Relationship Between the Mind Map Learning Strategy and Crtitical Thinking in Medical Students

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RELATIONSHIP BETWEEN THE MIND MAP LEARNING STRATEGY AND CRITICAL THINKING IN MEDICAL STUDENTS

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DEDICATION

Vorrei dedicare questo a mio figlio Massimo Stefano D'Antoni che è arrivato sei settimane prima del tempo, il 12 agosto 2008. Sempre sarà il mio piccolo angelo. Ti voglio bene. —*Papà*

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ABSTRACT

RELATIONSHIP BETWEEN THE MIND MAP LEARNING STRATEGY AND CRITICAL THINKING IN MEDICAL STUDENTS

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Background: One learning strategy underutilized in medical education is mind mapping. Mind maps are multi-sensory tools that may help students organize, integrate, and retain information. Recent work suggests that using mind mapping as a note-taking strategy facilitates critical thinking. The purposes of this study were to (1) investigate whether a relationship existed between mind mapping and critical thinking, as measured by the Health Sciences Reasoning Test (HSRT), (2) investigate whether a relationship existed between mind mapping and recall of domain-based information, and (3) assess student learning style with the Gregorc Style Delineator (GSD).

Methods: A sample of 131 first-year medical students was assigned to a standard note taking (SNT) group or mind map (MM) group. Subjects were administered a demographic survey, GSD, and pre-HSRT. They were then given an unfamiliar text passage, a pre-quiz based upon the passage, and a 30-minute break, during which time subjects in the MM group were given a presentation on mind mapping. After the break, subjects were given the same passage and wrote notes based on their group (SNT or MM) assignment. A post-quiz based upon the passage was administered, followed by a post-HSRT. Correlations were used to investigate whether any relationships existed between mind map depth, using a Mind Map Assessment System (MMAS), and critical thinking. Other correlations were used to investigate relationships between mind map depth, GSD learning style, and HSRT score.

Results: There were no significant differences in mean scores on both the pre-quizzes and post-quizzes between note-taking groups. No significant differences were found between pre- and post-HSRT mean total scores and subscores. The prevalence of dominant learning styles in all subjects regardless of note-taking group was: CS > AR > CR > AS. Interrater reliability of the MMAS was strong (*ICC* = .86).

Conclusion: Mind mapping was not found to increase short-term recall of domain-based information, or critical thinking, when compared to SNT. However, a brief introduction to mind mapping did allow novice MM subjects to perform similarly to subjects experienced with SNT. Future studies should be designed so that subjects gain proficiency in mind mapping prior to measuring critical thinking.

Chapter 1

INTRODUCTION

Background of the Problem

In recent years, many health care professions have advanced the entry-level degree required to practice (Cottrell, 2000; Glicken, 2002; Rothstein, 1998; Threlkeld, Jensen, & Royeen, 1999). Concurrently, several papers on teaching and learning strategies used by these professional educational programs have been published. Case-based teaching (Kim et al., 2006), web-based teaching (Zajaczek et al., 2006), didactic learning, and problem-based learning (PBL) (Dolmans, De Grave, Wolfhagen, & van der Vleuten, 2005) are innovative strategies that help students learn and ultimately integrate information (Gage & Berliner, 1998). A learning strategy is a thinking tool that a student can use to actively acquire information and some examples include mnemonics, charts, and maps (Gage & Berliner, 1998). Specifically in medical education, diverse learning strategies have been implemented over the years. For example, case-studies have been used to enhance integration skills in students (Kim et al., 2006), whereas PBL has been used to teach students to become lifelong, self-directed learners (Barrows, 1994).

Although these learning strategies may differ in efficacy and applicability, they are all based on a conceptual framework called the constructivist theory of learning, which states that meaningful learning, or learning with understanding (Daley, Shaw, Balistrieri, Glasenapp, & Piacentine, 1999), occurs when learners assimilate new information within their existing frameworks (Ausubel, 1978; Bodner, 1986; Gage & Berliner, 1998).

Constructivist theory is rooted in the subjectivist worldview, which emphasizes the role of the learner within the context of his environment (Burrell & Morgan, 1979). The interaction between the learner and his environment results in meaning or understanding; therefore, the two are inextricable (Burrell & Morgan, 1979). In the context of the aforementioned learning strategies (i.e., case-based teaching, web-based teaching, and PBL), all assume the learner is committed to lifelong learning and will integrate previous knowledge with newly acquired knowledge. The term used for this theory is "andragogy," which is the science and art of teaching adults (Knowles, 1977, 1984). The andragogical approach, like the subjectivist worldview, emphasizes the role of learners in the learning process and recognizes how previous experiences shape their learning and understanding (Forrest III & Peterson, 2006).

The theoretical basis of constructivism is depicted in Figure 1. Academic information is commonly available to the learner through reading, visualizing, or listening. Irrespective of the mechanism, information enters the mind of the learner, who is actively trying to make sense of the information. Because the sensemaking of the learner may be very different from that of the instructor presenting the information (Mezirow, 1981), one of the assumptions underlying constructivist theory is that the learner will integrate the information into a personal framework so that it will be retained (Bodner, 1986) and result in meaningful learning.

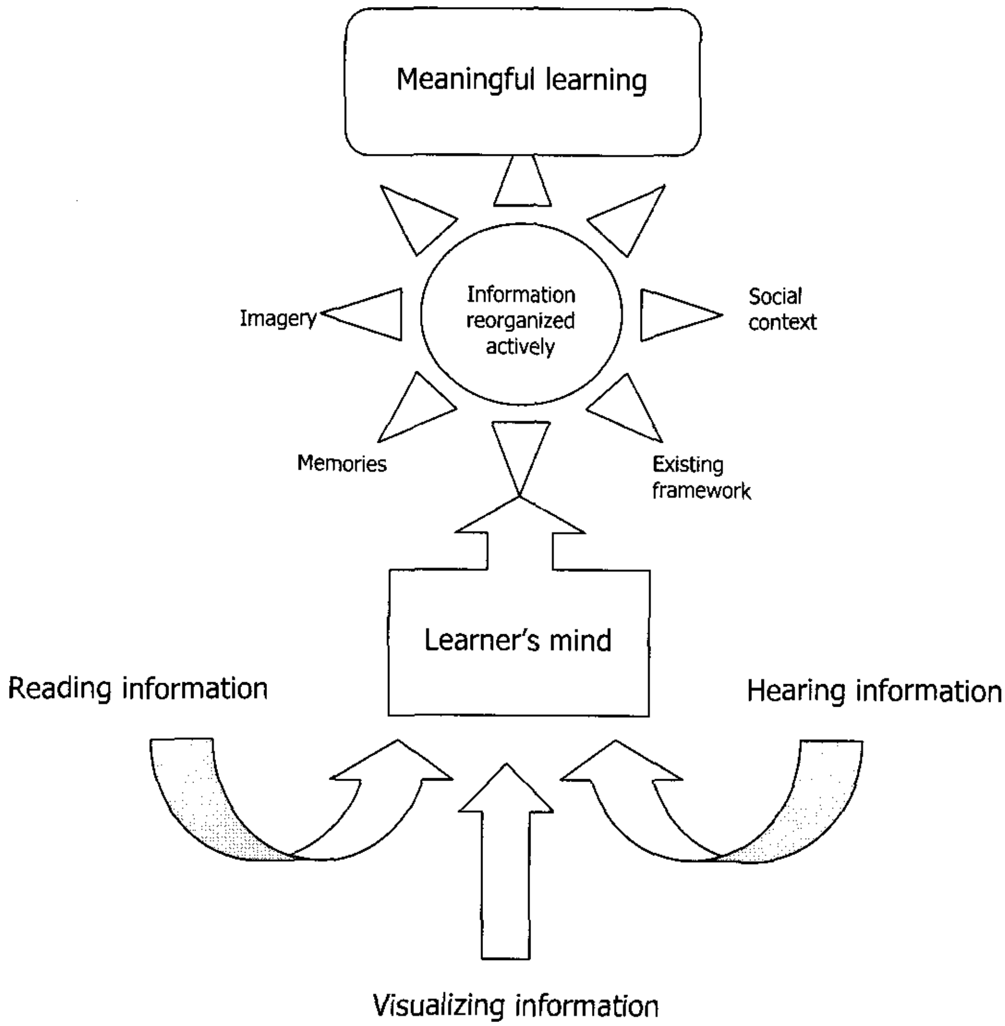

Figure 1. Theoretical assumptions that underlie constructivist theory using a bottom-up approach. Adapted from Ausubel (1978).

Meaningful learning is a necessary component of critical thinking. Critical thinking is a metacognitive, nonlinear process of purposeful judgment that includes self-directed learning and self-assessment (Bodner, 1986; Daley et al., 1999). How critical thinking should be taught and how it is learned are unclear (Taconis, Ferguson-Hessler, & Broekkamp, 2001; Willingham, 2007). Willingham (2007) stated that critical thinking occurs when a student penetrates beyond the surface structure of a problem and recognizes how the problem can be solved, and in addition, possesses the content knowledge integral to solving the problem. Without both components, a student may be able to critically analyze one problem, but will falter when given a similar problem in a different context (Willingham, 2007).

The concept map learning strategy, which was developed by Joseph Novak (1984), uses hierarchical order to link concepts together with propositions, or linking words, between concepts. These propositions are units of meaning that highlight the relationship between concepts (Irvine, 1995), and cross-links demonstrate relationships between concepts that would otherwise be unrecognized using a non-mapping learning strategy. Because the student creates the concept map without a template, the map ultimately represents the student's own interpretation and integration of ideas.

Another mapping strategy that relies on student interpretation and integration is the mind map learning strategy. This learning strategy has not been widely used in medical education despite recent research suggesting that mind mapping improves long-term memory in medical students (Farrand, Hussain, & Hennessy, 2002).

Mind mapping was developed by Tony Buzan (Buzan & Buzan, 1993) and the inspiration for this strategy arose from the notebooks of Leonardo da Vinci (Gelb, 1998). Unlike most learners' notes, da Vinci's notes were not linear but elliptical—he used pictures and text to illustrate ideas and often connected different concepts on the same page. While this method of note-taking was confusing to read (especially since he wrote backwards), it provided an opportunity to integrate ideas, which allowed da Vinci to effectively use both hemispheres of his cerebrum to problem solve. Mind maps, like da Vinci's notes, are multi-sensory tools that use visuospatial orientation to integrate information, and consequently, help students organize and retain information (McDermott & Clarke, 1998).

Mind maps can be used as a teaching tool to promote critical thinking in medical education by encouraging students (adult learners) to integrate information between disciplines and understand relationships between the basic and clinical sciences (McDermott & Clarke, 1998). The ability to integrate information by finding valid relationships between concepts allows students who construct either mind maps or concept maps to reach a metacognitive level (Willingham, 2007). However, the added dimensions of pictures and colors that are unique to mind maps have not only been shown to facilitate memory (Bellezza, 1983; Day & Bellezza, 1983), but may appeal to a wide range of students who have visual- and linear-oriented learning styles. Consequently, the advantage of using mind maps in medical education is that this strategy may benefit students with diverse learning styles compared to concept maps, which may only appeal to students with a linear-oriented learning style.

Adult learning styles have increasingly gained the interest of academics in the last several decades. Carl Jung theorized that humans have predictable patterns of behavior (Jung, 1971) and this led to the concept of preferred learning styles (Vanvoorhees, Wolf, Gruppen, & Stross, 1988). Based on Jung's work, David Kolb created the Learning Styles Inventory (LSI), a tool used to measure an individual's preferred learning style (Kolb, 1984). The LSI recognizes four types of learners: converger (active experimentation-abstract conceptualization), accommodator (active experimentation-concrete experience), assimilator (reflective observation-abstract conceptualization), and diverger (reflective observation-concrete experience) (Kolb, 1984).

Another instrument that can be used to measure an individual's preferred learning style is the Gregorc Style Delineator (GSD) (Gregorc, 1982). The GSD is a tool that classifies learners as Concrete-Sequential (CS), Abstract-Sequential (AS), Concrete-Random (CR), and Abstract-Random (AR) (Gregorc, 1982, 1984). The GSD is easy to interpret and has been used with cohorts of physicians (Vanvoorhees et al., 1988) and medical students (Ferretti, Krueger, Gabel, & Curry, 2007).

Need for the Study

The amount of information that medical students are expected to master is voluminous (Anderson & Graham, 1980) and there are limited learning strategies available to these students to master the volume of information required to succeed in medical school (Rye, Wallace, & Bidgood, 1993). Given this very large amount of information, many medical students resort to passive learning, a phenomenon that has been shown to increase the risk of academic difficulty in medical school (Dolan, Mallott, & Emery, 2002). Passive learning refers to learning strategies that emphasize memorization without an attempt to connect and understand information. Passive learners are not stimulated cognitively during the learning process, and do not attempt to form connections between units of information (Gage & Berliner, 1998). In contrast, active learning encourages this interconnectivity and engages the learner in activities that promote meaningful learning (Gage & Berliner, 1998). Concept maps and mind maps are active learning strategies that engage the learner in the learning process, and ultimately, allow the learner to actively integrate information on a metacognitive level (Buzan & Buzan, 1993; Freeman & Jessup, 2004). Therefore, both concept maps and mind maps are identical in their metacognitive mechanisms. These two learning strategies differ only in their structure and organization used to create the actual maps. Due to the paucity of studies on mind mapping in medical education, the author investigated whether a relationship exists between the active learning strategy of mind mapping, meaningful learning, and critical thinking in the adult learner.

A study such as this could help prevent students from experiencing academic difficulty during medical school since they use passive learning strategies that do not promote long-term learning (Dolan et al., 2002). In addition, a study that assesses whether a relationship exists between mind mapping and critical thinking is important because the purpose of medical education is to graduate physicians who can think critically and ultimately engage in analysis, deductive and inductive reasoning, and reflection (Koo & Thacker, 2008). The active mind map learning strategy could, therefore, be used to help medical students develop these characteristics and evolve into physicians who are able to think critically and provide excellent patient care (Kee & Bickle, 2004).

