills.
- Prior knowledge is suggested as another individual difference variable, and cognitive load theory as another theoretical framework interweaving the levels of generativity, self-regulated learning skills, and prior knowledge.

- Study of the effects of the reference map or feedback for the fully learner-generated concept map group is suggested. Especially, it is interesting to examine whether the levels of self-regulated learning skills play a role in incorporating the information from the reference map or feedback.
- Further investigation on the cognitive load during concept mapping activity is suggested. Novice versus expert issue is raised in relation to the cognitive load study, since more cognitive load is required for novice in generative learning environment.

Limitations of the Study

Participants were selected from a specific population – undergraduate students registered in a two-hundred level general education course. Since the results of this study are limited to the population with similar characteristics, caution is recommended when generalizing beyond the scope of this study.

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APPENDIX A

Expert-generated Concept Map and Corresponding Instruction

APPENDIX A: Expert-generated Concept Map and Corresponding Instruction

<Instruction>

You are in **Group A**.

STEP-by-STEP INSTRUCTION:

1. Please log in to Angel, and find the RESEARCH folder under MY GROUP. Click the link of **STAT 200 Research Participation-Spring 2008**.

2. If you haven't completed the **pre-survey on learning style**, please respond to the survey now.

3. Please read 'Read Me First'.

4. Click the link **1. Concept Mapping Practice**, and study the given content. The access code is *insys*. Use the blank sheet attached to this instruction to create a practice concept map. ***Please raise your hand*** when you are done with creating a practice map so I can give you the human heart concept map required for the next step. **Without a concept map of the human heart, you cannot proceed.**

5. When the concept map of the human heart is given, move on to the **2. Study Material on the Human Heart.** The access code is *insys*. While you are studying the material, **you are encouraged to refer to the given concept map to enhance your understanding of the human heart**. Also, you are encouraged to modify this map, if you think necessary, by adding, removing, or relocating the components. Please do whatever you'd like with the map!

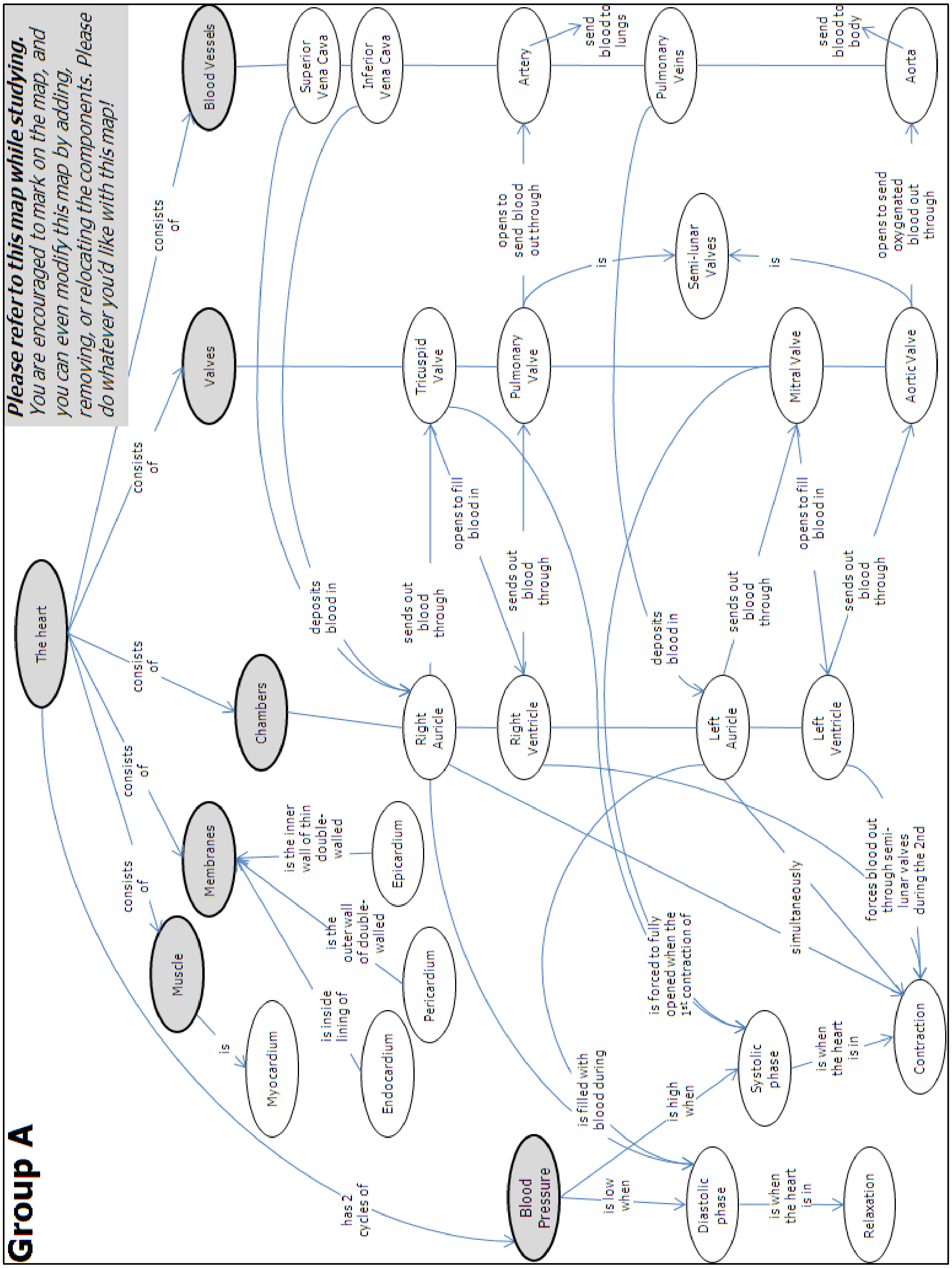
6. **If you think you are ready to take the Post-test on what you've learned, *please raise your hand***. The access code for the test will be given to you at this point. You cannot refer to the study materials or concept map during the test.

7. With the given code, please click **3. Post-test on what you've learned,** and take the test. AGAIN, PLEASE DO NOT GO BACK TO THE STUDY MATERIAL. JUST DO YOUR BEST!

8. Once you finish the test, please click **4. Post –survey on student perception**, and answer to the questions.

THANK YOU!!!

APPENDIX A: Expert-generated Concept Map and Corresponding Instruction



APPENDIX B

Partially Learner-generated Concept Map and Corresponding Instruction

APPENDIX B: Partially Learner-generated Concept Map and Corresponding Instruction

<Instruction>

You are in **Group B**.

STEP-by-STEP INSTRUCTION:

1. Please log in to Angel, and find the RESEARCH folder under MY GROUP. Click the link of **STAT 200 Research Participation-Spring 2008**.

2. If you haven't completed the **pre-survey on learning style**, please respond to the survey now.

3. Please read 'Read Me First'.

4. Click the link **1. Concept Mapping Practice**, and study the given content. The access code is *insys*. Use the blank sheet attached to this instruction to create a practice concept map. ***Please raise your hand*** when you are done with creating a practice map so I can give you the human heart concept map required for the next step. **Without a concept map of the human heart, you cannot proceed.**

5. When the concept map of the human heart is given, move on to the **2. Study Material on the Human Heart.** The access code is *insys*. While you are studying the material, please use the concept map as your learning tool, and **FILL IN THE BLANKs** as you proceed the study material. Also, you are encouraged to modify this map, if you think necessary, by adding, removing, or relocating the components. Please do whatever you'd like with the map!

