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Does the Use of Mind Mapping as a Learning Strategy by Physician Assistant Students Promote Critical Thinking as Measured by the Health Science Reasoning Test?

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Dissertation Committee

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"Does the Use of Mind Mapping as a Learning Strategy for Physician Assistant Students Promote Critical Thinking as Measured by Health Science Reasoning Test Score (HSRT)?"

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Dedication

I dedicate this work to my late mother, Thangam Samuel, who constantly encouraged and inspired me to have higher goals and achieve them.

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Abstract

Physician Assistant (PA) students need to assimilate and integrate voluminous information quickly and effectively to promote critical thinking skills needed to deliver competent care. Mind mapping is an innovative strategy used to facilitate students' recognition and recall of key information and ensure depth in their understanding via making connections between pieces of information. Based on the establishment of relationships between concepts expressed in mind maps, critical thinking skills are further developed.

Seventy-four PA students were randomly assigned to Standard Note Taking Group (SNTG) or Mind Mapping Group (MMG) to complete the pre-HSRT (Health Science Reasoning Test). MMG were then instructed on how to construct mind maps and create weekly mind maps for nine weeks. The SNTG followed their own method of study and did not make mind maps for nine weeks. Differences in the mean pre- and post-overall HSRT scores between the groups and within the groups were analyzed using independent and dependent t-test respectively. There was no significant difference between pre- and post-overall critical thinking scores as measured by HSRT post-nine weeks of intervention in both groups. There was no significant difference in the mean pre-HSRT overall critical thinking scores between the groups. However, there was a significant difference in the mean overall post-HSRT scores between the groups ($p=.026$). Hence, mind mapping is a viable active learning strategy to promote critical thinking in PA students.

Keywords: critical thinking, mind mapping, Health Science Reasoning Test

CHAPTER 1: INTRODUCTION

Background of the problem.

The increasing aging population in the US along with the expansion of chronic diseases, the explosion of secondary healthcare risk factors (e.g. obesity), and diverse medical needs of an increasingly diverse cultural base is expected to continue to drive the overall demand for medical services. Additionally, the expanded health insurance coverage resulting from the adoption of the Affordable Care Act has reduced financial barriers associated with securing healthcare and is expected to increase the demand for medical services (Department of Health and Human Services [DHHS], 2013). Yet, in the face of this increased need for healthcare, the nation faces an insufficient cadre of primary healthcare professionals, specifically physicians (Cawley, 2012).

It is projected that by 2025, the number of MDs will not be able to keep pace with the demands, resulting in a shortage of at least 124,000 primary care physicians (Dill & Salsberg, 2008). Physician Assistants (PAs) and Nurse Practitioners (NPs), given their scope of practice, can play a significant role in alleviating provider shortage and increasing the efficiency of the healthcare delivery system (Hooker, Cawley, & Leinweber, 2010). Long-term trends point to PAs and NPs becoming the principal frontline primary care providers, with physicians taking more specialty, managerial and executive functions in healthcare (Cawley, 2012).

Over the past four decades, there has been an increasing dependence on PAs and NPs, mid-level healthcare providers, to deliver primary care services. Thus, since the introduction of the Physician Assistant profession in the mid-1960s the profession has seen steady growth as a versatile component of the US healthcare workforce (Cawley,

2012). The Agency for Health Research and Quality (2014) reported that PAs make up 10% of the primary care workforce and represent nine percent of clinicians in community health centers. The Affordable Care Act recognized PAs for the first time as one of three primary care providers, the others being Nurse Practitioners and Physicians (American Academy of Physician Assistants [AAPA], 2016).

PAs work in a variety of specialties, including oncology, dermatology, gastroenterology, orthopedics, and behavioral health (Dower & Christian, 2009; Glicken & Miller, 2013). The National Commission on Certification of Physician Assistant (2013) reports that the profession grew 119% over ten years from 43,500 in 2003 to 95,583 at the end of 2013. The Bureau of Labor Statistics (2016) suggests that the employment of PAs is projected to grow 30% from 2014 to 2024, much faster than the average for all occupations. The above mentioned demonstrates the vital role of the physician assistant in today's healthcare delivery system and its potential expansion in the future.