Purposes of the Study

The primary purpose of this study was to investigate whether a relationship existed between the mind map learning strategy and critical thinking, as measured with the Health Sciences Reasoning Test (HSRT), and whether this relationship was stronger than one between the preferred learning strategy of standard note taking (SNT) and critical thinking.

The secondary purposes of this study were to determine whether (1) mind maps were superior to SNT in the short-term recall of factual information, (2) a relationship existed between mind map depth (assessed using a mind map assessment system) and HSRT scores, and (3) a relationship existed between mind map depth and preferred learning style, which was measured with the Gregorc Style Delineator (GSD).

Research Questions

For this study, the primary research questions were:

- Which learning strategy, mind mapping or SNT, produced a greater increase in HSRT scores?

- Did a relationship exist between mind map depth and HSRT score? If a relationship did exist, was there a positive or negative correlation between mind map depth and HSRT score?

A secondary research question was:

- Were the mean scores of the text passage (domain-based) quiz higher among medical students in the mind map group when compared to those in the SNT group?

Two subsidiary questions were framed in order to acknowledge the possibility of a relationship between learning style and mind maps:

- Did a relationship exist between mind map depth and preferred learning style as measured with the GSD?
- Did a relationship exist between HSRT score and preferred learning style as measured with the GSD?

Research Hypotheses

The research questions provided a basis for developing the four hypotheses of this study.

The *first hypothesis* (*H1*) postulates that the mean difference between pre- and post-HSRT scores is higher in medical students in the mind map (MM) group compared to those in the SNT group.

The *second hypothesis* (*H2*) postulates that mind map depth (assessed using a mind map assessment system) is positively correlated with a higher HSRT score.

The *third hypothesis* (*H3*) postulates that the mean score of the text passage (domain-based) quiz is higher in the MM group compared to the SNT group.

The *fourth hypothesis* (*H4*) postulates that mind map depth is positively correlated with learning style preference.

The *fifth hypothesis* (*H5*) postulates that HSRT score is positively correlated with learning style preference.

Chapter 2

REVIEW OF RELATED LITERATURE

Introduction

Medical students are considered adult learners and various adult learning strategies, such as problem-based learning, concept maps, and mind maps, have been used in this cohort of students (Farrand et al., 2002; McDermott & Clarke, 1998). Figure 2 illustrates how adults acquire new knowledge and how this knowledge can be learned while reading a textbook during self-study, listening to a lecture, or reviewing data obtained from a patient history in the clinical setting (Bellezza, 1983; I. J. Russell, Caris, Harris, & Hendricson, 1983). Factual knowledge obtained in academia, as well as life experiences of a non-academic nature, form a foundation for learning. The overlap between these two domains differ for each learner. For example, compare two medical students: one is forty years old and the other is twenty years old. The forty-year-old medical student, who has worked as an administrator for two decades, has a broader repertoire of life experiences and potentially less factual knowledge of the basic sciences because he has been out of academia for two decades. As a result, his learning foundation for integrating novel basic science knowledge is more likely to be based upon life experience rather than academic knowledge. In this case, an andragogical approach to teaching that allows the adult to cognitively process information within the context of his frame of reference is appropriate (Knowles, 1984). In contrast, the twenty-year-old student who was a biology major in college, has been in academia for most of his life and has limited life

Figure 2. Adult model of learning. Adults learn most effectively when they form a connection between newly and previously acquired knowledge (Bellezza, 1983). The model above illustrates how previous factual knowledge (acquired from academic pursuits) and life experiences (acquired from non-academic pursuits) overlap to form a learning foundation. The learner will then use either a linear or non-linear approach to acquire new knowledge. An example of a linear approach is the traditional outline and an example of a non-linear approach is the mind map learning technique, which relies upon visuospatial relationships. As depicted above, the learner may use both a linear and non-linear approach to learn, and the percentage of each differs with each learner. Adapted from D'Antoni and Pinto Zipp (2006).

experience; therefore, he may rely on more factual knowledge and less life experience as a learning foundation. In this case, a pedagogical approach to teaching that places more emphasis on the material is appropriate (Knowles, 1977).

Regardless of these differences, with their learning foundations in place, both students will then use either a linear or non-linear approach to acquire new knowledge. The predominant strategy used by students to learn is a linear approach (Isaacs, 1989; Morrison, McLaughlin, & Rucker, 2002; I. J. Russell et al., 1983), whereby the student outlines information into categories in a superior-to-inferior and left-to-right spatial pattern, as seen in standard note taking (D'Antoni & Pinto Zipp, 2006). Some learners may use both linear and non-linear approaches to varying degrees to acquire new knowledge, whereas others may only use one or the other. The advantage of a non-linear learning approach—as seen in both mind maps and concept maps—is that it allows students to recognize the intra- and inter-relationships between concepts, which reflects the kind of real-world thinking predominant in the clinical setting (Srinivasan, McElvany, Shay, Shavelson, & West, 2008).

Learning Styles

An appreciation of adult learning styles in medicine has recently emerged (S. S. Russell, 2006) even though the concept of learning styles has existed for the last three decades (Jung, 1971). The definition of learning style has also evolved. According to Hartley (1998), learning styles are the ways in which individuals characteristically approach different learning tasks. In contrast, learning strategies are techniques that students adopt when studying (Hartley, 1998). Hartley (1998) stated that learning styles are more innate to the learner than the more tangible learning strategies, which can be matched to the learning task. Different learning strategies, such as mind mapping, could be taught to students so that they have more options available to them when confronting a learning task.

A number of authors have reviewed different learning style models (Cassidy, 2004; DeBello, 1990). A four-stage learning cycle was proposed by Kolb (Kolb, 1976, 1984). In this model, learning is a continuous process and individuals may prefer one stage over another. According to Kolb (1976), the four stages are: concrete-experience (CE), abstract-conceptualization (AC), active-experimentation (AE), and reflective-observation (RO). The CE stage favors experiential learning, AC involves analytical and conceptual thinking to achieve understanding, AE involves trial-and-error learning, and RO involves intense consideration prior to action (Cassidy, 2004). Two bipolar dimensions of learning exist: prehension (attaining information from experience) is constituted by CE-AC and transformation (processing attained information) is constituted by AE-RO. Relative positioning along these dimensions defines the following learning styles: convergence, divergence, assimilation, and accommodation (Kolb, 1976).

The original learning style inventory (LSI), developed by Kolb (1976), was a 9-item self report scale that was revised into a 12-item self-report questionnaire (Kolb, 1984). A number of authors have examined the psychometric properties of Kolb's LSI, and have reported poor reliability and validity (Freedman & Stumpf, 1981; Geiger, Boyle, & Pinto, 1992; Geller, 1979; Newstead, 1992; Sims, Veres, Watson, & Buckner, 1986).

Gregorc (1982), who developed another LSI, stated that individuals have the following four observable channels: abstract, concrete, random, and sequential. These channels combine to form an individual's learning style, which reflects an innate worldview or approach (Cassidy, 2004). Thus, the transaction ability channels measured in the Gregorc Style Delineator (GSD) are concrete-sequential (CS), concrete-random (CR), abstract-sequential (AS), and abstract-random (AR) (Gregorc, 1984). According to Gregorc (1982), CS learners are "practical" and enjoy the concrete world of the physical senses, AS learners are "probable" and enjoy the abstract world of the intellect, AR learners are "potential" and enjoy the abstract world of feelings and emotions, and CR learners are "possible" and enjoy the concrete world of activity viewed through intuition (see Table 1).

The GSD consists of 10 columns where each column contains 4 words that are ranked in order by the individual. The GSD is a self-reflective inventory (Gregorc, 1984) that measures learning style according to Gregorc's model (Cassidy, 2004). In this study, learning style will be measured based on the model by Gregorc (1982) because this model includes a larger dimension of cognitive style (Rayner & Riding, 1997), better validity and reliability than previous LSIs, and has been used in medical education (Vanvoorhees et al., 1988).

Table 1.

Gregorc Style Delineator

	Mediation Channels			
Frames of Reference	CS	AS	AR	CR
Key Words	Practical	Probable	Potential	Possible
World of Reality	Concrete world of the physical senses	Abstract world of the intellect	Abstract world of feelings and emotions	Concrete world of activity viewed through intuition
Ordering Ability	Step-by-step linear progression	Two-dimension-al and tree-like	Web-like and multi-dimension-al	3-D patterns and links
Thinking Processes	Instinctive, methodical, deliberate	Intellectual, logical, analytical, creative	Emotional, psychic, perceptive, holistic	Intuitive, cutting-edge, impulsive, independe-nt
Creativity	Products, prototype, refinement, duplication	Synthesis, theories, models, matrices	Imaginatio-n, the arts, refinement, relationshi-ps	Intuition, originality, inventive, futuristic

Note. CS (Concrete-Sequential), AS (Abstract-Sequential), AR (Abstract-Random), CR (Concrete-Random). Adapted from Gregorc (1982).

Learning Strategies

Concept Maps

Concept maps are linear flow charts that use branch-like architecture, usually in a superoinferior direction, to organize information (Pinto & Zeitz, 1997). Concept mapping was developed over thirty years ago by Joseph Novak (Novak & Gowin, 1984). A literature review revealed several papers that discuss the usefulness of concept maps in medicine and other health professional fields, such as nursing (Daley et al., 1999), physical therapy (D'Antoni & Pinto Zipp, 2004), chiropractic (D'Antoni & Pinto Zipp, 2005), and even veterinary medicine (Edmondson & Smith, 1998).

Daley et al. (1999) evaluated the usefulness of concept maps in developing critical thinking skills in nursing students. Students in 6 senior clinical groups (N = 54) were told to construct concept maps during the first week of class and these same students created 3 maps over the course of the semester. The work of 3 students from each of the 6 groups (n = 18) were randomly selected for data analysis and scoring. Scoring criteria were based upon the development of propositions, hierarchy, and cross-links within the maps, which demonstrate nonlinear integration of material. A t test was used to compare mean scores of the first and final concept maps (p = .001) and the authors concluded that concept maps improved critical thinking in their cohort of nursing students. This conclusion was based on the premise that more in-depth (higher scoring) concept maps promoted critical thinking over time.

Over a decade ago, Irvine (1995) discussed how concept maps could be used to promote meaningful learning in nursing students. She based her definition of meaningful learning on Ausubel's Assimilation Theory (Ausubel, 1978), which states that one must relate or *assimilate* new information with pre-existing information in order to learn. Consequently, Irvine (1995) argued that concept maps facilitate the linking of new and old information.

Recently, Hill (2006) took a more pragmatic approach by describing how nursing students integrated their daily clinical experiences using concept maps. Students were given a concept map template and were asked to create a map as they gained information from their patient assessments throughout the day. They first constructed pre-conference maps from the data obtained when patients were admitted, and then modified the maps as they obtained more information throughout the day. At the end of the day, they met with nursing instructors to discuss their cases and then created post-conference maps. The author concluded from this qualitative study that the exercise was meaningful to the students because they were able to visualize changes made to their concept maps over time. In addition, when asked, the nursing instructors felt that the students demonstrated a stronger understanding of the nursing process as a result of using the maps (Hill, 2006).

West, Pomeroy, Park, Gerstenberger, and Sandoval (2000) studied the validity and reliability of the concept mapping assessment (CMA) technique in graduate medical education. These authors investigated whether concept maps could be scored reliably and whether CMA can measure changes in the conceptual framework of resident physicians.

A sample of 21 pediatric resident physicians (*N* = 21) were given a training session on how to construct concept maps and then asked to draw a concept map on the topic of seizures. Subjects then participated in a 3-session seizure education course and were asked to draw post-instruction concept maps. The maps were independently scored by 3 blinded raters and the interrater reliability was measured. The raters underwent a 30-minute concept map scoring training seminar prior to scoring the concept maps. Scores were based upon the following categories: concept links (2 points), level of hierarchy (5 points), cross-links (10 points), and examples (1 point). For each concept map, total scores and subscores for each category were generated and the correlation between raters' scores and subscores were determined using the Spearman rank correlation statistic. Pre-instruction and post-instruction scores were compared using the Wilcoxon signed rank test.

Mean scores of pre- and post- instruction concept maps increased significantly ($p = .03$). In addition, cross-links ($p = .02$) and concept links ($p = .01$) increased significantly. These results suggest that learning occurred as a result of the 3-session seizure education course. The authors assumed that the physicians' conceptual framework changed based not only on these results, but on the qualitative nature of the post-instruction maps, which were more complex with increased cross-linking than the pre-instruction maps. Interrater correlation of scores was weak to moderate for the pre-instruction map, and moderate to strong for the post-instruction map. The data suggest that concept maps can be reliably scored and can gauge the level and complexity of knowledge accrued by physicians as they progress through their residencies (West et al., 2000).

Although concept maps and mind maps have similar characteristics, they are fundamentally different in design as illustrated in Table 2. Concept maps are devoid of color and pictures, and are constructed in a top-to-bottom hierarchy. Mind maps, in contrast, use a central theme in the middle of a page with categories and subcategories that radiate peripherally, thus making them truly non-linear in design. The specificity of these categories increases towards the periphery of the page. The cross-links among categories highlight their intrinsic relationships, and allow the student to compare and contrast information. Unlike concept maps, mind maps are multisensory—they include color and pictures, which facilitate the conversion of information from short- to long-term memory (Bellezza, 1983; Day & Bellezza, 1983). This conversion, which was demonstrated in the study by Farrand et al. (2002), allowed medical students to retain domain knowledge.

Since critical thinking is dependent upon both content (domain) knowledge and problem familiarity (Willingham, 2007), mind mapping may facilitate critical thinking because it fosters student retention of factual information, as well as relationships between concepts (Farrand et al., 2002). The mind map technique is a unique strategy that addresses both these components of critical thinking; however, currently there are no data to support the hypothesis that mind maps facilitate critical thinking in medical students.