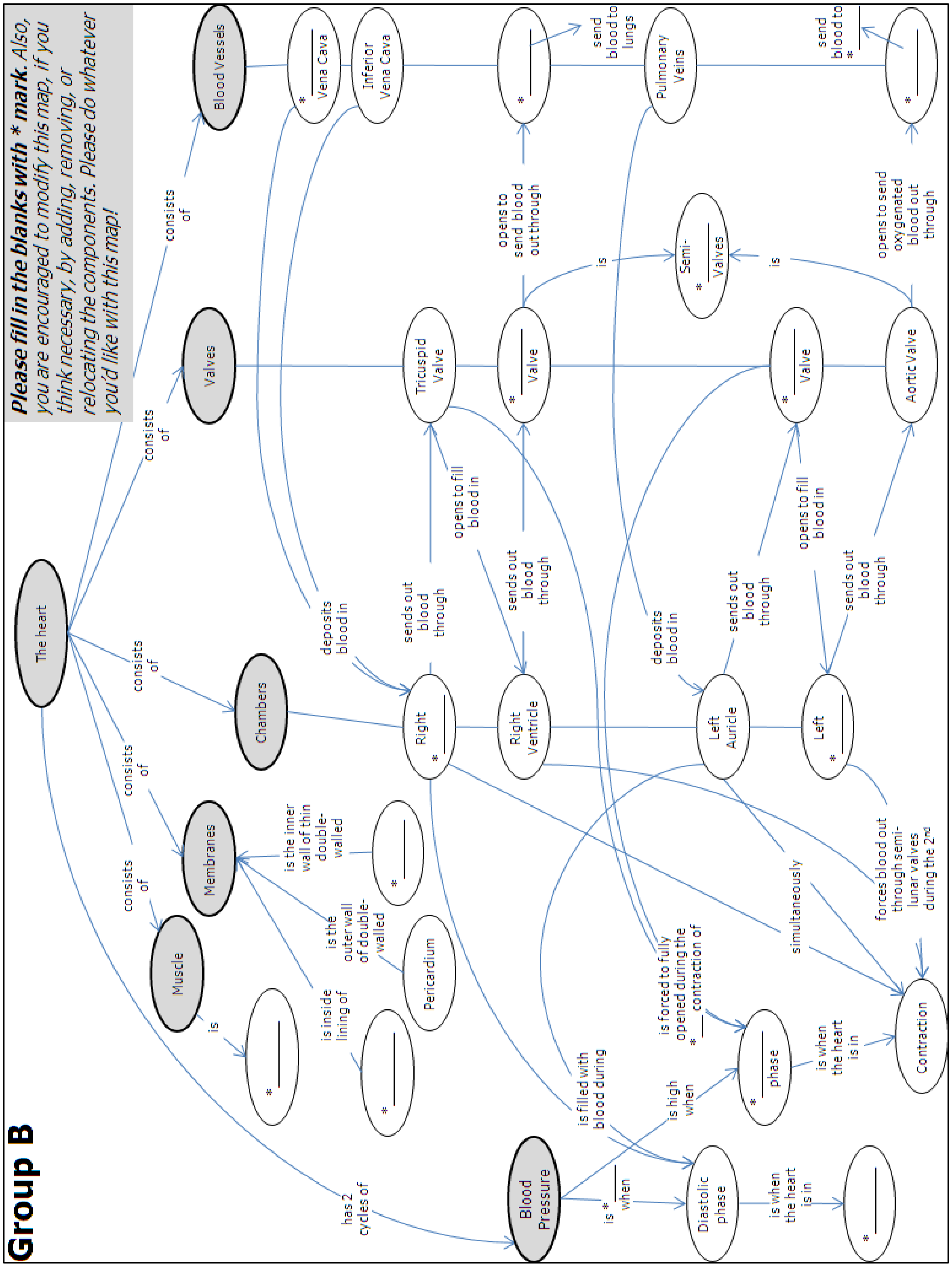
6. **If you think you are ready to take the Post-test on what you've learned, *please raise your hand***. The access code for the test will be given to you at this point. You cannot refer to the study materials or concept map during the test.

7. With the given code, please click **3. Post-test on what you've learned,** and take the test. AGAIN, PLEASE DO NOT GO BACK TO THE STUDY MATERIAL. JUST DO YOUR BEST!

8. Once you finish the test, please click **4. Post –survey on student perception**, and answer to the questions.

THANK YOU!!!

APPENDIX B: Partially Learner-generated Concept Map and Corresponding Instruction



APPENDIX C

Fully Learner-generated Concept Map and Corresponding Instruction

APPENDIX C: Fully Learner-generated Concept Map and Corresponding Instruction

<Instruction>

You are in **Group C**.

STEP-by-STEP INSTRUCTION:

1. Please log in to Angel, and find the RESEARCH folder under MY GROUP. Click the link of **STAT 200 Research Participation-Spring 2008**.

2. If you haven't completed the **pre-survey on learning style**, please respond to the survey now.

3. Please read 'Read Me First'.

4. Click the link **1. Concept Mapping Practice**, and study the given content. The access code is *insys*. Use the blank sheet attached to this instruction to create a practice concept map. ***Please raise your hand*** when you are done with creating a practice map so I can give you an additional material required for the next step. **Without this additional material, you cannot proceed.**

5. When the additional material is given, move on to the **2. Study Material on the Human Heart.** The access code is *insys*. While you are studying the material, please **CREATE YOUR OWN CONCEPT MAP** in the given space using 20 to 30 concepts from the human heart material.

6. **If you think you are ready to take the Post-test on what you've learned, *please raise your hand***. The access code for the test will be given to you at this point. You cannot refer to the study materials or concept map during the test.

7. With the given code, please click **3. Post-test on what you've learned,** and take the test. AGAIN, PLEASE DO NOT GO BACK TO THE STUDY MATERIAL. JUST DO YOUR BEST!

8. Once you finish the test, please click **4. Post –survey on student perception**, and answer to the questions.

THANK YOU!!!

APPENDIX C: Fully Learner-generated Concept Map and Corresponding Instruction

Group C: While you are studying the material, please **create your own concept map** of the human heart in the space below. 20 to 30 concepts would be appropriate. Don't forget the procedure you've learned from the previous activity! →