Need for the Study

It is essential to understand the PA professional role and responsibilities distinct from those of MDs and NPs, although there may be some similarities. Physician assistants are licensed professionals who practice medicine on teams with physicians, surgeons, and other healthcare workers. PAs can only practice under a licensed physician. They examine, diagnose, and treat patients. Physician assistants work in physicians' offices, hospitals, and other healthcare settings. They prescribe medications, manage patients with chronic conditions, perform minor surgical procedures, make rounds at nursing homes, and hospitals (AAPA, 2016). PAs are educated in intensive programs

accredited by the Accreditation Review Commission on Education for the Physician Assistant (Cawley, 2012).

Physician assistant programs are master's degree programs that are generally about 26 months in length and include both didactic and clinical components (Rhee, Wardley, Hutchinson, Applegate, Vangsnes, Meyer, Grinwis, & Fenn, 2003). The Pew Health Professions Commission in 1998 challenged professional schools to respond to the nation's evolving healthcare needs by revitalizing health education. Some of the strategies they recommended include promoting lifelong learning, inquiry-based education, and student-centered learning. The commission further articulated other competencies such as demonstrating critical thinking, reflection, and problem-solving skills. Similar skills and abilities are described in the National Health Care Standards (Amanda & Da Vanzo, 1995) and the Accreditation Review Commission on Education for the Physician Assistant (ARC-PA, 2018). Thus, professional competencies for the PAs include the effective and appropriate application of medical knowledge, interpersonal communication, practice-based learning, and patient-centered care (AAPA, 2012). Additionally, the competencies enunciate that PAs should demonstrate an investigative and analytical approach to clinical situations, evaluate and develop patient management systems (AAPA, 2012).

PAs must learn these skills and methods of practice in their academic preparation so that they are able to deliver high-quality care demanded by the patients and healthcare organizations. PAs should be able to relate, connect and integrate information to critically evaluate and effectively treat their patients (Brudvig, Dirkes, Dutta, & Rane, 2013; Day & Hale, 2005). PA faculty in preparing future PAs are confronted with the challenge of

transmitting an overwhelming body of knowledge in a short span. The heavy workload and extensive course requirements tend to make students passive recipients of abundant information and less likely to be involved in the learning process. Similarly, it may hinder students from learning important principles and integrating information (Rhee et al., 2003).

PA educators as mediators and facilitators of student learning must utilize appropriate teaching and learning strategies that can facilitate the development and application of effective critical thinking skills and augment the learning process, thereby contributing to better quality and performance in medical education. A teacher serves both as a guide and a resource for the students. Current insights on learning emphasize that learning should be a constructive, self-directed, collaborative and contextual process. (Vilela, Barbosa, Vilela, & Neto, 2013). Employing active learning strategies such as mind mapping may offer an opportunity to develop understanding and memory and provide future PAs with a strategy for life-long learning. Mind mapping (MM) allows the student to illustrate a vision, exhibit their contextual knowledge and creativity, and make associations with the central theme (Rosciano, 2015). Active learning is a process whereby students engage in activities such as reading, writing, discussion or problem solving that promote analysis, synthesis, and evaluation (Vilela et al., 2013).