Table 2.

Comparison of Concept Maps and Mind Maps

	Type of Map	
Parameter	Concept Map	Mind Map
Design		
Hierarchical structure	Top to bottom	Central to peripheral
Color	Unicolor	Multicolor
Pictures	None	Multiple
Propositions[a]	Many	Few to none
Purpose	Promotes critical thinking by establishing nonlinear relationships between concepts	Promotes critical thinking by establishing nonlinear relationships between concepts and enhances recall of information through the use of dynamic colors and pictures[b]

[a]Propositions are linking words that accompany lines connecting concepts.
[b]According to Willingham (2007), critical thinking can only occur when a student recognizes the approach needed to solve the problem and also possesses the content knowledge needed to understand the multiple aspects of the solution.

Mind Maps

A number of authors have explored the application of mind maps in nursing education. Michelini (2000) provided an overview on how to construct mind maps and discussed potential uses of mind mapping in home health care nursing. She suggested that mind mapping could be used by home health care nurses to teach patients when and how to take their medications, and that patients would better remember when to take their medications because of the pictorial nature of mind maps. She described the implementation of mind mapping among 8 nursing students ($N = 8$) in a home health care agency. The students gathered data about patients' homes (environmental assessment criteria) and represented the data in mind maps (Michelini, 2000). Although the author provided an example of one student map, she did not discuss how the map was scored or assessed, nor whether the student enjoyed the experience. Consequently, this paper provided some background information on how to use mind maps, but did not actually support the efficacy of mind mapping in home health care nursing with empirical data. In a position paper, Mueller, Johnston, and Bligh (2002) suggested that mind maps can be used to create care plans and promote holistic thinking in nursing students. The authors described how nursing students at their institution use mind maps to create care plans instead of the traditional, column-based care plans that have traditionally been used in nursing.

Farrand et al. (2002) were the first group to investigate the potential role of mind mapping in medical education. These researchers explored whether the mind map learning technique was superior to traditional note taking in both short- and long-term factual recall of written information in medical students. The authors exposed 50 medical students ($N = 50$) to a 600-word sample of text from *Scientific American* and then administered 3 short tests based upon the text to the subjects.

Since the purpose of the first test was to establish baseline data, all subjects were given the text passage and asked to study the text using their own preferred study strategy for 10 minutes. Their notes were collected and students were given a brief mental arithmetic test, followed by the first recall test. Following this test, subjects were then randomly divided into two groups: half were assigned to a mind map (experimental) group and the other half to a self-selected study (control) group. Subjects in this later group were given a recess and asked to return after 30 minutes. During this time period, subjects in the mind map group were given a presentation on how to construct mind maps followed by a question-and-answer session. After this 30-minute interval, both groups were again exposed to the same text for 10 minutes and instructed to use either the mind map or self-study technique to learn the material depending on their particular group. Following a mental arithmetic task to prevent rehearsal of the text, a second recall test was administered. In addition, all subjects were asked to complete a single-question, Likert-style survey that asked what their level of motivation was in studying the material. Subjects reconvened 1 week later and, at that time, they were given a third and final recall test without the benefit of being exposed to the material. The third recall test was used to evaluate the effects of both techniques on long-term memory.

Analysis of variance (ANOVA) was the statistic used to compare mean scores (correct number of questions answered out of 15 questions) between the second and third recall tests. The analysis included the baseline (first recall test) as a covariate to account for differences between groups. The dependent variable was the number of questions correct and the independent variables were the study groups: mind map and self-selected.

Recall of factual information by subjects in both groups was nearly the same at the first test (baseline), as determined by the number of correct answers. Recall was only slightly higher in the mind map group after the second test, and this difference was only significant after adjusting for baseline performance and motivation. One week later, a comparison of mean scores on the third test revealed that the mind map group had significantly higher factual recall when compared to the self-study group, suggesting that the mind map technique improved long-term memory of factual information in these subjects to a greater degree. The authors also found significant differences in self-reported motivation with the mind map group having lower levels of motivation than the self-selected study group. Although not supported by other literature, this finding may be explained by the fact that students were not given adequate time to adjust to using the mind map technique, and therefore, may have felt less comfortable using it.

A limitation of the study was that alternate assignment was used to place subjects into groups. A more robust technique such as randomization using a computer program would have increased the internal validity of the study.

Despite these limitations, the results of the study suggest that the mind map technique may improve both short- and long-term factual memory in medical students. However, this study did not address critical thinking. Studies exploring the relationship between mind mapping and critical thinking are needed before the usefulness of mind mapping can be fully supported in medical education.

Wickramasinghe et al. (2007) were the second group to publish a study on the effectiveness of mind maps in medical education. Using a similar study design as that used by Farrand et al. (2002), these authors selected 70 (N = 70) new entry medical students and assigned them into 2 groups: mind map and self-selected study groups. Both groups were exposed to a text passage on "iron deficiency anemia" and structured essay questions based on the passage were administered. The mind map group was given a 30-minute lesson on how to construct mind maps. Following the lesson, both groups were given the passage for 45 minutes and asked to write notes. Subjects in the mind map group were asked to exclusively use mind maps to create their notes, whereas those in the self-selected study group were asked to write notes based upon their preference. After this interval, both groups were given a test based upon the passage. Additionally, subjects in the mind map group were administered a questionnaire to ascertain their perceptions of mind mapping. The authors also developed a method to score the mind maps based on structure and content; however, they did not describe the method nor did they provide any data to support it (Wickramasinghe et al., 2007). The mean score obtained by all subjects (n = 70) was 34.4%. The mean score of subjects in the mind map group was 31.3% and the mean score of subjects in the self-selected study group was 37.6%. The authors reported that there was no significant difference in scores between groups (Wickramasinghe et al., 2007). They did, however, report that all of the subjects in the mind map group (100%) perceived that mind maps are useful for memorizing information, 97.1% perceived that mind maps are useful for summarizing information and they want to use the technique in the future, and 87.9% wanted to learn more about mind maps. Based upon the findings, the authors concluded that mind mapping may not be effective in improving retention of information in the short term (Wickramasinghe et al., 2007).

Constructing Mind Maps

The mind map learning technique is an example of a non-linear approach to learning that encourages the learner to think radially using visuospatial relationships (Buzan & Buzan, 1993; Gelb, 1998). According to Buzan and Buzan (1993), a mind map should be drawn on blank paper that is larger than standard 8 ½ by 11 inch paper. The rationale behind using larger paper is to allow the student to break away from the boundaries inherent in standard size paper and thus propagate creativity. The use of lined paper is discouraged because it theoretically restricts thought (Gelb, 1998). Once suitable paper is obtained, a medium for drawing the mind map is necessary—namely, colored pens or pencils. The student begins by drawing an image in the center of the paper that reflects the central theme, or topic, of the mind map (D'Antoni & Pinto Zipp, 2006). For example, a mind map on the rules of mind mapping could have an image of the cerebrum in the center of the page. This central image allows the student 360 degrees of freedom to develop the mind map. Next, the student would draw the main branches with key words extending from the central image and these branches represent the different categories relevant to the content of the mind map. In the previous example, some of the key words are *start*, *connect*, *print*, and *association*. It is important to print the words and ensure that their length is the same as the lines underneath them so that the completed map will be easier to comprehend (Gelb, 1998; Michelini, 2000). From these main branches, relevant sub-branches are created. Each of the branches and sub-branches should contain accompanying pictures to aid the student in recalling the information. The result is a non-linear, pictorial representation of information that highlights interconnections between concepts. Farrand et al. (2002) showed that this non-linear, visuospatial arrangement of branches enhances recall more than simple note taking. As suggested by D'Antoni and Pinto Zipp (2006), as more sub-branches are created, students can recognize patterns between key words that should be connected, which may result in the integration of different parts of the mind map. Researchers have not investigated whether the number of connections between branches of a mind map results in an increase in critical thinking or merely aids in the recall of factual information.

Summary

Medical schools strive to develop physicians who not only possess factual information, but are capable of critical thinking (Koo & Thacker, 2008). Although there are many published studies on adult learning theory and critical thinking in non-medical students, few studies have investigated the efficacy of specific learning strategies in facilitating critical thinking among medical students. Even though researchers have begun to investigate the link between concept maps and critical thinking (Daley et al., 1999; Ferrario, 2004; Irvine, 1995), none have investigated this relationship using mind maps. Because of the structural differences between concept maps and mind maps, the data supporting the use of concept maps to promote critical thinking are not generalizable to mind maps.

An important characteristic that distinguishes the expert physician from novice medical student is the integrated and complex knowledge framework possessed by the physician (Srinivasan et al., 2008). Although this framework is begun during medical education, it is never formally assessed and sometimes not even recognized (Srinivasan et al., 2008). This could be problematic because frameworks have been linked to critical thinking. A meta-analysis of strategies used to teach scientific problem solving found that effective strategies were those that build integrated frameworks of knowledge (e.g., mind maps) (Taconis et al., 2001). Consequently, this study will investigate the relationship between mind maps and critical thinking in medical students.

Chapter 3

METHODS

Design

According to Portney and Watkins (2000), clinical research can be described along a continuum from descriptive to exploratory to experimental. The design of this study is exploratory and quantitative in nature. Descriptive and correlational methods were used to investigate whether (1) mind mapping (MM) effects the recall of factual information compared to standard note-taking (SNT), (2) MM is correlated with critical thinking by documenting whether a more developed mind map (i.e., the greater the quality of the mind map) correlates with a higher score on the Health Sciences Reasoning Test (HSRT), and (3) a correlation exists between the depth of mind map, learning style preference (Gregorc Style Delineator), and HSRT score.

Variables

Independent Variable

The independent variable in this study was the note-taking strategy used by the medical students. Subjects were alternately assigned to 2 note-taking groups: a standard note-taking (control) group and mind map (experimental) group (Figure 3).

Subjects in both note-taking groups were asked to learn information contained in a 394-word text passage—on the topic of cacti and other succulent plants—from the verbal ability section of a previously published Graduate Record Examination (GRE). This passage was chosen because (1) it was specifically

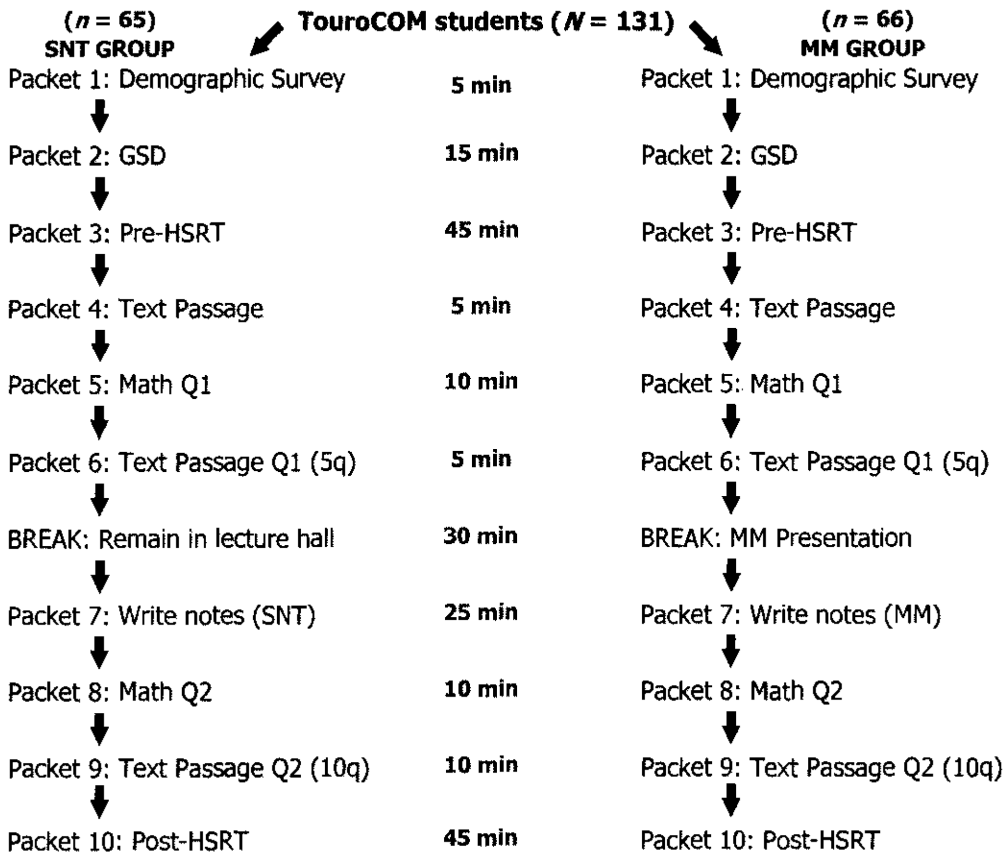

Figure 3. Research procedure.

written for undergraduate students who want to pursue graduate training, and therefore, matches the academic level of most of the medical students in the sample, (2) most of the medical students have never been exposed to a GRE passage since entry into medical school requires the Medical College Admissions Test (MCAT) and not the GRE, and (3) the quiz questions used to assess their understanding of the passage have been field-tested and standardized.

Subjects in the control group used standard note-taking (SNT) strategies that they have been using throughout their academic careers to learn the text passage. SNT is defined as any study strategy that does not rely on reorganizing information using architecture commonly seen in a concept map or mind map (Farrand et al., 2002). SNT is a process whereby notes are arranged in a hierarchy from the top of a page to the bottom, or from left to right, without any hierarchy (D'Antoni & Pinto Zipp, 2006). Subjects in the experimental (mind map) group were given a 30-minute presentation on mind maps and then instructed to create mind maps in order to take notes on the material in the text passage.

Dependent Variables

There were four dependent variables in this study. The first one was the score on the text passage quiz, of which there were two. These two quizzes, which were based on the content of the GRE text passage, were administered to all subjects after assignment to the groups. All subjects were simultaneously (but in different rooms) exposed to the passage for 5 minutes and were not permitted to write any notes. The passage was collected and followed by the administration of math quiz 1 (see Appendix A). This quiz was used to "blank" the minds of the subjects by preventing the simple recall of information that could result in a higher quiz score and confound the results (Farrand et al., 2002).