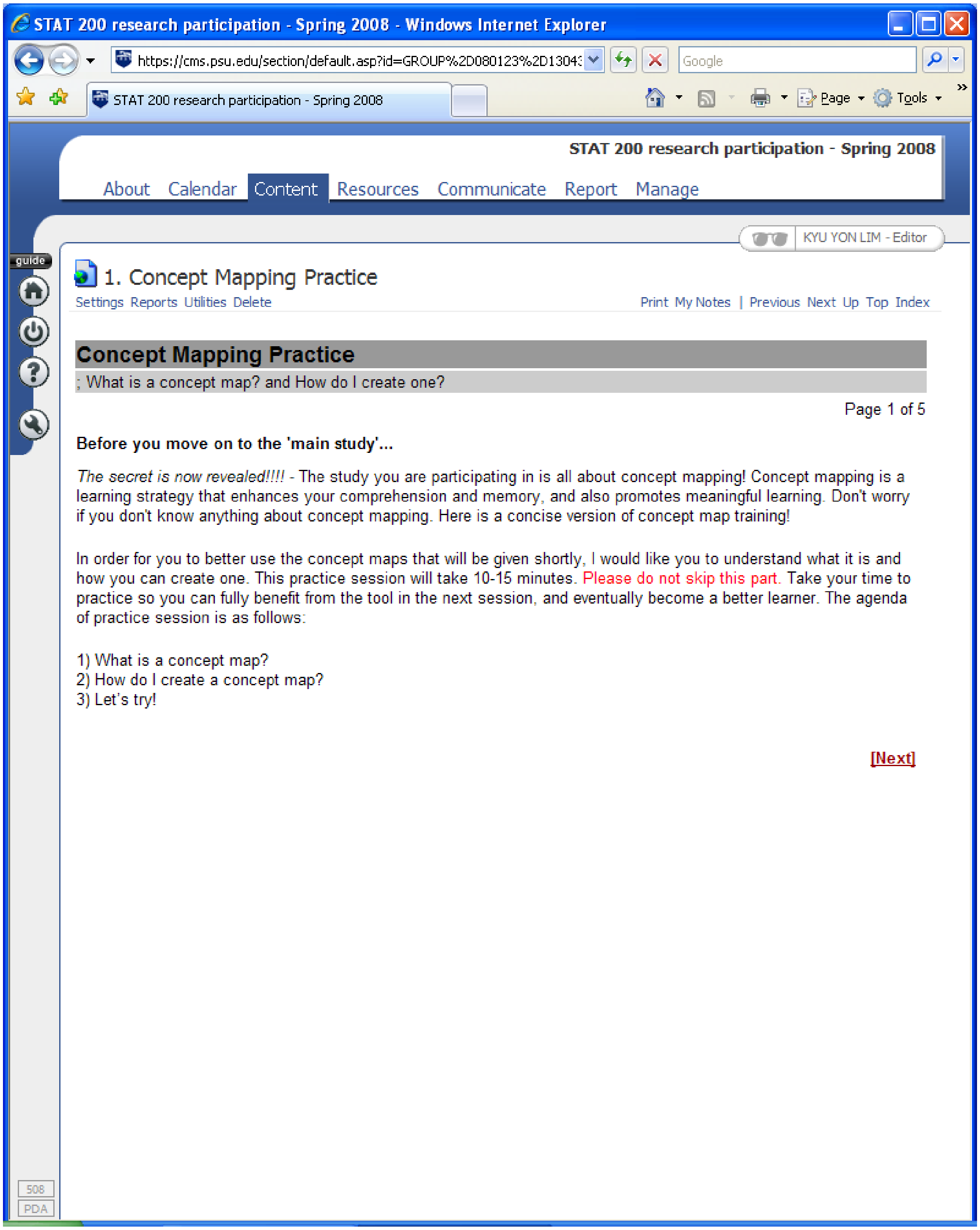
1) List up 20~30 important concepts related to the human heart.
2) Put general concepts on top.
3) Generate propositions by using concepts and linking words.
4) Put direction using arrows.
5) Review and modify if necessary.

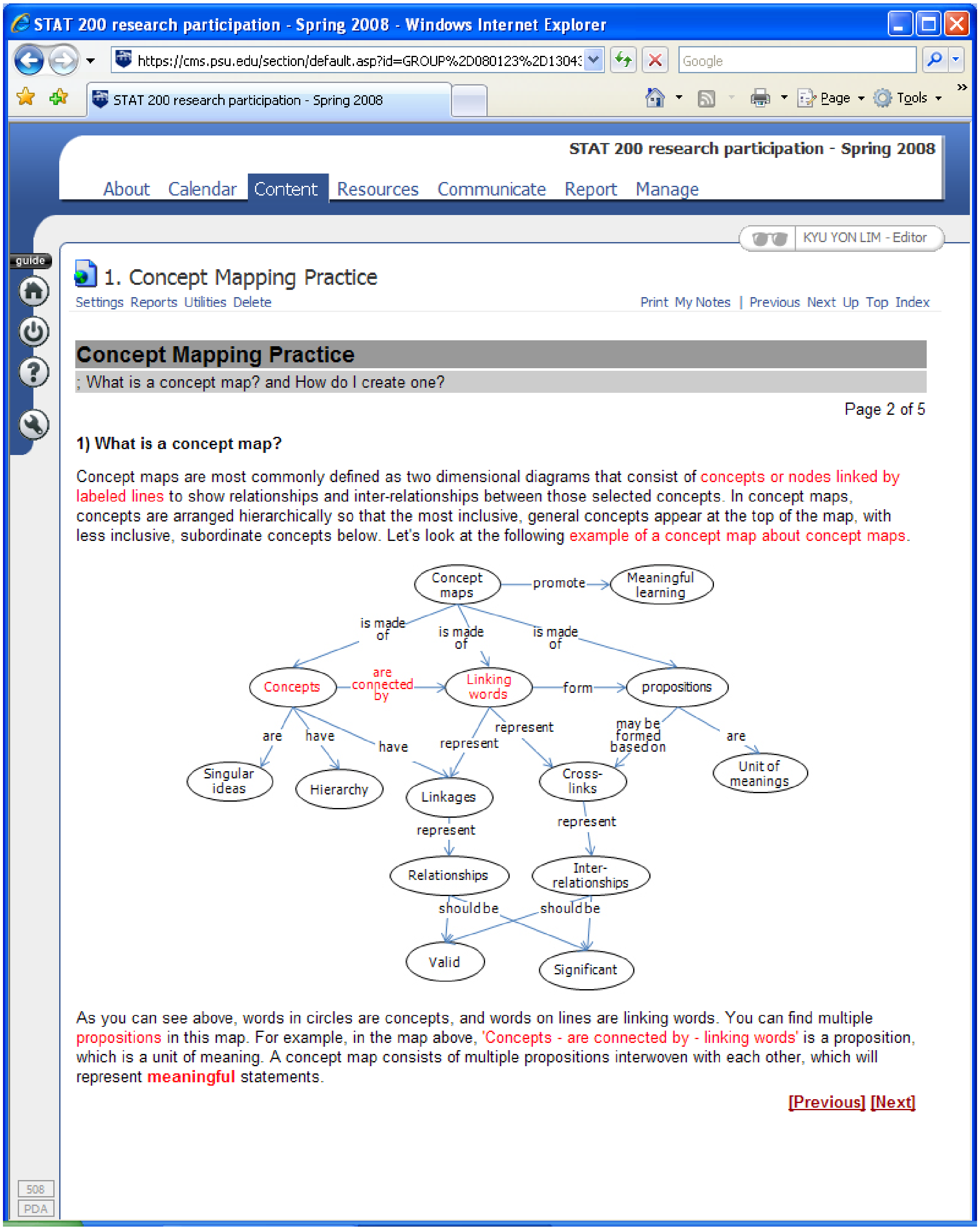
Please raise your hand when you are done studying!

APPENDIX D

Concept Mapping Training Material

APPENDIX D: Web-based Training Material for the Concept Mapping Activity





STAT 200 research participation - Spring 2008 - Windows Internet Explorer

https://cms.psu.edu/section/default.asp?id=GROUP%2D080123%2D13043

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KYU YON LIM - Editor

1. Concept Mapping Practice

Settings Reports Utilities Delete — Print My Notes | Previous Next Up Top Index

Concept Mapping Practice

; What is a concept map? and How do I create one?