The Problem

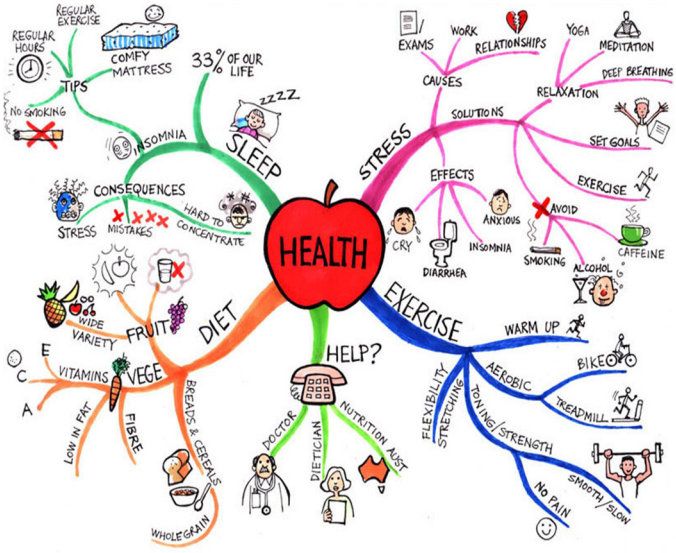
In PA programs, the volume and rate of information that is conveyed to students are more in-depth than undergraduate education and comparable to other health professional programs such as PT, MD, and NP programs. Often, PA students feel overwhelmed by the sheer amount of information they must learn (Augustin, 2014). Yet,

students in these environments are expected to organize, memorize, recall, analyze, and apply enormous amounts of information in a comparatively short span of time (Day & Hale, 2005). Often students are not familiar with how to learn effectively and improve memory, thus compromising their learning further (Augustin, 2014). Additionally, critical thinking is an essential skill that all health care professionals must have to make clinical decisions. Healthcare professionals are trained to make life-changing decisions that affect an individual's physical, psychological, and social well-being (Brudvig et al., 2013).

To be successful, the physician assistant student must critically integrate information quickly and effectively. To promote the critical integration of volumes of information in a short time, educators need to utilize teaching and learning strategies that promote critical thinking among PA students and enable them to emerge as sound clinicians who deliver competent care (Brudvig et al., 2013; Day & Hale, 2005). Standard teaching and learning processes involve using notes and outlines. Although these practices are helpful, they lack creativity and associations. Apperson (2016) states that the key to educational and learning processes is one's ability to organize information. Organizing information involves creating frameworks like concept and mind maps that facilitate analysis, memorization, and understanding the relationship between concepts (Davies, 2010). When associations are developed in a creative manner, learning and knowledge are improved, and critical thinking develops (Spencer, Anderson, & Ellis, 2013). Mind mapping may be such a strategy to achieve this goal (Zipp, Maher, & D'Antoni, 2009; Kern, Bush, & McCleish, 2006). Yet, the mind map is an underused tool in medical education (Spencer et al., 2013).

In general, mapping tools represent diagrammatic relationships of different kinds. They are used to visually display information, impart critical and analytical skills to students, and allow students to explore associations between concepts. A mind map is a specific type of map, as it is a visual non-linear representation of a network of connected and related concepts (Figure 1) (Davies, 2010).

Significance of the study



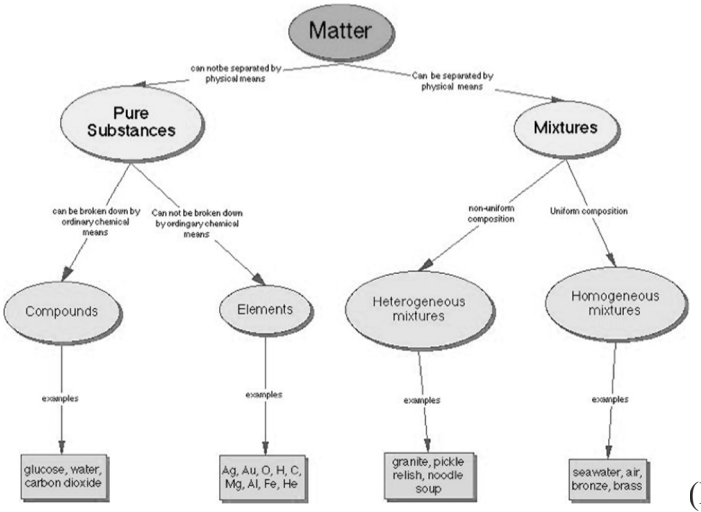
(Genovese, 2019)

Figure 1. Mind map on the concept of health

The map can be visualized as having five sections in a clockwise fashion. Section 1 focuses on stress, section 2 on exercise, 3 on help, 4 on diet and 5 on sleep.