After math quiz 1, all subjects were administered text passage quiz 1 (see Figure 3). The purpose of this 5 multiple-choice question quiz was to test the students' factual understanding of the passage without any note-taking strategy. This baseline quiz was used as a covariate to account for potential differences between the groups prior to initiating any note-taking strategy.

After taking text passage quiz 1, subjects in the mind map group were given a presentation on mind maps and how to construct them, while at the same time, subjects in the control group were sequestered for a break. After 30 minutes, all subjects were then re-exposed to the text passage and instructed to take notes using either standard note-taking (SNT) or mind maps (MMs), depending on their group assignment. All subjects were given 25 minutes (see Figure 3) for note-taking and at the end of this time period, all passages and notes were collected. This was followed by the administration of math quiz 2 (see Appendix B) in order to again discourage the simple recall of information by the subjects. After math quiz 2, all subjects were simultaneously administered text passage quiz 2 based upon the passage. This quiz consisted of 10 multiple-choice questions: the same 5 questions from quiz 1 plus an additional 5 questions. This was done to see if the students retained the factual information and to address potential testing effects (i.e., higher scores due to repeated testing exposure).

The second dependent variable of this study was the HSRT score. The HSRT consists of 33 multiple-choice questions that measure critical thinking by challenging students to form reasoned judgments based on textually presented information consisting of a number of vignettes (N. C. Facione & Facione, 2006). The information presented in the vignettes includes diagrams, charts, and other data related to health care scenarios. The HSRT does not test domain knowledge (i.e., subject-specific knowledge such as that found in anatomy and biochemistry); therefore, subject-specific knowledge is not needed by the students taking the exam. The HSRT has been extensively studied in health professional students and working professionals (N. C. Facione & Facione, 2006). The HSRT reports an overall numerical score and 5 subscales: analysis, inference, evaluation, deductive reasoning, and inductive reasoning. Analysis, inference, and evaluation are subscales advanced by the authors of the Delphi Report of the American Philosophical Association (APA, 1990). In contrast, deductive and inductive reasoning follow a more traditional paradigm of reasoning (N. C. Facione & Facione, 2006). In the HSRT, the Delphi subscales are scored using 6 items and the traditional reasoning subscales are scored using 10 items. The scoring scheme for the HSRT is depicted in Table 3.

The third dependent variable of this study was the score obtained on the mind maps created by subjects in the MM group. In order to investigate whether a relationship existed between mind map depth, HSRT score, and learning preference, the mind maps were scored by three independent examiners (AVD, GPZ, and VGO) using a mind map assessment system (MMAS) adapted from a

Table 3.

HSRT Scoring Scheme

HSRT Subscale	Score	Description
	Delphi (6 items)	
Analysis	0, 1, 2	Weakness
Inference	3, 4	Average strength
Evaluation	5, 6	Strong
	Traditional Reasoning (10 items)	
Deductive Reasoning	0, 1, 2, 3	Weakness
Inductive Reasoning	4, 5, 6, 7	Average strength
	8, 9, 10	Strong

concept map assessment (CMA) system by the author.

The fourth dependent variable of this study was the Gregorc Style Delineator (GSD), which was used to assess learning style preference. No study has attempted to correlate student preference for using the mind map technique based on learning style. The GSD is a valid and reliable tool that classifies learners as Concrete-Sequential (CS), Abstract-Sequential (AS), Concrete-Random (CR), and Abstract-Random (AR) (Gregorc, 1982). Table 1 contains the characteristics of the four classifications of learners measured by the GSD: CS learners are product-oriented, AS learners are proof-oriented, CR learners are perception-oriented, and AR learners are person-oriented. The reliability range of the GSD (alpha coefficients) has been demonstrated to be from 0.89 to 0.93 with test-retest correlation coefficients from 0.85 to 0.88 (Gregorc, 1984). Construct validity and predictive validity were demonstrated with correlations ranging from 0.55 to 0.78 (Gregorc, 1984). The GSD score was used to determine if a relationship existed between learning style preference, depth of mind map, and HSRT score.

Instrumentation

Measuring Critical Thinking

In order to explore the hypothesis that mind mapping promotes critical thinking, it is necessary to discuss how critical thinking is measured. Many concept map studies have not measured critical thinking, but instead, inferred that critical thinking occurred based upon the scoring of concept maps. Well-designed concept maps or mind maps, in and of themselves, do not directly equate with critical thinking since there is no objective measure of critical thinking. In a recent dissertation, Roop (2002) investigated the effect of concept mapping on critical thinking in nursing students by using a quasi-experimental, control group design with a convenience sample of 29 (n = 29) students. Students in the experimental group constructed 2 concept maps, and these maps were scored using the method described by Novak and Gowin (1984), which was described in the *Concept Maps* section of this paper and also investigated by West et al. (2002). Although this is a valid and reliable method for scoring the depth and integration of concept maps using hierarchy and links, it does not necessarily measure critical thinking.

Valid and reliable critical thinking tools are described in the research literature. Studley (2005) investigated the effect of concept mapping on critical thinking in baccalaureate nursing students using the Critical Thinking Indicators tool to measure critical thinking (Ennis & Millman, 2005). Boyadjian-Samawi (2006) investigated concept mapping and critical thinking in baccalaureate nursing students using the California Critical Thinking Skills Test (CCTST) and California Critical Thinking Disposition Inventory (CCTDI) to measure critical thinking. These tests are valid and reliable for measuring critical thinking in college students (P. A. Facione, 1990) but many of these students are not health professional students. In contrast, the Health Sciences Reasoning Test (HSRT)—which, evolved from the CCTST and was developed by Facione and Facione (2006)—is a standardized, 33-item multiple choice test that has been shown to be a valid and reliable indicator of critical thinking specifically developed for health professional students. HSRT normative data are available that have been sampled from 3,800 (N = 3,800) health science students (N. C. Facione & Facione, 2006). The sample was split into undergraduate- and graduate-level health science students. The latter group may include medical students and the normative data for this cohort (n = 1,900) is as follows: total (M = 22.61, Mdn = 23, and SD = 4.10), analysis (M = 4.45, Mdn = 5, and SD = 1.17), inference (M = 3.81, Mdn = 4, and SD = 1.28), evaluation (M = 5.00, Mdn = 5, and SD = 1.08), induction (M = 7.71, Mdn = 8, and SD = 1.38), and deduction (M = 7.19, Mdn = 8, and SD = 2.01). The HSRT can be used in a pretest-posttest design (N. C. Facione & Facione, 2006) to measure changes in critical thinking based upon an intervention, such as the introduction of the mind map learning strategy.

Mind Map Assessment System

Currently, there are no valid and reliable instruments to score mind maps reported in the literature. However, in several studies instruments for concept map assessment (CMA) have been reported. West, Park, Pomeroy, and Sandoval (2002) compared 2 CMA scoring systems (structural and relational methods) using a methodology similar to their aforementioned previous study (West et al., 2000).

The CMA structural method scoring system assigns weighted numerical scores based upon hierarchical structure, cross-links, and concept-links (Novak & Gowin, 1984; West et al., 2002). In contrast, the CMA relational method scoring system is based on the quality of each concept-link, without considering the structure of the map (West et al., 2002). Analysis of the data revealed that the relational method failed to demonstrate the validity seen in the structural method. Therefore, the structural method is more sensitive than the relational method in measuring changes and differences in concept maps. A study investigating the reliability of CMA was recently published and the interrater reliability (G-coefficient) of the CMA structural scoring system was found to be 0.98 (Srinivasan et al., 2008). A comparison of the structural and relational CMA scoring systems is outlined in Table 4.

Concept maps and mind maps are structurally similar and rely on a non-linear framework. From the perspective of the learner, both maps are identical because they allow the learner to reach a metacognitive level by integrating information to achieve deep learning. In the present study, therefore, the CMA structural scoring system could have been used to score the mind maps because of the identical nature of the metacognitive processes facilitated by both maps. However, two components unique to mind maps would have been excluded from the assessment; namely, pictures and colors. In order to prevent this exclusion, the CMA structural scoring system was adopted to score the mind maps with the addition of pictures and colors, which led to the creation of the mind map assessment system (MMAS) depicted in Table 5. The inclusion of scores for the number of pictures and colors allowed the scoring to include the unique constructs of the mind map in addition to those found in the CMA.

Table 4.

Comparison of Concept Map Assessment Systems

Structural System	*Relational System*
Weighted scores based on hierarchical structure, cross-links, and concept-links.	Based on the quality of each concept-link without considering the structure of the map.
Scoring	**Scoring**
• Concept-link (2 points each) • Cross-links (10 points each) • Hierarchy (5 points each) • Examples (1 point each) • Invalid components (0 points)	• Invalid relationship between concepts (0 points) • Valid relationship between concepts but propositional label is incorrect (1 point) • Valid relationship and propositional label correct but lacks foundational or core relationship to subject matter (2 points) • Valid relationship and propositional label and foundational or core relationship apparent (3 points)

Note. Adapted from West et al. (2002).

Table 5.

Mind Map Assessment System

Mind Map Assessment System
Weighted scores based on hierarchical structure, cross-links, concept-links, pictures, and color.
Scoring
• Concept-link (2 points each)
• Cross-links (10 points each)
• Hierarchy (5 points each)
• Examples (1 point each)
• Invalid components (0 points)
• Pictures (5 points each)
• Colors (5 points each)

Note. Adapted from West et al. (2002).

The MMAS was used to assess the depth of student mind maps in this study and establishing its interrater reliability was necessary.

Three examiners (AVD, GPZ, and VGO) scored the mind maps of all subjects in the MM group and verified the face validity of the MMAS. The examiners were experienced educators who have used mind maps in the academic setting with health professional students and have participated in previous mind map research. The examiners met to ensure that they understood how to use the MMAS and were given the MMAS scoring form. After the study was complete, the examiners scored all the mind maps (n = 66) independently.

Figure 4 is an example of a high-scoring mind map from one of the subjects in the MM group. AVD assigned this mind map a total score of 400, GPZ assigned it a total score of 337, and VGO assigned it a total score of 377. The average total score of this mind map, based on all 3 examiners, was 371.33.

Descriptive statistics of all the mind map scores (n = 66) between the examiners are found in Appendix C. Examiner 1 (AVD) recorded the following for total mind map score: M = 200 and SD = 55.50 with a *Min* score of 102 and a *Max* score of 400. Examiner 2 (GPZ) recorded the following for total mind map score: M = 175.47 and SD = 63.22 with a *Min* score of 92 and a *Max* score of 415. Examiner 3 (VGO) recorded the following for total mind map score: M = 279.35 and SD = 77.77 with a *Min* score of 134 and a *Max* score of 539. Data for separate categories are found in Appendix C.

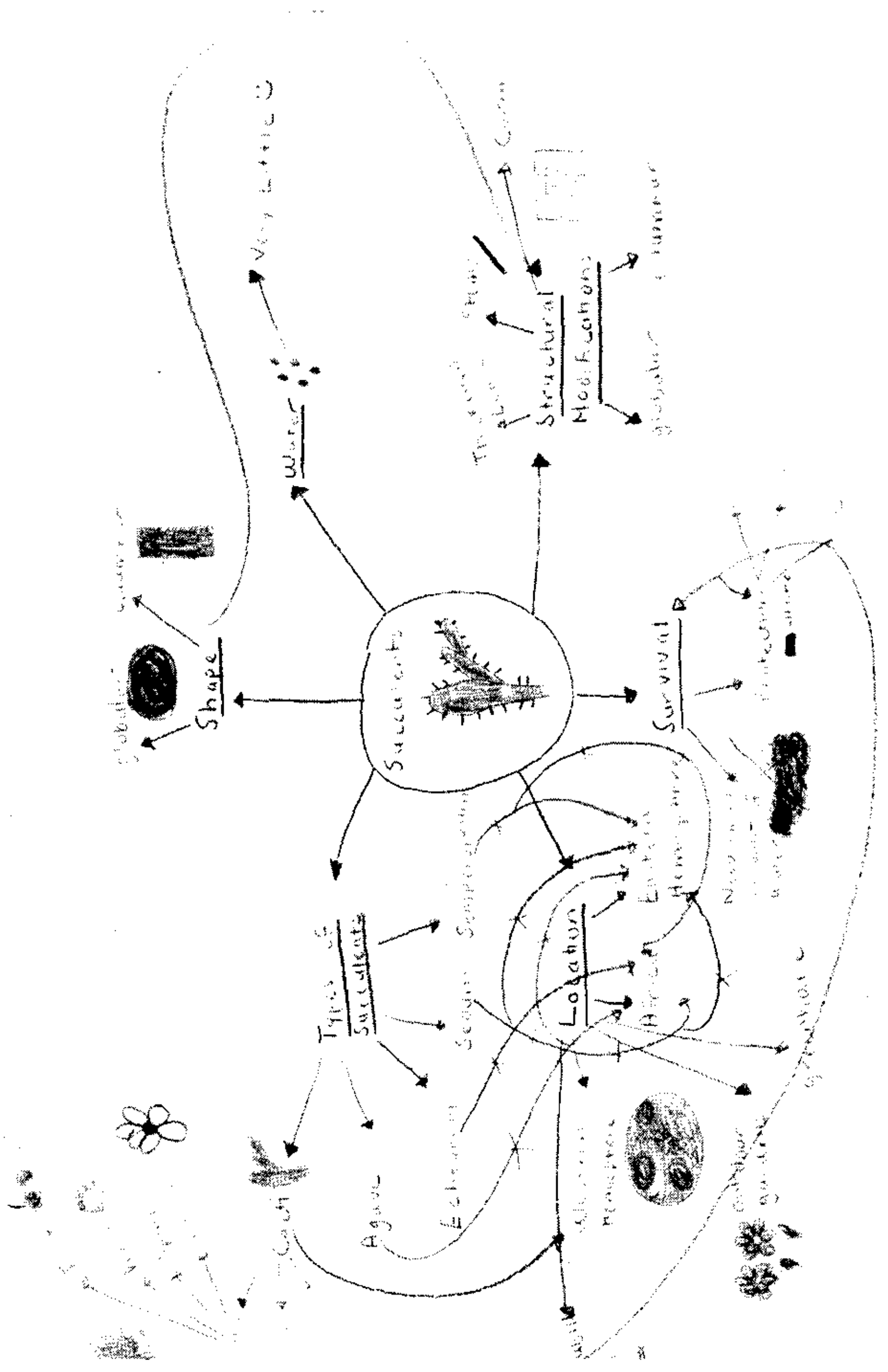

Figure 4. An example of a high-scoring mind map from one of the medical students in this study. AVD assigned this mind map a total score of 400, GPZ assigned it a total score of 337, and VGO assigned it a total score of 377. The average total score of this mind map, based on all 3 examiners, was 371.33. Note the hierarchical organization of the mind map and the effective use of pictures and colors. In addition, this map contains numerous cross-links, which resulted in higher scores.