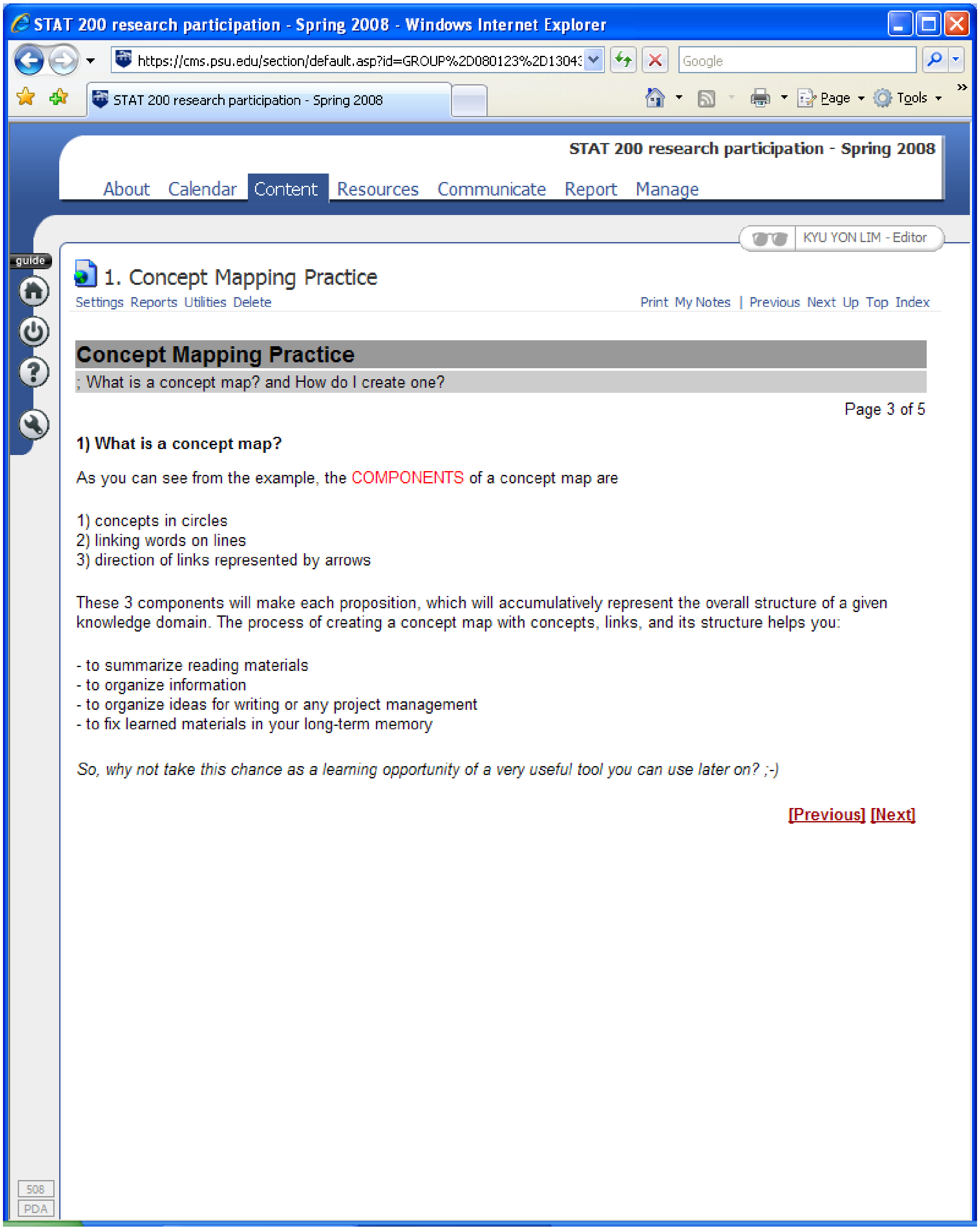
Page 2 of 5

1) What is a concept map?

Concept maps are most commonly defined as two dimensional diagrams that consist of concepts or nodes linked by labeled lines to show relationships and inter-relationships between those selected concepts. In concept maps, concepts are arranged hierarchically so that the most inclusive, general concepts appear at the top of the map, with less inclusive, subordinate concepts below. Let's look at the following example of a concept map about concept maps.

As you can see above, words in circles are concepts, and words on lines are linking words. You can find multiple propositions in this map. For example, in the map above, 'Concepts - are connected by - linking words' is a proposition, which is a unit of meaning. A concept map consists of multiple propositions interwoven with each other, which will represent **meaningful** statements.

[Previous] [Next]



Concept Mapping Practice

; What is a concept map? and How do I create one?

Page 3 of 5

1) What is a concept map?

As you can see from the example, the COMPONENTS of a concept map are

1) concepts in circles
2) linking words on lines
3) direction of links represented by arrows

These 3 components will make each proposition, which will accumulatively represent the overall structure of a given knowledge domain. The process of creating a concept map with concepts, links, and its structure helps you:

- to summarize reading materials
- to organize information
- to organize ideas for writing or any project management
- to fix learned materials in your long-term memory

So, why not take this chance as a learning opportunity of a very useful tool you can use later on? ;-)

[Previous] [Next]

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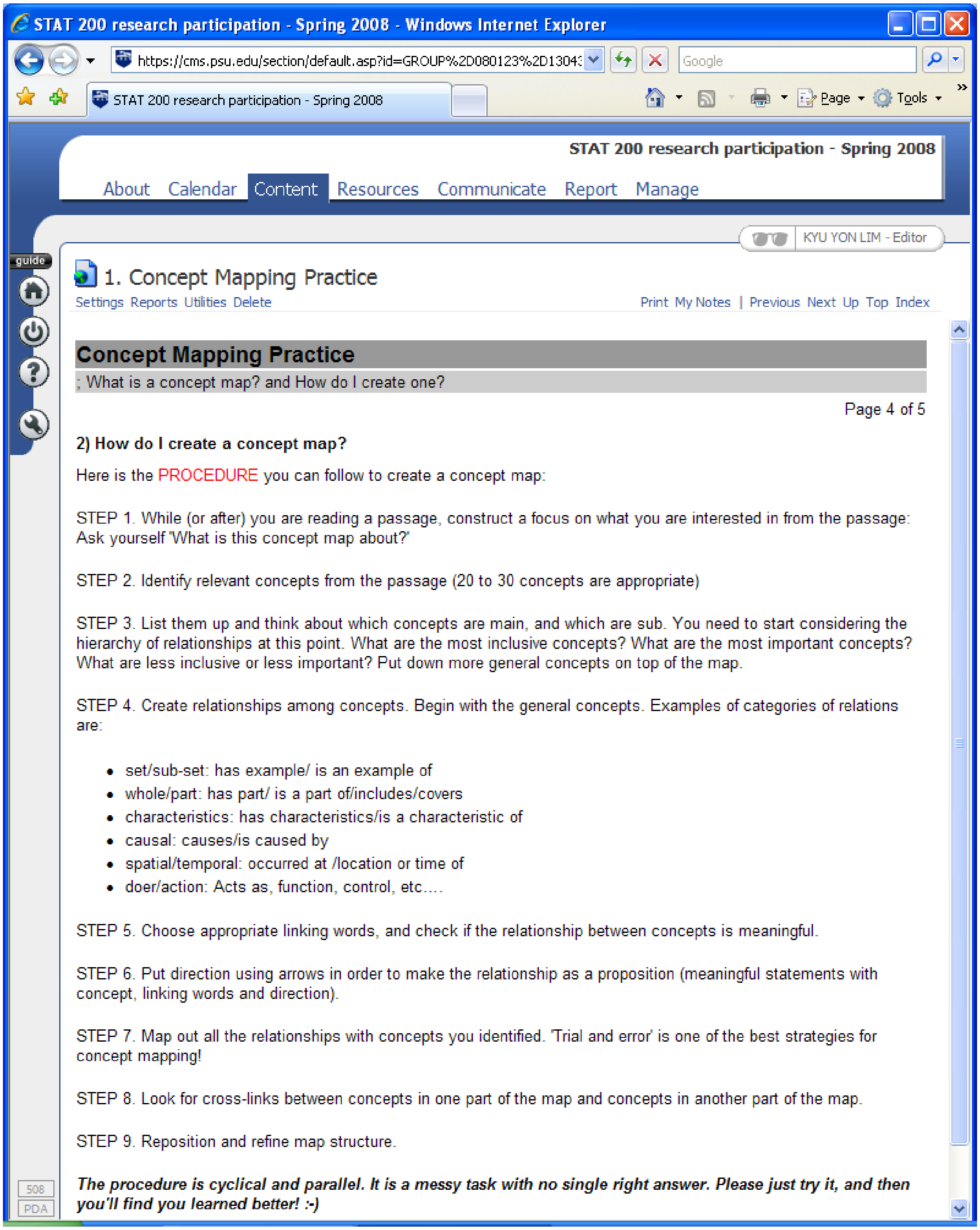