Tony Buzan pioneered mind mapping in the 1970s. A mind map consists of a central topic placed in the middle of the page with categories and subcategories that radiate peripherally and are usually pictorial in nature and uses color (Buzan, 2010). Mind mapping is not the only type of map used as a learning strategy. Concept mapping (CM) (Fig-2) is unicolor, uses hierarchical order to link concepts together with propositions or linking words between concepts and does not use pictures (Novak & Godwin, 1984). Interestingly, both learning strategies are rooted in a conceptual

framework called the constructivist theory of learning, which states that meaningful learning or learning with understanding occurs when learners assimilate new information within their existing framework (Ausubel, 1978; Bodner, 1986).

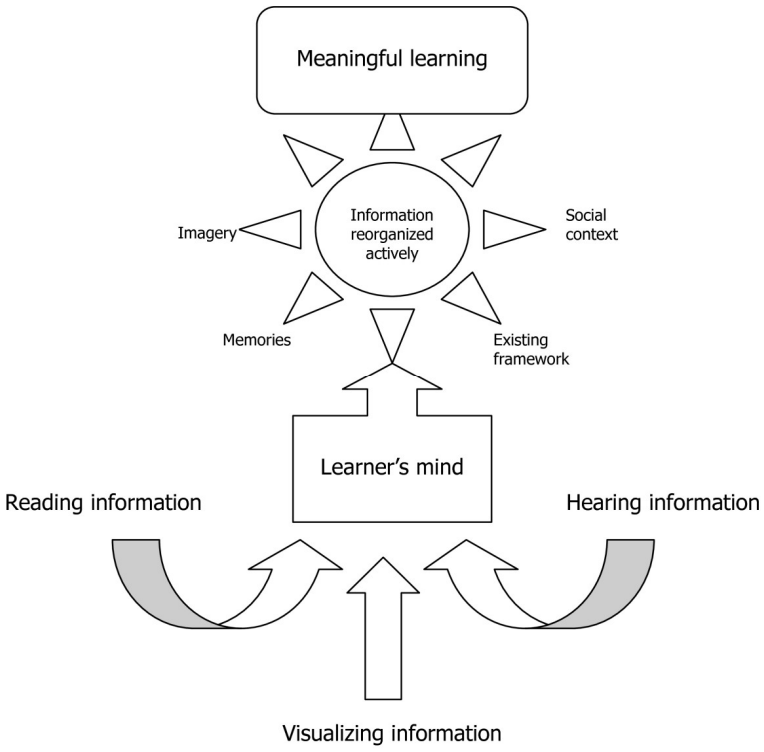


(Dubick, 2012)

Figure 2. Concept map on matter

The concept map (Fig 2) has two major themes presented in a linear fashion: Theme 1 focuses on pure substances and 2 on mixtures. Several subthemes are also presented in the map: compounds, elements, and heterogeneous mixtures.

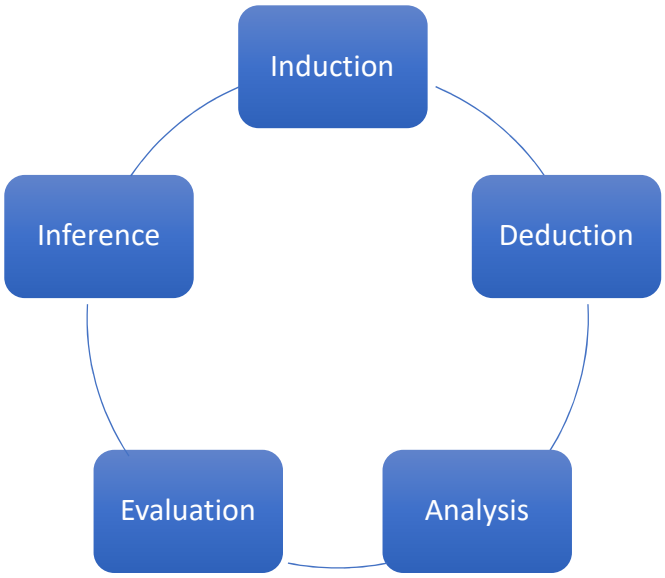
In constructivist orientation, learning is a process of constructing meaning (Fig-3). One of the assumptions underlying constructivist theory is that the student will integrate information into his/her mental models to make sense and that results in meaningful learning (Muirhead, 2006). Mapping, in general, allows the presentation of new material to build on existing knowledge (Davies, 2011).