Interrater reliability refers to the variations that exist among two or more human examiners (Portney & Watkins, 2000). In the present study, it was necessary to measure the interrater reliability among the 3 examiners who used the MMAS to score the mind maps to determine if the observed mind map scores represented the true scores (Portney & Watkins, 2000). Thus, interrater reliability was accomplished using the intraclass correlation coefficient (*ICC*) as an index to reflect both correlation and agreement among the examiners. The *ICC* range is from 0 to 1 and there are six methods of *ICC* (Shrout & Fleiss, 1979). The second method (covariance matrix) was chosen because the 3 examiners are representative of a larger population of similar examiners (Portney & Watkins, 2000). In this method, ANOVA is used and the examiner is the independent variable (McGraw & Wong, 1996).

The results of the *ICC* analysis for 66 mind map scores based on 3 examiners follow: concept-link ($ICC = .05$, $p = .39$), cross-link ($ICC = .58$, $p = .00$), hierarchy ($ICC = .23$, $p = .10$), example ($ICC = .53$, $p = .00$), picture ($ICC = .86$, $p = .00$), color ($ICC = .73$, $p = .00$), and total score ($ICC = .86$, $p = .00$). These data are also found in Appendix D. The interrater reliability of the MMAS is similar to that reported for the CMA structural system (Srinivasan et al., 2008; West et al., 2002).

The high *ICC* value for overall total score suggests that the MMAS can be reliably scored by different examiners; however, further research is needed to investigate its construct validity and reliability. As expected, pictures and colors demonstrated strong interrater reliability (.86 and .73, respectively). This suggests that these variables can also be reliably scored by different examiners. Cross-links (.58) and examples (.53) were moderately reliable. Cross-links were often difficult to identify from concept-links in the mind maps, and this was especially true for the more complex mind maps. This may explain why they were found to be moderately reliable. Another explanation is that most of the mind maps contained few or no cross-links, which could have lowered the reliability. Like cross-links, most of the mind maps contained few examples and some did not have any examples—this may explain why they had moderate reliability. In this study, concept-links and hierarchies were found to have very weak reliability, and this may be due to confusion as to their operational definitions. Each concept-link should have been assigned a numeric value (2 points each). However, unlike concept-links which are individually scored and summated, each level of hierarchy (5 points each) should have been scored only once. For example, the mind map in Figure 4 has quaternary (fourth-level) hierarchy, which can be examined in the left-upper quadrant of the map. Therefore, 20 points should have been assigned for hierarchy in this mind map. The examiners agreed that distinguishing between concept-links and hierarchies was the most difficult aspect of using the MMAS to assess the mind maps.

Setting

This study was conducted at an osteopathic medical school located in a large metropolitan area in the Northeastern Unites States.

Sample

An *a priori* power analysis (Faul & Erdfelder, 1992) using a one-tailed *t*-test revealed a minimum sample size of 70 subjects. This calculation was based on the following: effect size d = 0.8, alpha = 0.05, and power = 0.95. The large sample size (N = 131) assumes a normal distribution of the population, and therefore, parametric statistics were used to analyze the data. The sample of convenience consisted of first-year medical students who voluntarily participated in this study.

Chapter 4

RESULTS

Characteristics of the Sample

A total of 131 subjects (N = 131) volunteered to participate in the study. All subjects were first-year medical students matriculated in an osteopathic medical school in a large metropolitan area in the Northeastern Unites States. The study was conducted on a half-day during orientation week. The study took place in adjacent lecture halls. Subjects were lined up outside the lecture halls and then alternately assigned to either the SNT group (n = 65), in one lecture hall, or the MM group (n = 66), in the other lecture hall. A research assistant facilitated the assignment of subjects and was blinded to group assignment. None of the subjects in either group used mind maps as their preferred learning strategy prior to the study.

There were 32 males (49.2%) and 33 females (50.8%) in the SNT group. The MM group consisted of 31 males (47%) and 35 females (53%). Thus, the gender distributions were similar in both groups. The ethnicity of subjects in the SNT group were: 1 African American (1.6%), 29 Caucasians (45.3%), 23 Asian Americans / Pacific Islanders (35.9%), 1 Hispanic / Latino / Mexican American (1.6%), and 10 Mixed / Other (15.6%). The ethnicity of subjects in the MM group were: 3 African Americans (4.7%), 35 Caucasians (54.7%), 18 Asian Americans / Pacific Islanders (28.1%), 3 Hispanics / Latinos / Mexican Americans (4.7%), and 5 Mixed / Other (7.8%). These data are depicted in Table 6.

Table 6.

Demographic Comparison Between Subjects in Both Groups (N = 131)

		SNT Group (*n* = 65)	MM Group (*n* = 66)
Gender	Male	32 (49.2%)[a]	31 (47.0%)
	Female	33 (50.8%)	35 (53.0%)
		SNT Group (*n* = 64)[b]	MM Group (*n* = 64)[c]
Ethnicity	African American	1 (1.6%)	3 (4.7%)
	Anglo American, Caucasian	29 (45.3%)	35 (54.7%)
	Asian American/ Pacific Islander	23 (35.9%)	18 (28.1%)
	Hispanic, Latino, Mexican American	1 (1.6%)	3 (4.7%)
	Mixed/Other	10 (15.6%)	5 (7.8%)

[a]Data are presented as number of subjects (percentage) within the group. [b]One subject in the control group did not disclose ethnicity. [c]Two subjects in the study group did not disclose ethnicity.

The mean age of subjects in both groups was similar. In the SNT group, the mean age of subjects was 24.45 years (*SD* = 3.26) and in the MM group, the mean age of subjects was 24.74 years (*SD* = 3.91). Using one-way analysis of variance (ANOVA), no significant difference in mean age between groups was found. Subjects in the SNT group had a mean total SAT score of 1285.71 (*SD* = 112.06) and those in the MM group had a mean total SAT score of 1254.46 (*SD* = 110.20). No significant difference in total SAT score between groups was found. In addition, no significant differences in SAT verbal and math subscores between groups were found (see Table 7). The mean total MCAT score of subjects in the SNT group was 27.26 (*SD* = 3.04) and the mean total MCAT score of subjects in the MM group was 27.05 (*SD* = 3.17). No significant difference in total MCAT score between groups was found. In addition, no significant differences in MCAT biology, physics, and verbal subscores between groups were found (see Table 7).

Table 7.

Comparison of SAT and MCAT Scores Between Subjects in Both Groups (N = 131)

Variable	*M*	*n*[a]	*SD*
	SNT Group Subjects (*n* = 65)		
Age	24.45	65	3.26
SAT (Total)	1285.71	49	112.06
SAT (Verbal)	639.49	39	77.45
SAT (Math)	656.50	40	69.52
MCAT (Total)	27.26	65	3.04
MCAT (Biology)	9.49	61	1.24
MCAT (Physics)	9.05	61	1.51
MCAT (Verbal)	8.89	61	1.95
	MM Group Subjects (*n* = 66)		
Age	24.74	66	3.91
SAT (Total)	1254.46	56	110.20
SAT (Verbal)	623.08	39	65.58
SAT (Math)	654.10	39	66.44
MCAT (Total)	27.05	66	3.17
MCAT (Biology)	9.52	62	1.30
MCAT (Physics)	9.02	62	1.54
MCAT (Verbal)	8.68	62	1.80

[a]For some variables, *n* changes because subjects did not recall or never took the assessment (i.e., some students took the ACT instead of the SAT).

Quiz Assessment of Domain Knowledge

The mean score of the pre-quiz (quiz 1) among subjects in the SNT group was 3.15 (SD = 1.22) and the mean score of the pre-quiz (quiz 1) among subjects in the MM group was 3.42 (SD = .84). A two-tailed independent samples *t* test revealed no significant difference between the means: t (129 df) = –1.47, p = .14.

The mean score of the post-quiz (quiz 2) among subjects in the SNT group was 7.85 (SD = 1.40) and the mean score of the post-quiz (quiz 2) among subjects in the MM group was 7.64 (SD = 1.22). A two-tailed independent samples *t* test revealed no significant difference in means between the groups: t (129 df) = .912, p = .36. Figure 5 is a bar chart depicting these data.

A comparison of the means of the pre-quiz (quiz 1) scores and post-quiz (quiz 2) scores between groups revealed no significant differences (SNT pre-quiz mean = 3.15, MM pre-quiz mean = 3.42, SNT post-quiz mean = 7.85, and MM post-quiz mean = 7.64). However, the difference between means of the pre-quiz (quiz 1) and post-quiz (quiz 2) scores in each group differed. In the SNT group, this difference was 4.70 (7.85 – 3.15 = 4.70) and in the MM group, this difference was 4.22 (7.64 – 3.42 = 4.22). In order to further analyze these results and control for the fact that the quiz scores themselves were slightly skewed (i.e., a long tail created by a few students who did very poorly), a standardized *z* score

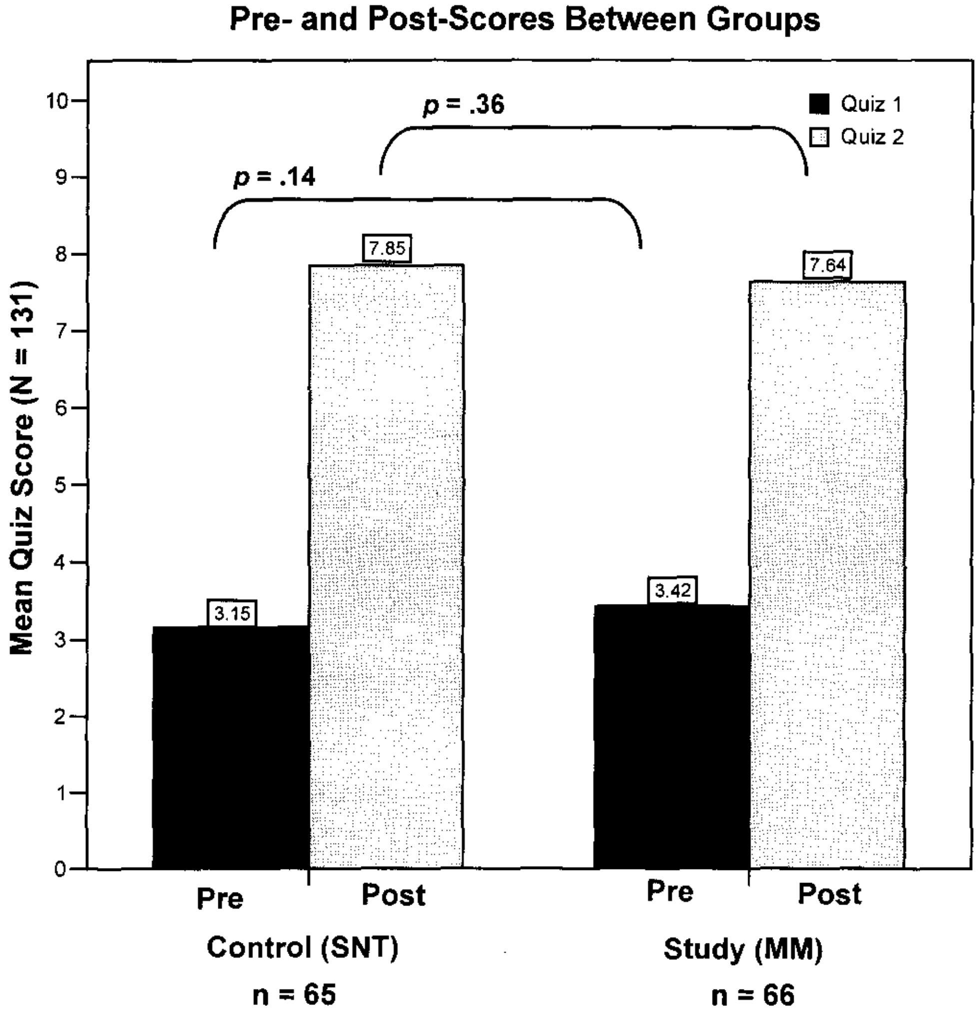

Figure 5. Pre- and post-quiz scores between groups. Both quizzes were based on a 394-word text passage. There are no significant differences in mean scores between groups on both the pre-quiz (quiz 1) and post-quiz (quiz 2).

was used. A difference *z* score was created between the standardized quiz scores so that the degree to which the variability in each quiz affected the outcome would be the same (Portney & Watkins, 2000). Unlike the quiz scores, the difference *z* score conforms to a Gaussian distribution as demonstrated in Figure 6. The difference *z* score is standardized with a mean of 0 and a *SD* of 1.08. On the average, subjects in the MM group had lower scores on the second quiz (–.2061 *SD*), while those in the SNT group increased by about the same amount (.2093 *SD*). This represents about two-tenths of a *SD*. The fact that the scores of the groups vacillated by almost the same amount is not by chance. A two-tailed independent samples *t* test revealed a significant difference between the means of the *z* score difference: t (129 df) = 2.241, p = .027.