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1. Concept Mapping Practice

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Concept Mapping Practice

; What is a concept map? and How do I create one?

Page 4 of 5

2) How do I create a concept map?

Here is the PROCEDURE you can follow to create a concept map:

STEP 1. While (or after) you are reading a passage, construct a focus on what you are interested in from the passage: Ask yourself 'What is this concept map about?'

STEP 2. Identify relevant concepts from the passage (20 to 30 concepts are appropriate)

STEP 3. List them up and think about which concepts are main, and which are sub. You need to start considering the hierarchy of relationships at this point. What are the most inclusive concepts? What are the most important concepts? What are less inclusive or less important? Put down more general concepts on top of the map.

STEP 4. Create relationships among concepts. Begin with the general concepts. Examples of categories of relations are:

- set/sub-set: has example/ is an example of
- whole/part: has part/ is a part of/includes/covers
- characteristics: has characteristics/is a characteristic of
- causal: causes/is caused by
- spatial/temporal: occurred at /location or time of
- doer/action: Acts as, function, control, etc....

STEP 5. Choose appropriate linking words, and check if the relationship between concepts is meaningful.

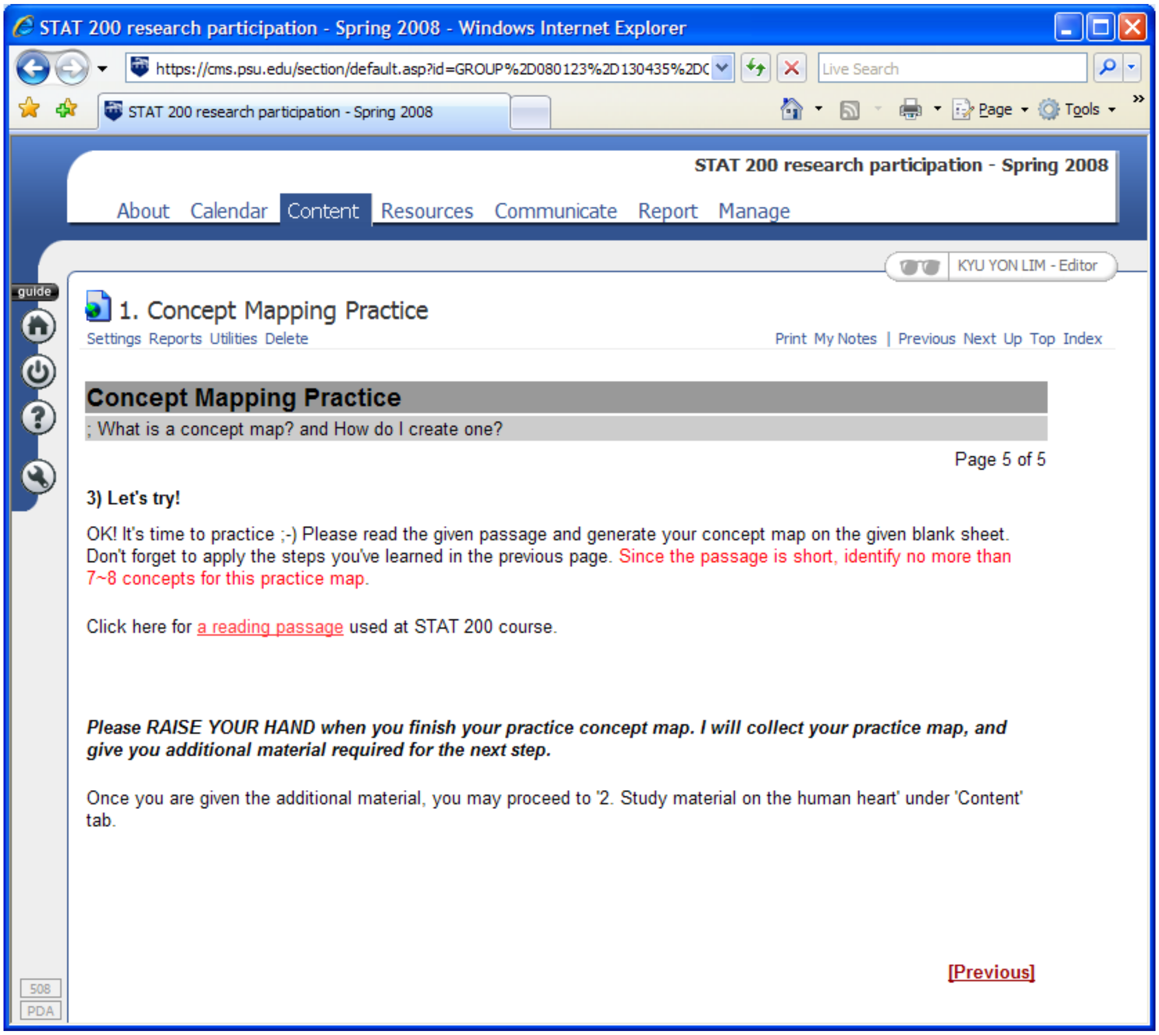
STEP 6. Put direction using arrows in order to make the relationship as a proposition (meaningful statements with concept, linking words and direction).

STEP 7. Map out all the relationships with concepts you identified. 'Trial and error' is one of the best strategies for concept mapping!

STEP 8. Look for cross-links between concepts in one part of the map and concepts in another part of the map.

STEP 9. Reposition and refine map structure.

The procedure is cyclical and parallel. It is a messy task with no single right answer. Please just try it, and then you'll find you learned better! :-)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1. Concept Mapping Practice

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Print My Notes | Previous Next Up Top Index

Concept Mapping Practice

; What is a concept map? and How do I create one?

Page 5 of 5

3) Let's try!