(Ausubel, 1978).

Figure 3. Constructivist theory of learning

In mind mapping, because the student creates the mind map without a template or flow chart to direct their thinking, the map ultimately represents the student's own interpretation and integration of ideas, resulting in meaningful learning (D'Antoni Zipp, Olson & Cahill, 2010). Meaningful illustration expounded by the mind mapper assists in a richer and deeper integration of information that can nurture both declarative (explicit) and implicit knowledge associated with critical thinking and long-term learning (Ambrose et al., 2010). Critical thinking (Figure-4) is an objective analysis and evaluation of an issue to form a judgment (Facione & Facione, 2006).



(Facione & Facione, 2006)

Figure 4. Attributes of Critical Thinking

Meaningful learning is necessary for critical thinking (D'Antoni et al., 2010), Likewise, knowledge is essential for critical thinking. While critical thinking involves higher order thinking skills, these cannot be utilized without knowledge (Stalheim-Smith, 1998). Since critical thinking is dependent upon content (domain) knowledge and problem familiarity, MM may facilitate critical thinking because it fosters the retention of factual information (Farrand, Hussain, & Hennessy, 2002). To be successful, PA students and subsequently PAs must possess effective critical thinking skills along with domain-specific knowledge (Fig-5). PAs also need to make competent clinical decisions regarding pathophysiology, signs, symptoms, and diagnostic findings to determine the most appropriate diagnosis and treatment (Day & Hale, 2005).

Davies (2010) specified that mapping facilitates analysis, memory, and understanding of relationships among concepts. Furthermore, Mollberg et al. (2011) suggested that understanding the intra and interrelationship between concepts as manifested in mind mapping reflects the type of thinking that is needed in clinical

practice. Research in higher education has recognized mind mapping as a potential teaching and learning strategy that actively engages the learner in synthesizing and integrating information in a meaningful, non-linear manner. Mind maps boosted memory (Farrand et al., 2002); fostered creativity (Mueller, Johnston & Bligh, 2002); enhanced learning (Kern et al., 2006); helped in planning and organizing information (D'Antoni & Zipp, 2006); promoted collaboration (Rosciana, 2015; Spencer et al., 2013) encouraged critical thinking, problem-solving, integration of information (Zipp, Maher, & D'Antoni, 2015; Farrand et al., 2002) and radiant thinking (Spencer et al., 2013). Moreover, mind mapped care plans enabled students to focus on the patient and provided a better understanding of the treatment process (Mueller, Johnston & Bligh, 2001; Kern et al., 2006, & Boley, 2008).

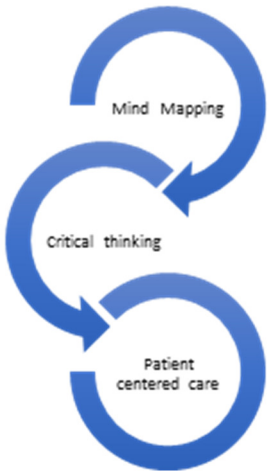


Figure 5. Promoting Critical Thinking

The outcomes of mind mapping are all very relevant, important and useful for physician assistant students and future practicing PAs. Given the absence of evidence supporting the use of mind maps in PA education and the clear need for educational strategies to be employed that can efficiently assist PA students to quickly and effectively integrate information to meet the needs of being a front-line generalist, research

addressing PA students and effective learning strategies to promote critical thinking is imperative.

Purpose of the study

- To assess the critical thinking skills of Physician assistant students using mind mapping as a learning strategy and
- To determine if there is a significant difference in the critical thinking skills between mind mapping students versus standard note-taking students.