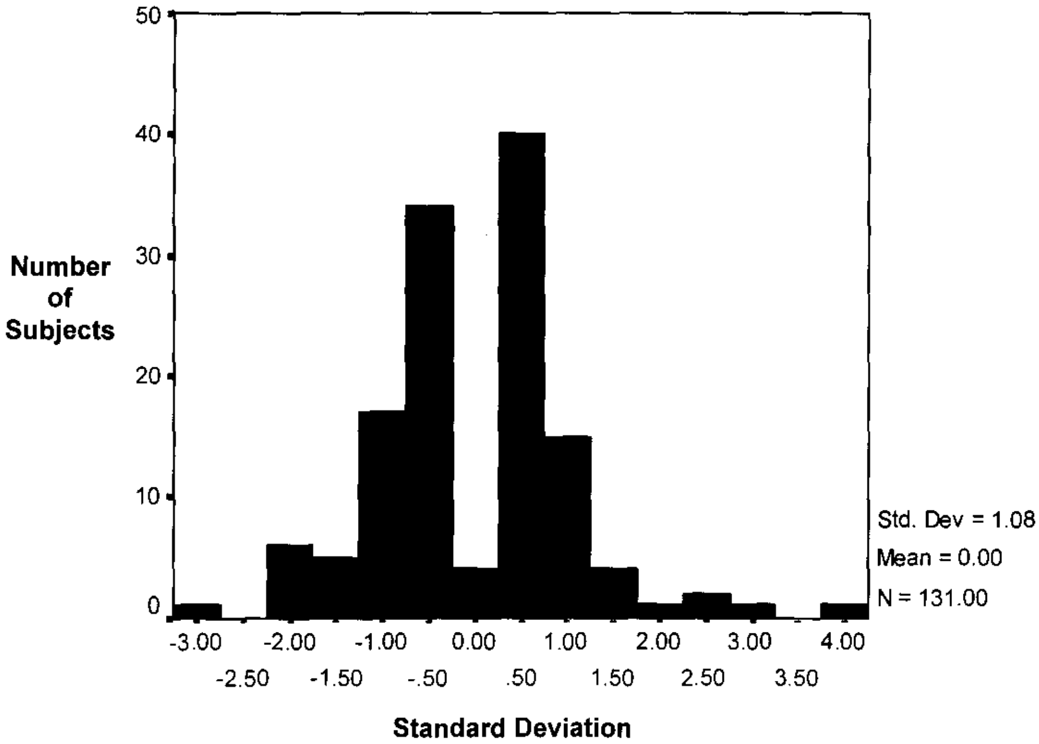

Figure 6. Histogram of the differences between the pre-quiz and post-quiz scores based upon a standardized *z* score. A difference score was created between the standardized quiz scores so that the degree to which the variability in each quiz affected the outcome would be the same. The difference score is standardized with a mean of 0 and a *SD* of 1.08. On the average, subjects in the MM group had lower scores on the second quiz (–.2061 *SD*), while those in the SNT group increased by about the same amount (.2093 *SD*). This represents about two-tenths of a *SD* and the difference was found to be significant ($p = .027$).

HSRT Assessment of Critical Thinking

All subjects were given the HSRT prior to the intervention (pre-HSRT) and after the intervention (post-HSRT). Descriptive statistics of pre-HSRT scores for all subjects (N = 131) were as follows: total (M = 23.75, SD = 3.38), analysis (M = 4.85, SD = 1.06), inference (M = 3.82, SD = 1.25), evaluation (M = 5.30, SD = .84), induction (M = 7.97, SD = 1.20), and deduction (M = 7.59, SD = 1.76). Descriptive statistics of post-HSRT scores for all subjects (N = 131) were as follows: total (M = 23.73, SD = 3.78), analysis (M = 4.84, SD = 1.05), inference (M = 3.74, SD = 1.24), evaluation (M = 5.28, SD = .88), induction (M = 7.96, SD = 1.24), and deduction (M = 7.69, SD = 1.91). Descriptive statistics comparing pre-HSRT scores between subjects in the SNT group and MM group are found in Table 8. Similarly, descriptive statistics comparing post-HSRT scores between subjects in the SNT group and MM group are found in Table 9.

ANOVA was used to compare the means of pre- and post-HSRT total scores and subscores between the SNT group and MM group. No significant differences were found among any of the pre- and post-HSRT total scores and subscores. The results of these analyses for the pre-HSRT were: total (p = .26), analysis (p = .16), inference (p = .72), evaluation (p = .78), induction (p = .88), and deduction (p = .31). The results of this analysis for the post-HSRT are: total (p = .45), analysis (p = .68), inference (p = .87), evaluation (p = .64), induction (p = .94), and deduction (p = .54). The bar chart in Figure 7, which displays pre- and post-HSRT total scores, demonstrates that no significant differences exist between pre- and post-HSRT total scores between the groups.

Table 8.

Descriptive Statistics of Pre-Health Sciences Reasoning Test (Pre-HSRT) Scores in SNT and MM Groups (N = 131)

Variable	*M*	*Mdn*	*Trimmed M*	*SD*	*SEM*	*Min*[a]	*Max*[b]
			SNT Group (*n* = 65)				
Total Score	23.41	24	23.54	3.69	.45	11	31
			Subscale Scores[c]				
Analysis	4.72	5	4.81	1.21	.15	1	6
Inference	3.78	4	3.81	1.30	.16	1	6
Evaluation	5.27	5	5.37	.89	.11	2	6
Inductive Reasoning	7.98	8	8.10	1.26	.15	3	10
Deductive Reasoning	7.43	8	7.57	1.97	.24	2	10
			MM Group (*n* = 66)				
Total Score	24.07	24	24.05	3.04	.37	16	33
			Subscale Scores[c]				
Analysis	4.98	5	5.03	.88	.10	3	6
Inference	3.86	4	3.88	1.21	.14	1	6
Evaluation	5.31	5	5.38	.80	.09	2	6
Inductive Reasoning	7.95	8	7.98	1.14	.14	5	10
Deductive Reasoning	7.74	8	7.76	1.52	.18	5	10

[a]Minimum. [b]Maximum. [c]There are five HSRT subscales: analysis, inference, evaluation, inductive reasoning, and deductive reasoning.

Table 9.

Descriptive Statistics of Post-Health Sciences Reasoning Test (Post-HSRT) Scores in SNT and MM Groups (N = 131)

Variable	*M*	*Mdn*	*Trimmed M*	*SD*	*SEM*	*Min*[a]	*Max*[b]
			SNT Group (*n* = 65)				
Total Score	23.47	24	23.66	3.82	.47	9	30
			Subscale Scores[c]				
Analysis	4.87	5	4.94	1.05	.13	1	6
Inference	3.72	4	3.74	1.26	.15	1	6
Evaluation	5.24	6	5.35	1.03	.12	2	6
Inductive Reasoning	7.96	8	8.05	1.26	.15	4	10
Deductive Reasoning	7.58	8	7.74	2.06	.25	1	10
			MM Group (*n* = 66)				
Total Score	23.97	24	24.20	3.75	.46	12	30
			Subscale Scores[c]				
Analysis	4.80	5	4.88	1.05	.13	1	6
Inference	3.75	4	3.76	1.22	.15	1	6
Evaluation	5.31	5	5.36	.72	.08	3	6
Inductive Reasoning	7.95	8	8.01	1.24	.15	4	10
Deductive Reasoning	7.78	8	7.90	1.75	.21	2	10

[a]Minimum. [b]Maximum. [c]There are five HSRT subscales: analysis, inference, evaluation, inductive reasoning, and deductive reasoning.

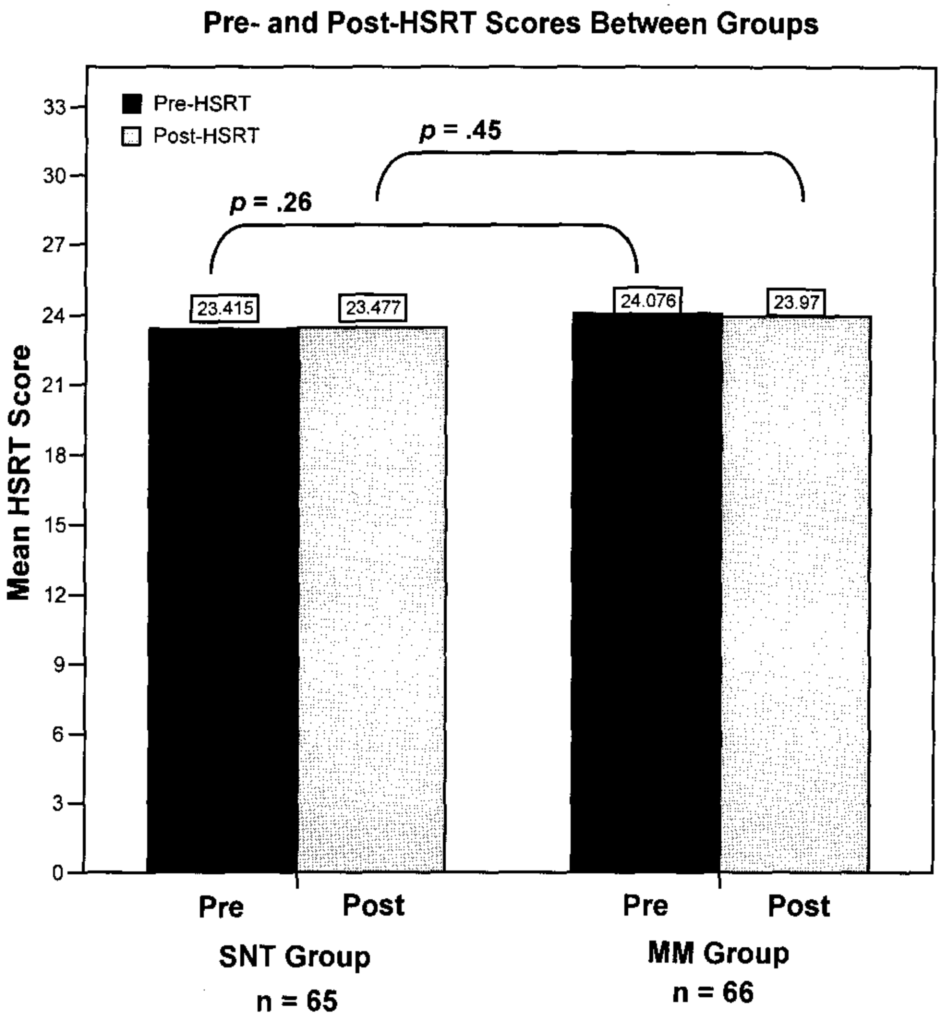

Figure 7. Pre- and post-HSRT total scores between groups. There are no significant differences in mean total scores between groups on both the pre-HSRT and post-HSRT.

Learning Style Assessment Using the Gregorc Style Delineator

In this study learning style was measured with the GSD. Each learning style in the GSD is scored in a range from 10 to 40 points (Gregorc, 1982). According to Gregorc (1982), learning styles can be categorized as dominant style (27-40 points), intermediate style (16-26 points), and low style (10-15 points). As seen in Table 10, a total of 125 subjects completed the GSD with 6 excluded because they did not complete the GSD correctly (i.e., the four learning styles of the GSD did not summate to 100). The most frequent dominant style among all subjects regardless of group assignment was Concrete-Sequential (CS), of which 21 (16.8%) were present. The next dominant style among all subjects was Abstract-Random (AR), of which 18 (14.4%) were present. The next dominant style among all subjects was Concrete-Random (CR), of which 15 (12.0%) were present. Finally, the least frequent dominant style among all subjects was Abstract-Sequential (AS), of which 6 (4.8%) were present. Table 10 also displays 2- and 3-combination dominant learning styles for all subjects.

The data depicted in Table 11 include the GSD dominant learning styles for subjects in the SNT and MM groups. In the SNT group the dominant style among subjects, from highest to lowest, was CR (10 subjects, 16.1%), CS (9 subjects, 14.5%), AR (7 subjects, 11.3%), and AS (5 subjects, 8.1%). In the MM group the dominant style among subjects, from highest to lowest, was CS (12 subjects, 19%), AR (11 subjects, 17.5%), CR (5 subjects, 7.9%), and AS (1 subject, 1.6%). Table 11 also displays 2- and 3-combination dominant learning styles for subjects in each group.

Table 10.

Dominant Gregorc Style Delineator (GSD) Learning Styles Among All Subjects (N = 125)[a]

Dominant Style[b]	Respondents	Percent
None	2	1.6
CS	21	16.8
AS	6	4.8
AR	18	14.4
CR	15	12.0
CS and AS	26	20.8
CS and AR	9	7.2
CS and CR	8	6.4
AS and AR	3	2.4
AS and CR	4	3.2
AR and CR	8	6.4
CS and AS and AR	2	1.6
CS and AS and CR	2	1.6
CS and AR and CR	1	.8
Total	125	100

Note. Each learning style in the GSD is scored from 10 to 40 points, and dominant learning style is from 27 to 40 points (Gregorc, 1982).
[a]Because 6 subjects completed the GSD incorrectly (total did not summate to 100), they were excluded from the analysis. [b]CS (Concrete-Sequential), AS (Abstract-Sequential), AR (Abstract-Random), and CR (Concrete-Random).

Table 11.