OK! It's time to practice ;-) Please read the given passage and generate your concept map on the given blank sheet. Don't forget to apply the steps you've learned in the previous page. Since the passage is short, identify no more than 7~8 concepts for this practice map.

Click here for a reading passage used at STAT 200 course.

Please RAISE YOUR HAND when you finish your practice concept map. I will collect your practice map, and give you additional material required for the next step.

Once you are given the additional material, you may proceed to '2. Study material on the human heart' under 'Content' tab.

[Previous]

APPENDIX E

Motivated Strategies and Learning Questionnaire

Appendix E: Motivated Strategies and Learning Questionnaire

The following questions ask about your motivation and attitudes toward learning strategies. You are free to stop whenever you feel uncomfortable answering to any of following questions. However, if you complete the survey, you will receive feedback on your different learning traits and skills. If you have any questions, please email the principal investigator, Kyu Yon Lim at kxl266@psu.edu

Do you want to receive the feedback of this survey? If you select 'yes', you will receive an email with the results. Yes ____ No ____

Remember there is no right or wrong answer, just answer as accurately as possible. If you think the statement is very true of you, click the circle on 7; if a statement is not at all true of you, click on 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

Items	Not at all true of me						Very true of me
1. I prefer course material that really challenges me so I can learn new things.	1	2	3	4	5	6	7
2. Getting a good grade is the most satisfying thing for me right now.	1	2	3	4	5	6	7
3. The most important thing for me is improving my overall grade point average.	1	2	3	4	5	6	7
4. If I can, I want to get better grades than most of the other students.	1	2	3	4	5	6	7
5. I prefer course material that arouses my curiosity, even if it is difficult to learn.	1	2	3	4	5	6	7
6. The most satisfying thing for me is trying to understand the content as thoroughly as possible.	1	2	3	4	5	6	7
7. When I have the opportunity, I choose course assignments that I can learn from, even if they don't guarantee a good grade.	1	2	3	4	5	6	7
8. I want to do well because it is important to show my ability to my family, friends, or others.	1	2	3	4	5	6	7
9. When I study the readings for class, I outline the material to help me organize my thoughts.	1	2	3	4	5	6	7
10. During class time, I often miss important points because I'm thinking of other things.	1	2	3	4	5	6	7
11. When reading for class, I make up questions to focus my reading.	1	2	3	4	5	6	7
12. I often find myself questioning things I hear or read to decide if I find them convincing.	1	2	3	4	5	6	7
13. When I study, I practice saying the material to myself over and over.	1	2	3	4	5	6	7
14. When I become confused about something I'm reading for the class, I go back and try to figure it out.	1	2	3	4	5	6	7
15. When studying, I go through the readings and my class notes and try to find the most important ideas.	1	2	3	4	5	6	7
16. If course readings are difficult to understand, I change the way I read the material.	1	2	3	4	5	6	7
17. When studying, I read my class notes and course reading	1	2	3	4	5	6	7

Items	Not at all true of me						Very true of me
over and over again.							
18. When a theory, interpretation or conclusion is presented in class or in the readings, I try to decide if there is good supporting evidence.	1	2	3	4	5	6	7
19. I make simple charts, diagrams, or tables to help me organize course material.	1	2	3	4	5	6	7
20. I treat the course material as a starting point and try to develop my own ideas about it.	1	2	3	4	5	6	7
21. When studying, I pull together information from different sources, such as lectures, readings and discussions.	1	2	3	4	5	6	7
22. Before I study new course material thoroughly, I often skim it to see how it is organized.	1	2	3	4	5	6	7
23. I ask myself questions to make sure I understand the materials I have been studying in the class.	1	2	3	4	5	6	7
24. I try to change the way I study in order to fit the course requirements and the instructor's teaching style.	1	2	3	4	5	6	7
25. I often find that I have been reading for class but don't know what it was all about.	1	2	3	4	5	6	7
26. When studying, I memorize key words to remind me of important concepts.	1	2	3	4	5	6	7
27. I try to think through a topic to decide what I am supposed to learn from it rather than just reading it over when studying for the class.	1	2	3	4	5	6	7
28. I try to relate ideas in the subject to those in other courses whenever possible.	1	2	3	4	5	6	7
29. When studying, I go over my class notes and make an outline of important concepts.	1	2	3	4	5	6	7
30. When reading for class, I try to relate the material to what I already know.	1	2	3	4	5	6	7
31. I try to play around with ideas of my own related to what I am learning in the class.	1	2	3	4	5	6	7
32. When studying, I write brief summaries of the main ideas from the readings and the concepts from the lectures.	1	2	3	4	5	6	7
33. I try to understand the material by making connections between the readings and the concepts from the lectures.	1	2	3	4	5	6	7
34. Whenever I read or hear an assertion or conclusion in class, I think about possible alternatives.	1	2	3	4	5	6	7
35. When studying, I make lists of important items and memorize the lists.	1	2	3	4	5	6	7
36. When studying, I try to determine which concepts I don't understand well.	1	2	3	4	5	6	7
37. When studying, I set goals for myself in order to direct my activities in each study period.	1	2	3	4	5	6	7
38. If I get confused taking notes in class, I make sure I sort it out afterwards.	1	2	3	4	5	6	7
39. I try to apply ideas from course readings in other class activities such as lecture and discussion	1	2	3	4	5	6	7

Please take a look at your watch and write down current time - ___:___ pm

APPENDIX F

Knowledge Acquisition Test

Appendix F: Knowledge Acquisition Test

Factual Knowledge

Directions: Select the answer you feel best completes the sentence.

1. _____ is(are) the thickest walled chamber(s) of the heart.
A.Auricles
B.Myocardium
C.Ventricles
D.Pericardium
E.Endocardium

2. The contraction of the heart occurs during the ______ phase.
A.Systolic
B.Sympathetic
C.Diastolic
D.Parasympathetic
E.Sympatric

3. Lowest blood pressure in the arteries occurs during the _____ phase.
A.Sympatric
B.Sympathetic
C.Diastolic
D.Systolic
E.Parasympathetic

4. Blood from the right ventricle goes to the lungs through the _____.
A.Tricuspid Valve
B.Aortic Artery
C.Pulmonary Artery
D.Pulmonary Veins
E.Superior Vena Cava

5. The ______ is(are) the strongest section(s) of the heart.
A.Left Ventricle
B.Aorta
C.Septum
D.Right Ventricle
E.Tendons

6. When blood returns to the heart from the lungs, it enters the _____.
A.Left Auricle
B.Pulmonary Valve
C.Left Ventricle
D.Right Ventricle
E.Pulmonary Artery

7. Vessels that allow the blood to flow from the heart are called the _____.
A.Veins
B.Arteries
C.Apex
D.Tendons
E.Valves

8. Blood passes from the left ventricle out the aortic valve to the ______.
A.Lungs
B.Body
C.Aorta
D.Pulmonary Artery
E.Left Auricle

9. The chamber of the heart which pumps oxygenated blood to all parts of the body is the _____.
A.Right Auricle
B.Left Auricle
C.Aorta
D.Left Ventricle
E.Right Ventricle

10. The _____ is another name for the part of the heart called the heart muscle.
A.Apex
B.Epicardium
C.Endocardium
D.Myocardium
E.Septum

11. ______ is(are) the part(s) of the heart which controls its contraction and relaxation.
A.Myocardium
B.Endocardium
C.Ventricles
D.Auricles
E.Septum