Research Questions

1. What learning strategies do PA students use to support their learning in PA school?
2. Is there a difference in the overall level of critical thinking skills of PA students at baseline, as measured by the Health Science Reasoning Test (HSRT) based on group assignment?
3. Is there a significant difference between pre- and post-overall critical thinking scores for PA students who participated in the Mind Mapping Group (MMG), post-nine weeks intervention, as measured by HSRT?
4. Is there a significant difference between pre- and post-overall critical thinking scores for PA students who participated in the Standard Note Taking Group (SNTG), post-nine weeks intervention, as measured by HSRT?
5. Is there a significant difference in the overall critical thinking score as measured by HSRT between Standard Note Taking Group and mind mapping group, post-nine weeks intervention?

Research Hypothesis

In response to the research questions posed, hypotheses were developed. The first question is descriptive and therefore has no hypothesis. The research hypotheses postulate the following:

The first hypothesis postulates (HA1): There is a difference between the overall level of critical thinking skills of PA students at baseline as measured by HSRT based on group assignment.

The second hypothesis postulates (HA2): There is a significant difference between pre- and post-overall critical thinking scores for the MM group as measured by HSRT post-nine weeks intervention, with scores being higher at the post.

The third hypothesis (HA3): There is a significant difference between pre- and post-overall critical thinking scores for the SNT group as measured by HSRT post-nine weeks intervention, with scores being higher at the post.

The fourth hypothesis postulates (HA4): There is a significant difference in overall critical thinking as measured by HSRT between SNTG and MMG, post-nine weeks, with MMG presenting higher scores in critical thinking.

Chapter II: LITERATURE REVIEW

Introduction

In recent years, understanding how to assist medical students in their learning journey via diverse teaching and learning strategies has gained popularity, and to that end, there has been an increase in the publication of learning strategies used in medical education that may help students learn and integrate information (Vilela et al., 2013). Additionally, the students are required to critically analyze, synthesize information from diverse sources and enhance understanding. How students assimilate knowledge and use thought processes impacts their learning and development of critical thinking skills (Kocherlakota, Zimmerman & Berger, 2013). Although the development of critical thinking has been proposed as a core competency for the PAs, evidence supporting effective teaching and learning strategies that foster this development is sparse. Active learning strategies such as case studies, role play, and problem-based learning are recognized strategies used to foster critical thinking in students (Popil, 2011; Worrell & Profetto-McGarthe, 2007). A learning strategy is a thinking tool that a student uses to actively acquire information; some examples include mnemonics, charts, or maps (Gage & Berliner, 1998).

Educators have employed mapping tools for numerous educational purposes (Pudelko, Young, Vincent & Charlin, 2012). Biggs (1987) indicated that when students construct a map, they are more likely to understand relationships, remember them and examine their constituent parts. Mapping is often easier to follow than written descriptions, although it depends on the type of maps created (Larkin & Simon, 1987; Mayer & Gallini, 1990). Moreover, Twardy (2004) proposed that mapping involves

active engagement by the learner and leads to greater learning. Mapping has multiple purposes in health-related education: synthesizing disease processes, health promotion activities, and forming a differential diagnosis. Students can learn this technique in a relatively short span of time and then use the maps in a variety of ways across the curriculum to augment their learning. These mapping tools include mind mapping and concept mapping. Sometimes the terms have been used interchangeably (Davies, 2011). However, there are clear differences in each of these mapping tools.

Tony Buzan pioneered mind mapping in the 1970s. A mind map is a visual non-linear technique where knowledge and information are hierarchically formatted with colors and pictures to enhance ideas and contains key terms associated with a subject (Vilela et al., 2013). Joseph Novak, on the other hand, developed concept mapping (CM). CM uses hierarchical order to link concepts together, with propositions or uses linking words, between concepts (Novak & Godwin, 1984). Both learning strategies support meaningful learning wherein new information is linked to prior knowledge structures and concepts as proposed by Ausubel (1978) and Bodner (1986). Both concept maps and mind maps promote active learning on a metacognitive level (D'Antoni, Zipp & Olsen, 2009). Both tools are used to organize and represent information; they are context dependent, hierarchically structured, improve comprehension and memorization. Although concept maps and mind maps have similar characteristics, they are fundamentally different in design (D'Antoni et al., 2009). Table 1 illustrates the difference between concept map and mind map.