Comparison of Dominant Gregorc Style Delineator (GSD) Learning Styles Among Subjects in the SNT Group and MM Group (N = 125)[a]

	Respondents (Percent)	
Dominant Style[b]	SNT Group	MM Group
None	2 (3.2)	–
CS	9 (14.5)	12 (19)
AS	5 (8.1)	1 (1.6)
AR	7 (11.3)	11 (17.5)
CR	10 (16.1)	5 (7.9)
CS and AS	12 (19.4)	14 (22.2)
CS and AR	8 (12.9)	1 (1.6)
CS and CR	5 (8.1)	3 (4.8)
AS and AR	–	3 (4.8)
AS and CR	–	4 (6.3)
AR and CR	1 (1.6)	7 (11.1)
CS and AS and AR	1 (1.6)	1 (1.6)
CS and AS and CR	1 (1.6)	1 (1.6)
CS and AR and CR	1 (1.6)	–
Total	62 (100)	63 (100)

Note. Each learning style in the GSD is scored from 10 to 40 points, and dominant learning style is from 27 to 40 points (Gregorc, 1982).
[a]Because 6 subjects completed the GSD incorrectly (total did not summate to 100), they were excluded from the analysis. [b]CS (Concrete-Sequential), AS (Abstract-Sequential), AR (Abstract-Random), and CR (Concrete-Random).

A further analysis of learning styles was conducted using correlational methods. Correlations between different variables in this study were investigated using the Pearson *r* statistic, and those found to be significant are listed in Table 12. There were no significant correlations found between mind map depth (MMAS total scores and subscores) and pre-HSRT (total scores and subscores). The pre-HSRT was used for the correlations because it was given at the beginning of the study when student fatigue was not a factor. In addition, at the beginning of the study students had never taken the HSRT.

Learning Style Correlations

A significant correlation was found between CR learning style and SAT math score ($r = -.242$, $p = .033$, $n = 78$). A significant correlation was found between CR learning style and MCAT verbal score ($r = .190$, $p = .039$, $n = 119$). A significant correlation was found between AS learning style and MCAT biology score ($r = .235$, $p = .010$, $n = 119$). Finally, a significant correlation was found between AS learning style and MCAT physics score ($r = .237$, $p = .009$, $n = 119$).

HSRT Correlations

A significant correlation was found between pre-HSRT inductive reasoning score and SAT verbal score ($r = .239$, $p = .035$, $n = 78$). A significant correlation was found between pre-HSRT inference score and MCAT biology score ($r = .305$, $p = .001$, $n = 123$). A significant correlation was found between pre-HSRT total score and MCAT physics score ($r = .182$, $p = .044$, $n = 123$). A significant correlation was found between pre-HSRT analysis score and MCAT verbal score ($r = .243$, $p = .007$, $n = 123$). A significant correlation was found between pre-

HSRT inference score and MCAT verbal score ($r = .197$, $p = .029$, $n = 123$). A significant correlation was found between pre-HSRT deductive reasoning score and MCAT verbal score ($r = .390$, $p = .000$, $n = 123$). A significant correlation was found between pre-HSRT total score and MCAT verbal score ($r = .423$, $p = .000$, $n = 123$). A significant correlation was found between pre-HSRT analysis score and MCAT total score ($r = .209$, $p = .017$, $n = 131$). A significant correlation was found between pre-HSRT inference score and MCAT total score ($r = .317$, $p = .000$, $n = 131$). A significant correlation was found between pre-HSRT inductive reasoning score and MCAT total score ($r = .177$, $p = .043$, $n = 131$). A significant correlation was found between pre-HSRT deductive reasoning score and MCAT total score ($r = .303$, $p = .000$, $n = 131$). Finally, a significant correlation was found between pre-HSRT total score and MCAT total score ($r = .391$, $p = .000$, $n = 131$).

Table 12.

Significant Correlations Between Variables

Variables	*n*	Pearson *r*	*p* value
CR learning style × SAT math	78	–.242	.033
CR learning style × MCAT verbal	119	.190	.039
AS learning style × MCAT biology	119	.235	.010
AS learning style × MCAT physics	119	.237	.009
pre-HSRT IR[a] × SAT verbal	78	.239	.035
pre-HSRT inference × MCAT biology	123	.305	.001
pre-HSRT total × MCAT physics	123	.182	.044
pre-HSRT analysis × MCAT verbal	123	.243	.007
pre-HSRT inference × MCAT verbal	123	.197	.029
pre-HSRT DR[b] × MCAT verbal	123	.390	.000
pre-HSRT total × MCAT verbal	123	.423	.000
pre-HSRT analysis × MCAT total	131	.209	.017
pre-HSRT inference × MCAT total	131	.317	.000
pre-HSRT IR[a] × MCAT total	131	.177	.043
pre-HSRT DR[b] × MCAT total	131	.303	.000
pre-HSRT total × MCAT total	131	.391	.000

Note. CR (Concrete-Random), AS (Abstract-Sequential).
[a]IR (Inductive Reasoning) score. [b]DR (Deductive Reasoning) score.

Chapter 5

DISCUSSION

The present study is the first investigation to use a large sample of 131 first-year medical students (*N* = 131) to investigate the relationship between mind mapping, learning style, and critical thinking. Subjects unfamiliar with mind mapping were assigned to either a SNT group (*n* = 65) or MM group (*n* = 66). Subjects in the SNT and MM groups were found to be similar based upon the fact that no significant differences were found between any of the demographic variables obtained. In the SNT group, there were 49.2% males and 50.8% females, and in the MM group, there were 47% males and 53% females. The homogeneity between subjects in each group was expected because all of the students were accepted to medical school, and therefore, had to undergo a rigorous application process and meet standard entrance requirements including pre-medical courses and a robust score on the MCAT (Emanuel, 2006).

Quiz Assessment of Domain Knowledge

The difference in mean score of the pre-quiz (quiz 1) between subjects in the SNT group (3.15, *SD* = 1.22) and MM group (3.42, *SD* = .84) was not significant (*p* = .14). This baseline finding suggests that both groups retained the same amount of information equally based upon a single, 5-minute exposure to the text passage.

The post-quiz (quiz 2) was administered to subjects after they were re-exposed to the text passage and instructed to write notes using either their preferred note-taking strategy (SNT) or newly acquired mind mapping (MM) strategy. Although the mean score of the post-quiz (quiz 2) was slightly higher among subjects in the SNT group (7.85, *SD* = 1.40) compared to those in the MM group (7.64, *SD* = 1.22), the difference was not significant (p = .36). This result suggests that mind mapping is not superior to standard note-taking for the short-term recall of domain-based information; these outcomes concur with the results of Wickramasinghe et al. (2007). However, it should be emphasized that subjects in the MM group did not score significantly less than those in the SNT group even though they were only given a single, brief overview of the mind map learning strategy without a practice period to increase proficiency in creating mind maps. The fact that no significant difference was found between groups may lend support to the utility of mind mapping in the educational environment. Subjects in the SNT group had the benefit of using their preferred note-taking strategy and by allowing them to do so, these subjects were able to cognitively organize, integrate, and learn the information based on a system that has been firmly reinforced throughout their academic careers. Moreover, subjects in the SNT group focused on learning the material in a short period of time without being distracted to write their notes in a new way. In contrast, subjects in the MM group were forced to use the unfamiliar mind map learning strategy (based on a brief introductory learning session) that may have distracted them from optimally learning the material. Yet, despite the lack of exposure to mind maps and their novice status, subjects in the MM group were able to integrate, and ultimately, retain enough information so that they did not score significantly less than subjects in the SNT group. This important finding suggests the strength of mind mapping even after a single, 30-minute introductory session on the mind map strategy for the novice learner, and supports the notion of adult learner capability noted in andragogical theory. Repeated exposure to the mind map note-taking strategy over time so that students gain proficiency in creating them may lead to enhanced critical thinking (Srinivasan et al., 2008), and ultimately, an advantage over SNT.

As mentioned previously, there were 10 questions on quiz 2: the first 5 were the same questions found on quiz 1 and questions 6 through 10 were new. When looking at questions 6 through 10 on quiz 2, the mean score among subjects in the SNT group was 3.95 (SD = .87) and the mean score among subjects in the MM group was 3.79 (SD = .86). This difference was not found to be significant (p = .27). Similar to responses for questions 1 through 5 on quiz 2, the mean score in the SNT group was slightly higher on quiz 2 (questions 6 through 10) than the MM group, but not significant. Again, this finding may have been due to the fact that subjects in the SNT group were using a familiar note-taking strategy, whereas those in the MM were using an unfamiliar strategy.

Further analysis of the difference between mean total scores of the pre-quiz (quiz 1) and post-quiz (quiz 2) in each group was calculated using a standardized z score (Figure 6). The SNT group revealed an increase of about two-tenths of a SD (.2093 SD), while the MM group decreased by about two-tenths of a SD (–.2061 SD). Using a two-tailed independent samples t test, this difference was found to be significant (p = .027). This demonstrates that subjects in the SNT group outperformed those in the MM group based on the overall test.

This result suggests that mind mapping did not enhance short-term memory in this novice group of subjects who were only exposed to a brief overview of how to construct mind maps and were not given repeated practice on mind maps to bring them to a proficient level for mind map creation.

The results of the present study support those of Wickramasinghe et al. (2007), who found that the mean quiz score of subjects in their mind map group was 31.3% and the mean quiz score of subjects in their self-selected study group was 37.6%. These authors reported that there was no significant difference in scores between groups and that the self-selected study group scored slightly higher (Wickramasinghe et al., 2007).

The results of the present study are in contrast to those of Farrand et al. (2002), who reported that recall was only slightly higher in the mind map group after the second quiz. However, after adjusting for baseline performance and motivation, this difference was significant. Without the adjustment, the difference was not significant, which is consistent with the findings of the present study. Farrand et al. (2002) reported a robust difference in recall in favor of subjects in the mind map group after one week. Long-term memory was not investigated in the present study.

HSRT Assessment of Critical Thinking

The HSRT was used in this study to measure critical thinking and was administered prior to note-taking (pre-HSRT) and after note-taking (post-HSRT). The mean total score on the pre-HSRT for subjects in the SNT group was 23.41 (*SD* = 3.69) and the mean total score on the pre-HSRT for subjects in the MM group was 24.07 (*SD* = 3.04). This difference was not significant ($p = .26$) and this finding demonstrates that both groups had similar baseline critical thinking abilities as measured by the HSRT. The slightly higher mean pre-HSRT total score among subjects in the MM group compared to those in the SNT group also parallels the pre-quiz (quiz 1) results. Recall that subjects in the MM group had a pre-quiz (quiz 1) mean score of 3.42 compared to 3.15 among those in the SNT group. Therefore, although not significant, there was a pattern demonstrated between baseline scores for both the pre-HSRT and pre-quiz (quiz 1) among subjects in the SNT and MM groups even though both assessments measured critical thinking and domain knowledge, respectively.

The mean total score on the post-HSRT for subjects in the SNT group was 23.47 (*SD* = 3.82) and the mean total score on the post-HSRT for subjects in the MM group was 23.97 (*SD* = 3.75). The difference between means was not significant ($p = .45$). However, although not significant, subjects in the SNT group scored better on the post-HSRT (*M* = 23.47) than the pre-HSRT (*M* = 23.41), whereas subjects in the MM group scored worse on the post-HSRT (*M* = 23.97) than the pre-HSRT (*M* = 24.07). These results may suggest that mind mapping does not promote greater critical thinking compared to standard note-taking. However, subjects in the MM group did not score significantly different than those in the SNT group on the post-HSRT, a finding that suggests the power of mind mapping even when it was introduced to a novice group of subjects during a brief introductory session. The fact that subjects in the MM group scored worse on the post-HSRT compared to their pre-HSRT total scores could be explained by their unfamiliarity in creating mind maps. Additionally, requiring MM subjects to learn mind mapping may have created contextual interference that hampered short-term retention as demonstrated by the results of the post-HSRT; however, this may actually promote long-term retention as noted in the contextual interference literature (Lee & Magill, 1983). Subjects in the MM group may have been so preoccupied with creating mind maps that they failed to think critically about the information. Therefore, repeated exposure to mind mapping over time may be a necessary requisite in order to better test whether the use of mind mapping increases critical thinking as measured by the HSRT.

Learning Style Assessment Using the Gregorc Style Delineator

There were no significant correlations found between mind map depth (assessed with the MMAS using total scores and subscores) and GSD learning styles. Nor were there significant correlations found between HSRT (total scores and subscores) and GSD learning styles. These results suggest that, in the context of this study, GSD learning styles were independent and did not influence the construction of mind maps. However, descriptive statistics were used to ascertain the frequency of single and combined dominant learning styles in the entire sample and after group assignment, as has been done in previous studies (Vanvoorhees et al., 1988).

The most frequent single dominant learning style (27-40 points) among all subjects in this study regardless of group assignment was Concrete-Sequential (CS) at 16.8%. As shown in Table 1, CS learners are practical and enjoy stepwise, linear progression (Gregorc, 1982). Their instinctive and methodical way of thinking (Gregorc, 1982) is molded and refined over many years and they value meticulous planning. There are a paucity of studies that have investigated GSD learning styles in medical students. Vanvoorhees et al. (1988) found that CS was the dominant learning style (63%) in a large sample of primary care physicians (*N* = 391). Therefore, the results of the present study confirm those of Vanvoorhees et al. (1988), although the present study was conducted with medical students and not physicians. CS learners prefer validating information using their own physical senses (Gregorc, 1982; Vanvoorhees et al., 1988) and learning information from credentialed experts (Vanvoorhees et al., 1988). Thus, the medical school experience would be comforting to them since medical education relies heavily on trained and credentialed experts who are expected to provide the most reliable scientific information.

Interestingly, the next most frequent single dominant learning style among all subjects in this study regardless of group assignment was Abstract-Random (AR) at 14.4%. AR individuals are potential learners who enjoy web-like and multidimensional approaches (Gregorc, 1982). These learners are much different than CS learners: AR learners are emotional and prefer to think holistically, whereas CS learners are methodical and prefer to think linearly (Gregorc, 1982). Vanvoorhees et al. (1988) found that AR was the next dominant learning style in 13.8% of their physician sample. Again, the results of the present study are in accordance with those of Vanvoorhees et al. (1988).