12. The _____ is the name given to the inside lining of the heart wall.
A.Epicardium
B.Endocardium
C.Pericardium
D.Myocardium
E.Septum

13. Blood from the body enters the heart through the ______.
A.Aortic Artery
B.Pulmonary Veins
C.Pulmonary Artery
D.Superior and Inferior Vena Cavas
E.Superior Vena Cava Only

14. The membrane which borders on the inside lining of the pericardium and is connected to the heart muscle is called the _______.
A.Extoxim
B.Epicardium
C.Endocardium
D.Myocardium
E.Ectocardium

15. The _______ allow(s) blood to travel in one direction only.
A.Septum
B.Valves
C.Arteries
D.Veins

16. The _______ is the common opening between the right auricle and the right ventricle.
A.Mitral Valve
B.Tricuspid Valve
C.Septic Valve
D. Pulmonary Valve
E. Aortic Valve

17. The _______ is the triangular flapped valve between the left auricle and the left ventricle.
A.Aortic Valve
B.Pulmonary Valve
C.Septic Valve
D.Tricuspid Valve
E. Mitral Valve

18. The semi-lunar valves are located at the entrance to the ______.
A.Pulmonary Veins
B.Superior and Inferior Vena cavas
C.Pulmonary and Aortic Arteries
D.Mitral and Tricuspid Valves
E.ventricles

19. The outside covering of the heart is called the ______.
A.Endocardium
B.Epicardium
C.Pericardium
D.Myocardium
E.None of These

20. Immediately before entering the aorta, blood must pass through the ______.
A.Left Ventricle
B.Mitral Valve
C.Lungs
D.Superior Vena Cava
E.Aortic Valve

Conceptual Knowledge

Directions: Select the answer you feel best completes the sentence.

21. Which valve is most like the tricuspid in function?
A.Pulmonary
B.Aortic
C.Mitral
D.Superior Vena Cava

22. When blood is being forced out the right ventricle, in which position is the tricuspid valve?
A.Beginning to open
B.Beginning to close
C.Open
D.Closed

23. When the blood is being forced out the aorta, it is also being forced out of the.
A.Pulmonary Veins
B.Pulmonary Arteries
C.Superior Vena Cava
D.Cardiac Artery

24. The contraction impulse in the heart starts in
A.The Right Auricle
B.Both ventricles simultaneously
C.Both Auricles Simultaneously
D.The Arteries

25. In the diastolic phase the ventricles are
A.Contracting, full of blood
B.Contracting, partially full of blood
C.Relaxing, full of blood
D.Relaxing, partially full of blood

26. During the first contraction of the systolic phase, in what position will the mitral valve be?
A.Begging to open
B.Open
C.Beginning to close
D.Closed

27. During the second contraction of the systolic phase, blood is being forced away from the heart through the
A.Pulmonary and Aortic Arteries
B.Superior and Inferior Vena Cavas
C.Tricuspid and Mitral Valves
D.Pulmonary Veins

28. When blood is entering through the vena cavas, it is also entering through the
A.Mitral Valve
B.Pulmonary Veins
C.Pulmonary Artery
D.Aorta

29. When the heart contracts, the
A.Auricles & Ventricles contract simultaneously
B.Ventricles contract first, then the auricles
C.Right side contracts first, then the left side
D.Auricles contract first, then the ventricles

30. While blood from the body is entering the superior vena cava, blood from the body is also entering through
A.Pulmonary Veins
B.Aorta
C.Inferior Vena Cava
D.Pulmonary Artery

31. When the blood leaves the heart through the pulmonary artery, it is also simultaneously leaving the heart through the
A.Tricuspid Valve
B.Pulmonary veins
C.Aorta
D.Pulmonary Valve

32. When the pressure in the right ventricle is superior, in what position is the tricuspid valve?
A.Closed
B.Open
C.Beginning to Close
D.Confined by pressure from the right auricle

33. When the ventricles contract, blood is forced out the
A.Superior and Inferior Vena Cavas
B.Pulmonary veins
C.Tricuspid and Mitral Valves
D.Pulmonary and Aortic Valves

34. Blood leaving the heart through the aorta had left the heart previously through the
A.Vena cavas
B.Pulmonary veins
C.Pulmonary artery
D.Tricuspid and Mitral Valves

35. When the blood in the aorta is exerting a superior pressure on the aortic valve, what is the position of the mitral valve?
A.Closed
B.Open
C.Beginning to open
D.Confined by pressure from the right ventricle

36. When the tricuspid and mitral valves are forced shut, in what position is the pulmonary valve?
A.Closed
B.Beginning to open
C.Open
D.Beginning to close

37. During the second contraction of the systolic phase, in what position is the aortic valve?
A.Fully open
B.Partially open
C.Partially closed
D.Fully closed

38. Blood is being forced out the auricles simultaneously as blood is
A.Entering only the vena cavas
B.Being forced out the pulmonary and aortic valves
C.Passing through the tricuspid & mitral valves
D.Being forced out through the pulmonary artery

39. If the aortic valve is completely open, the
A.Second contraction of the systolic phase is occurring
B.Diastolic phase is occurring
C.Tricuspid & mitral valves are completely open
D.Blood is rushing into the right & left ventricles

40. When the heart relaxes, the
A.Auricles relax first, then the ventricles
B.Right side relaxes first, then the left side
C.Left side relaxes first, then the right side
D.Ventricles relax first, then the auricle

APPENDIX G

Informed Consent Forms

Appendix G-1: Informed Consent for Fall 2007 Semester

ORP USE ONLY: IRB#24238 Doc. #1
The Pennsylvania State University
Office for Research Protections
Approval Date: 11/21/07 JKG
Expiration Date: 11/04/08 JKG
Social Science Institutional Review Board

Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: The Effect of Concept Mapping and Learners' Self-Regulation Skills

Principal investigator: Kyu Yon Lim, Ph.D. Candidate in Instructional Program
315 Keller Bldg., University Park, PA 16802 / (814)861-3724 / kxl266@psu.edu

Advisor: Barbara Grabowski, Professor of Education
315 Keller Bldg., University Park, PA 16802 / (814)865-0473 / blg104@psu.edu

1. **Purpose of the Study:** The purpose of this study is to examine how different types of instructional variables help students learn from instruction.

2. **Procedures to be followed:** If you agree to participate, you will be asked to sign this consent form, complete an online questionnaire, come to the computer lab you selected, and then study an instructional unit on the parts and function of the human heart. You will then be asked to complete 2 post-tests to assess what you have learned.

3. **Discomforts and Risks:** There are no known psychological or academic risks associated with this study.

4. **Benefits/Rewards:** The benefit of participating in the study is to (a) have a greater understanding of the human heart and how it functions, (b) have experience on how instruction is currently being designed to improve learning, (c) get the feedback on 10 different learning traits and skills upon request.

5. **Duration/Time:** The duration of the study is about 1.5 hours.

6. **Statement of Confidentiality:** Your participation in this research is confidential. The data will be stored and secured at principal investigator's laptop as password protected files. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Social Science Institutional Review Board and the PSU Office for Research Protections. Your confidentiality will be safe to the degree permitted by the technology used. Specifically, no guarantees can be made regarding the interception of data sent via the Internet by any third parties. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

7. **Right to Ask Questions:** Please contact Kyu Yon Lim at kxl266@psu.edu or 814-861-3724 with questions or concerns about this study. You may also call this number if you feel this study has

harmed you. If you have questions about your rights as a research participant, please contact the Office for Research Protections at 814- 865-1775.