Table 1

Difference between concept map and mind map

Concept Map	Mind Map
Design Top to bottom Unicolor No pictures Many propositions	**Design** Central to peripheral Multicolor Multiple pictures Few or no propositions
Purpose Promotes critical thinking by establishing relationships between concepts.	**Purpose** Promotes critical thinking by establishing nonlinear relationships between concepts and enhances recall of information with dynamic colors and pictures*.

* Bellezza,1983; Day & Bellezza, 1983.

Mind maps, in contrast to concept maps, use a central theme in the middle of a page with categories and subcategories that radiate peripherally, thus making them truly non-linear. The cross-links among categories highlight their intrinsic relationships and allow the student to compare 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). Empirical support from the cognitive sciences shows that visually displaying information enhances learning (Biggs, 1987) and allows for dual coding (Vekiri, 2002) of information by more than one sensory modality, as is the case with mind maps (Kern et al., 2006; Edwards & Cooper, 2010).

Both mind maps and concept maps allow students to recognize the intra and interrelationships between concepts, which reflects the kind of real-world thinking predominant in the clinical setting (Srinivasan, McElvany, Shay, Shavelson, & West,

2008). Both strategies (mind maps & concept maps) differ in their organization of information (D'Antoni et al., 2009). In mind maps the key concepts are written in branches, with the most general concepts being placed in the middle. This central positioning of the main topic allows the mapper 360 degrees of freedom to develop and explore concepts and relationships associated with the topic via the emerging branches from this central theme. Lines from the center become thinner as they radiate peripherally (Zipp et al., 2015). In contrast, in concept maps, the key concepts are enclosed in a box or bubble, linking lines contain propositions and the most general concepts are at the top of the map.

Mind maps emphasize diagrams and pictures to aid associations; concept maps generally use hierarchical structure and phrases to aid understanding of relationships. As per Buzan (1991), mind maps tap into the natural nonlinear thinking process and potentiate learning by using both left and right brain capacities. Further concept maps do not require the mapper to relate, connect, or integrate the material in a visual manner. Instead, concept maps encourage a linear word-based presentation of information (Pudelko et al., 2012) without deep integrated connections between concepts and pictures, which is key in the elaborative processing of information for long-term memory (Zipp et al., 2015).

Having recognized the distinctive features of mind mapping, it is important to explore the literature on how mind maps were used in medical education and whether they foster knowledge integration and development of critical thinking for use in physician assistant education. The following section examines the empirical evidence on the use of mind mapping as a learning strategy in diverse health-related education.

Mind map enhanced memory

Farrand et al. (2002) found that mind mapping improved the long-term memory of factual information in medical students by 10%. They proposed that mind mapping may facilitate critical thinking because it fostered student retention of factual information, as well as relationships between concepts (Farrand et al., 2002). Similarly, Wickramasinghe, Widanapathirana, Kuruppu, Liyanage, and Karunathilake (2007) discovered that most medical students who had been newly introduced to Mind Mapping perceived it to be helpful for memorizing information in an organized way compared to their previous self-study techniques.

D'Antoni et al. (2010) demonstrated that the mind map learning strategy did not result in a significant gain in short-term, domain-based knowledge (assessed using multiple-choice quizzes) compared to standard note-taking (SNT) 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 had been firmly established. This important finding suggested the strength of mind mapping even after a single, 30-minute introductory session in promoting critical thinking in the novice learner and supports the notion of adult learner capability (Ausubel, 1978). The results showed that mind mapping can be easily taught to medical students who had no previous background in mind mapping and doing so requires no cost or expensive equipment (D'Antoni et al., 2010). Thus, mind mapping may be an attractive resource to add to the study strategy repertoire of entering medical students to help them learn and organize information.

Mind map helped in the organization and integration of information.