The next most frequent single dominant learning style among all subjects in this study regardless of group assignment was Concrete-Random (CR) at

12%. CR individuals are intuitive learners who enjoy three-dimensional patterns and links (Gregorc, 1982). Vanvoorhees et al. (1988) found that AS and CR dominant learning styles were present in 11.9% and 11.2% physicians in their sample, respectively. CR learners enjoy personal proof rather than reliance on outside authority (Gregorc, 1982; Vanvoorhees et al., 1988). They will often delve deeply into a subject and correlate their findings with personal proof and experience.

The next most frequent single dominant learning style among all subjects in this study regardless of group assignment was Abstract-Sequential (AS) at 4.8%. AS individuals are intellectual learners who enjoy two-dimensional and tree-like patterns (Gregorc, 1982). These learners enjoy the validation of truths using scientific methodologies and controls (Gregorc, 1982; Vanvoorhees et al., 1988). The fact that as a single dominant learning style AS was the least represented among students in the sample could be due to the nature of the style itself. AS individuals have "abstract" perceptions and "sequential" orderings, which can be viewed as polar entities. This style allows individuals to visualize data without relying on their physical senses; yet they still prefer the systematic arrangement of information (Gregorc, 1982). Perhaps most medical students in the present study were not single AS or single CR dominant because their nature to succeed and achieve top grades throughout their careers reflect a dominant learning style that is more congruent in perceptions and orderings (i.e., CS and AR).

The order of most frequent double dominant learning styles among all subjects in this study regardless of group assignment follows: CS and AS at 20.8%, CS and AR at 7.2%, CS and CR at 6.4%, AR and CR at 6.4%, AS and CR at 3.2%, and AS and AR at 2.4% (see Table 10). This represents almost half the entire sample (46.4%). This finding may reflect the fact that these medical students—many of whom have achieved great academic success—are able to match the learning task with more than one learning style. Therefore, multiple dominant learning styles allows them greater flexibility to match learning style with learning task, and this can lead to higher academic achievement (Gaden, 1992). Gregorc (1982) stated that most individuals will be strongly oriented to one, two, or even three learning styles and this was confirmed in the present study. The fact that almost half the sample were double dominant is interesting and when added to the frequency of triple dominant (see Table 10), the percentage increases to 50.4%. Although studies have reported learning style preferences in medical students (Leiden, Crosby, & Follmer, 1990; Newland & Woelfl, 1992), none have specifically reported the prevalence of GSD learning styles. Therefore, it is unknown whether these percentages are commonplace among other medical students. However, these findings may lend support to the hypothesis that learning styles influence critical thinking, which could be investigated in future studies. As far as number of respondents, there were 60 subjects with single dominant learning styles of which CS was most common. There were 58 subjects with double dominant learning styles and 5 subjects with triple dominant learning styles. And most of these subjects (48 / 63 = 76%) had CS as one of their dominant learning styles.

When looking at individual groups, in the SNT group, the order of single dominant learning styles was: CR (16.1%) > CS (14.5%) > AR (11.3%) > AS (8.1%). In the MM group, the order of single dominant learning styles was: CS (19%) > AR (17.5%) > CR (7.9%) > AS (1.6%). A comparison of single, double, and triple dominant learning styles between groups (see Table 11) revealed that there were 37 subjects with at least one dominant learning style of CS in the SNT group compared to 32 subjects in the MM group.

Significant Correlations

In order to examine whether relationships existed between variables such as learning style and mind map score, parametric correlational statistics (Pearson *r*) were calculated. Although most of the significant correlations found in this study were weak, some may lead to new hypotheses and future studies in the areas of learning styles in medical education and mind mapping. There were no significant correlations found between any of the four GSD learning styles and total mind map score based on the MMAS. Moreover, no significant correlations were found between any of the four GSD learning styles and any of the MMAS subscores except one—there was a significant positive correlation between CR and examples ($r = .292$, $p = .02$, $n = 63$). Although this is a weak correlation, it has some relation to the subject under investigation. According to Gregorc (1982), CR learners enjoy the physical and random world; they can appreciate three-dimensional patterns in unstructured problem-solving situations. Because this kind of thinking is facilitated when creating mind maps (D'Antoni & Pinto Zipp, 2006), it makes sense that CR learners would use many examples when creating mind maps. Mind maps are also created in an unstructured way by using a blank page; therefore, this strategy may be particularly useful for CR learners. Although not significant, the correlation between CR and total mind map score ($r = .191$, $p = .133$, $n = 63$) had the lowest p value compared to the other learning styles—AS, AR, and CS—which, had p values of .499, .598, and .695, respectively.

In addition, the AS, AR, and CS correlations were all negative and CR was the only positive correlation. A significant negative correlation was found between CR and SAT math score ($r = -.242$, $p = .033$, $n = 78$). This finding may be due to the fact that CR learners are more interested in intuitive leaps and often leave the details to others (Gregorc, 1982). These learners may become frustrated with the orderly fashion of problem solving (Gregorc, 1982); therefore, they may not do well on definitive math problems in which a certain sequence is needed to arrive at the answer. This may be too restrictive to their thinking, and thus, they may simply choose a random answer than be forced to solve the problem in a certain way. A significant positive correlation was found between CR and MCAT verbal score ($r = .190$, $p = .039$, $n = 119$). Although weak, this correlation could be explained by the fact that CR learners enjoy the freedom associated with reading a text passage and placing information in their order. Therefore, as would be expected, they may score well on an exam such as the MCAT verbal section which requires the examinee to read a text passage and answer a series of questions based upon the passage.

A significant positive correlation was found between AS and MCAT biology score (r = .235, p = .010, n = 119). Another significant positive correlation was found between AS and MCAT physics score (r = .237, p = .009, n = 119). Both correlations may be explained because both subjects are based on facts, logic, and require a certain level of analysis. AS learners share these attributes and these individuals enjoy learning, knowledge acquisition, and scholarship (Gregorc, 1982).

There were significant positive correlations found between the MCAT total score and pre-HSRT as seen in Table 12. For example, there was a significant positive correlation between MCAT total score and pre-HSRT total score (r = .391, p = .000, n = 131). This finding suggests that both exams are testing critical thinking even though the MCAT tests this thinking using domain knowledge. The fact that significant positive correlations were found between MCAT total score and the pre-HSRT subscores of deductive reasoning, inductive reasoning, inference, and analysis suggest that the HSRT may be useful to administer to medical students at the start of medical school and yearly to measure changes in their critical thinking abilities. Moreover, the HSRT may also be useful in prospectively identifying students who may experience academic difficulty or difficulty in passing the licensing examinations if correlations could be demonstrated between the HSRT and those courses taken during medical school, as well as, the HSRT and licensing examinations.

Chapter 6

SUMMARY AND CONCLUSIONS

The results of this study demonstrate that the mind map learning strategy does not result in a significant gain in short-term, domain-based knowledge (assessed using multiple-choice quizzes) compared to standard note-taking in medical students. However, in subjects who were unfamiliar with mind mapping, a short 30-minute presentation on the strategy allowed them to score similarly to subjects in the SNT group who used strategies that have been firmly established. By using preferred note-taking strategies, subjects in the SNT group were able to rely on previous note-taking experiences that helped shaped their current understanding and learning of the material in the text passage (Forrest III & Peterson, 2006), while those in the MM group could not rely on prior mind map note-taking experiences as they were novices. However, subjects in the MM group could have relied on previous knowledge of other non-mind map note-taking strategies, and this could explain why they were able to score similarly. The similarity in mean scores between groups lends support to the andragogical theory (Knowles, 1977, 1984) that adults learn best when they integrate newly acquired information with previous experience to form a knowledge framework (Ausubel, 1978; Bodner, 1986). This lends credence to the idea that multiple mind mapping sessions may be necessary for students to gain proficiency in the strategy before significant changes in the acquisition of domain-based knowledge and critical thinking can be identified. Recently, Srinivasan et al. (2008) reported that concept map scores significantly increased in physicians who created concept maps on two separate occasions. They recommended that future concept map studies should allow subjects to create concept maps on multiple occasions. This may also be true of mind maps because researchers have demonstrated that mind map depth increases as students gain proficiency in their construction over time (D'Antoni & Pinto Zipp, 2006; Daley et al., 1999; Hill, 2006). Future studies can be designed to allow subjects to create multiple mind maps so that they can gain proficiency in the technique of mind mapping. This would enable them to move from novice to expert mind mappers, which would ultimately allow them to place emphasis on critical thinking, which occurs during mind map creation when relationships are found between different concepts.

In this study, the mind map learning strategy did not result in a significant gain in critical thinking (as measured by the HSRT) among subjects in the MM group compared to those in the SNT group. However, subjects in the MM group did not score significantly worse than those in the SNT group. This finding not only parallels the results of the domain-based knowledge described above, but also suggests that mind mapping may increase critical thinking over time. In the future, the HSRT can be administered to subjects at baseline and throughout the study to further assess if a change in critical thinking occurs over time. Based on the literature, the length of time needed to develop critical thinking is unknown. If, however, critical thinking occurs in temporal bursts (Willingham, 2007), then the timing of mind map studies may be important if one intends to measure critical thinking over time.

Mind mapping research is in its infancy. There are many areas in need of investigation and these include more robust study designs, the evolution of better ways to measure critical thinking, and the development of valid and reliable tools to assess mind maps. There are few quasi-experimental or experimental studies in mind mapping research; therefore, more robust study designs with better controls should enhance our understanding of the relationship between mind mapping and critical thinking. There also exists a need to develop better measures of critical thinking (Willingham, 2007) that are sensitive to changes in the knowledge frameworks of physicians (Srinivasan et al., 2008). The evolution of these knowledge frameworks are fundamental for the progression from novice medical student to expert physician, and Srinivasan et al. (2008) argue that these frameworks are not measured in medical education. Consequently, the MMAS was developed to allow for the mind maps to be quantitatively assessed in this study. Although strong interrater reliability of the MMAS was demonstrated, further studies are needed to address its reliability and construct validity so that it can be effectively used in the academic setting.

The effect of learner attributes, such as preferred learning style, on critical thinking and note-taking is important and has only begun to be investigated in medical education. An impediment to these kinds of studies is the idea that medical students are already proficient at learning, and therefore, do not need to self-assess their learning styles (Leiden et al., 1990). Future research can further investigate the role of learning styles in medical education that could help students acquire critical thinking skills and also drive the creation of curricula that are sensitive to these styles.

Mind maps have historically been underutilized in medical education and their usefulness as a learning tool for medical students has not been firmly established. This study demonstrated that mind mapping results in a similar gain of short-term, domain-based knowledge and critical thinking compared to standard note-taking after a single mind map session.

These results were found in medical students, and therefore, are not generalizable to non-science graduate students. However, the results may be applicable to graduate students in other health professions. Future research could be done with health professional students to explore any long-term effect that mind mapping may have on critical thinking and whether this is influenced by dominant learning style.

Chapter 7

APPENDICES

Appendix A

Math Quiz 1

INSTRUCTIONS: This math quiz consists of 3 questions. Please use this page to calculate your answers. You are NOT permitted to use a calculator, cell phone, or any other electronic device to aid in your calculations. **You have 10 minutes to complete this quiz.**

1. Calculate the following for *x*:

   $x = 15 + 2 + 187 + 40 + 11 + 523 + 76 + 1001 + 5 + 40$

2. Gina's current salary is $30,000 per year and her company gives her a 5% raise each year. Six years from now, what will her salary be?

3. How much kinetic energy does a small car weighing 1900 lb and traveling at a speed of 12 mph (17.6 ft/sec) have? **Units must be in ft lb.**

   KE, Kinetic Energy
   w, weight
   v, velocity
   g, gravity (32 ft/sec^2)

   $$KE = \frac{wv^2}{2g}$$

Appendix B

Math Quiz 2

INSTRUCTIONS: This math quiz consists of 3 questions. Please use this page to calculate your answers. You are NOT permitted to use a calculator, cell phone, or any other electronic device to aid in your calculations. **You have 10 minutes to complete this quiz.**

1. Calculate the following for *y*:

$$y = \frac{100 + 42 + 18 + 240 + 80 + 80}{\sqrt{64}}$$

2. Mary has a monthly salary of $1,200 and she spends $280 per month on food. What percent of her monthly salary does she spend on food?

3. Cassandra invested one part of her $10,000 at 7.5% per year, and the other part at 8.5% per year. Her income from the two investments was $820. How much did she invest at each rate?

Appendix C

Descriptive Statistics of Mind Map Scores (*n* = 66) Between Three Examiners

Variable	*Min*[a]	*Max*[b]	*M*	*SD*
		Examiner 1 (AVD)		
Concept-link	4	106	38.97	20.43
Cross-link	0	130	23.03	25.05
Hierarchy	10	25	17.88	3.72
Example	4	31	15.65	5.75
Picture	5	135	59.39	27.63
Color	20	60	45.08	10.72
Total score	102	400	200.00	55.50
		Examiner 2 (GPZ)		
Concept-link	0	10	1.12	2.22
Cross-link	0	200	35.91	41.98
Hierarchy	0	105	50.53	20.51
Example	2	19	8.44	3.86
Picture	0	120	46.52	25.41
Color	20	45	32.95	5.94
Total score	92	415	175.47	63.22
		Examiner 3 (VGO)		
Concept-link	0	16	4.48	3.93

Cross-link	0	300	53.48	58.05
Hierarchy	5	350	117.80	62.95
Example	0	53	20.55	11.28
Picture	0	105	48.71	29.10
Color	20	55	34.32	8.54
Total score	134	539	279.35	77.77

[a]Minimum. [b]Maximum.

Appendix D

Intraclass Correlation Coefficient (*ICC*) of Mind Map Scores (n = 66) Based on Three Examiners

Variable	*ICC*	*p*
Concept-link	.05	.39
Cross-link	.58	.00*
Hierarchy	.23	.10
Example	.53	.00*
Picture	.86	.00*
Color	.73	.00*
Total score	.86	.00*

Note. Significant differences were tested at the 95% confidence interval.
*p < .05.

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