8. **Compensation:** As a reward, participants will be given extra credit of 1.5 % of total score and entered in a drawing for one iPod shuffle. If you choose not to participate in this study, you still can receive the extra credit by submitting a reflective essay about the given topic.

9. **Voluntary Participation:** Your participation is voluntary. You are free to stop the study at any time. You can choose not to answer questions without penalty. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

You must be 18 years of age or older to consent to participate in this research study. If you consent to participate in this research study and to the terms above, please sign your name and indicate the date below.

You will be given a copy of this consent form to keep for your records.

____

Participant signature Date

____

Investigator signature Date

Appendix G-2: Informed Consent for Spring 2008 Semester

ORP USE ONLY: IRB#24238 Doc. #1
The Pennsylvania State University
Office for Research Protections
Approval Date: 02-02-2008 D. Maney
Expiration Date: 11-04-2008 D. Maney
Social Science Institutional Review Board

Informed Consent Form for Social Science Research
The Pennsylvania State University

Title of Project: The Effect of Concept Mapping and Learners' Self-Regulation Skills

Principal investigator: Kyu Yon Lim, Ph.D. Candidate in Instructional Program
315 Keller Bldg., University Park, PA 16802 / (814)861-3724 / kxl266@psu.edu

Advisor: Barbara Grabowski, Professor of Education
315 Kller Bldg., University Park, PA 16802 / (814)865-0473 / blg104@psu.edu

1. **Purpose of the Study:** The purpose of this study is to examine how different types of instructional variables help students learn from instruction.

2. **Procedures to be followed:** If you agree to participate, you will be asked to sign this consent form, complete an online questionnaire, come to the computer lab you selected, and then will study an instructional unit on the parts and function of the human heart. You will then be asked to complete 2 post-tests to assess what you have learned, and a post-survey on your perception on the given instructional method. Several of you may be invited to an individual interview to discuss your experience regarding the given instructional method.

3. **Discomforts and Risks:** There are no known psychological or academic risks associated with this study.

4. **Benefits/Rewards:** The benefit of participating in the study is to (a) have a greater understanding of the human heart and how it functions, (b) have experience on how instruction is currently being designed to improve learning, (c) get the feedback on 10 different learning traits and skills upon request.

5. **Duration/Time:** The duration of the study is about 1.5 hours. In addition, individual interviews will take 30 minutes.

6. **Statement of Confidentiality:** Your participation in this research is confidential. The data will be stored and secured at principal investigator's laptop as password protected files. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Social Science Institutional Review Board and the PSU Office for Research Protections. Your confidentiality will be safe to the degree permitted by the technology used. Specifically, no guarantees can be made regarding the interception of data sent via the Internet by any third parties. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared.

7. **Right to Ask Questions:** You can ask questions about this research. Please contact Kyu Yon Lim at kxl266@psu.edu or 814-861-3724 with questions or concerns about this study. You may also call this number if you feel this study has harmed you. If you have questions about your rights as a research participant, please contact the Office for Research Protections at 814- 865-1775.

8. **Payment for Participation:** As a reward, participants will be given extra credit of 1.5 % of total score and entered in a drawing to win one of three $25 valued gift cards. If you choose not to participate in this study, you still can receive the extra credit by submitting a reflective essay about the given topic. Additional information is available from the principal investigator listed above.

9. **Voluntary Participation:** Your participation is voluntary. You are free to stop the study at any time. You can choose not to answer questions without penalty. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise.

You must be 18 years of age or older to consent to participate in this research study. If you consent to participate in this research study and to the terms above, please sign your name and indicate the date below. You will be given a copy of this consent form to keep for your records.

____

Participant signature Date

____

Investigator signature Date

APPENDIX H

Post-Survey for Spring 2008 Semester

Appendix H: Post-Survey for Spring 2008 Semester

This survey is designed to understand your learning process and use of concept mapping activities. You are free to stop whenever you feel uncomfortable answering to any of following questions. However, if you complete the survey, you are providing valuable information and insights to the researcher so better learning environment be designed. If you have any questions, please email the principal investigator, Kyu Yon Lim at kxl266@psu.edu

Now, please answer to the follow questions **based on the concept mapping activity for human heart study. This is not about the practice map on statistics**. Please answer as detailed as possible.

1. Gender: Major: Semester standing:
2. Please describe the process you went through when you studied the human heart material. How did you study to learn better?
3. (only for Group A and B) If you were given a ready-made concept map for human heart material, what did you do first in order to use the given concept map? What were the next steps?
4. (only for Group A and B) If you were given a ready-made concept map for human heart material, did you try to modify/add the given map? Did you put your own note on the map? Why or why not?
5. (only for Group C) If you were given a blank sheet of paper and asked to create a concept map for human heart material, what did you do first? What were the next steps?
6. What was the most difficult part or challenging issue when using or creating the concept map? Why?
7. How much mental effort did you put when you were using or creating the concept map during heart material study? Could you put the amount of effort on a scale of 1 to 7? (1 being 'lowest effort', 7 being 'highest effort')
8. Please describe the amount of mental effort made for the concept mapping activity during heart material study compared to the other learning strategies you are familiar with (e.g. underlining, note-taking, summarizing, etc)
9. How did this map help or hinder your learning?
10. Is this method useful for you?

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VITA

Education

2008	Ph. D. in Instructional Systems, The Pennsylvania State University (PSU) *Minor in Educational Psychology (Measurement)*
1999	M. A. in Educational Technology, Ewha Women's University, Seoul, Korea
1997	B. A. in Educational Technology, Ewha Women's University, Seoul, Korea *Minor in English Education*

Employment

2006 to 2008	Research Assistant The Leonhard Center for the Enhancement of Engineering Education, PSU
2004 to 2005	Graduate Assistant ANGEL Support Group, Information Technology Services, PSU Multimedia Lab, Instructional Systems, PSU
2000 to 2004	e-Learning Consultant/ Lead Instructional Designer CREDU Inc., e-Contents and Consulting Division, Seoul, Korea
1999 to 2000	Instructional Designer Samsung Human Resources Development Center, Seoul, Korea

Selected Publications

Smith, B. K., Sharma, P., **Lim, K. Y.**, Akilli, G. K., Kim, K., Fujimoto, T., & Hooper, P. (2008). A case study of methods used to find meaning in online Fantasy Sports discussion forums. In J. Jansen (Ed.) *Handbook of Weblog Analysis.*

Lim, K. Y., Lee, H.W. & Grabowski, B. (2008, Accepted). Does concept mapping strategy work for everyone?: The levels of generativity and learners' self-regulated learning skills. *British Journal of Educational Technology.*

Lee, H.W., **Lim, K. Y.**, & Grabowski, B. (2007). Generative learning: Principles and implications for meaning making. In M. Spector (Ed). *Handbook of Research in Educational Communications and Technology.* Routledge.

Toto, R., **Lim, K. Y**. & Wise, J.C. (2007). Supporting Innovation: The diffusion and Adoption of Tablet PCs in the College of Engineering. In J. Prey, R. Reed & D. Berque (Eds.) *The Impact of Tablet PCs and Pen-based Technology on Education: Beyond the Tipping Point*. Purdue University Press.