Zipp et al. (2009) found that physical therapy students who utilized mind mapped care plans perceived mind mapping enabled them to organize material (38%), prioritize information (9.5%), and integrate course material (33.3%). Further, the sentiments expressed by the students supported mind mapping as a positive learning strategy for connecting information that aided in creating an integrated patient-centered plan of care.

Mind map in the nurse care plan

Mueller, Johnston, and Bligh (2001) described anecdotal data of mind-mapped care plans used by student nurses. The students stated that a mind-mapped care plan enabled them to focus on the patient, provided a holistic view, helped them make connections amongst information and organize their thoughts. The color-coding in the mind map enabled both students and faculty to see at a glance all components of the nursing process (Mueller et al., 2001). Their findings further supported Buzan and Buzan's (2000) notions that color and diagrams aid in knowledge recollection and creative associations between ideas. Additionally, the results illustrated that MM was easy to teach and could be adopted in different fields of health education.

Kern et al. (2006) also evaluated the mind-mapping method of patient care planning in the nursing curriculum. A summative survey reported results (holistic view of patients, improved critical thinking) comparable to those of Mueller et al. (2001). In contrast to the above studies, where students constructed their mind maps, Boley (2008) established that pre-made mind maps given to nursing students helped students achieve measurable improvements in their learning. Biggs (1987) on the other hand, had suggested that when students make their own mind maps it stimulates them to explore more relevant connections and associations between concepts resulting in deeper

learning. In addition, Buzan's theory (1996) emphasized that learning occurs when students make their own maps. But Boley's results showed that students did benefit from instructor-made maps based on weekly quiz grades.

Overall, mind maps helped to organize and summarize information. Using pictures and colors supported learning and remembering information. The ability to recall information is extremely important in health professions education, as this information constitutes the building blocks that practicing professionals integrate and apply to critically evaluate patients' needs and provide effective treatment (Srinivasan et al., 2008).

Mind map in collaborative learning

Rosciano (2015) evaluated the effectiveness of mind mapping as an active learning strategy among associate degree nurses using a cooperative learning environment. A questionnaire illustrated that 97% of students agreed that mind map enhanced their creativity and that it was an effective and useful strategy. Additionally, a self -assessment rubric indicated that 66% of the students exhibited radiant thinking. Radiant thinking is the ability to think diversely starting from the central thought. Radiant thinking stimulates association and knowledge attainment (Buzan & Buzan, 1996).

Similarly, Spencer et al. (2013) utilized mind mapping with co-operative learning among nursing student. The authors suggested that the key component of the learning process occurred when the presenters described their maps to their student colleagues. The authors noted that the collaborative MM broadened perspective and aided in the conceptualization of relationships between different disease processes while helping students draw conclusions and think beyond the basic concepts. A mind map thus helped

to explore relationships between ideas and concepts and generate solutions to problems. MM helped in viewing relevant issues and analyzing choices considering the big picture Spencer et al., 2013).

Kotcherlakota et al. (2013) combined mind map with the fish-bowl technique to help graduate students identify their research focus and organize information. The authors stated that mind mapping assisted students to use their critical thinking skills in organizing and presenting their research concept of interest. The students also expressed in an open-ended comment that mind map expanded their thinking and that the discussion group was tremendously helpful. Their results illustrated that mind maps were useful for collaborating with others to develop plans or implement key projects (research). Mind maps allowed the participants to harness the input of all members of a group in a dynamic and creative way, enhancing critical thinking, co-operation, and problem-solving (Kocherlakota et al., 2013).

Mind map encouraged critical thinking and problem solving

Zipp et al. (2015) evaluated critical thinking skills in physical therapy students following one semester of mind map infusion and found a positive change between the pre-(21.4) and post-(23.1) overall HSRT scores. The scores were comparable to those of Huhn, Black, Jensen, and Deutch (2011), Bartlett and Cox (2002) and Vendrely (2005). Although the sample size was small, the authors believed mind map immersion to be a teaching and learning strategy that aided in the development of critical thinking skills. They further inferred that continued use of mind maps over the curriculum may lead to further development of student critical thinking skills and the advancement of novice mind mappers to experienced mind mappers.

Mind map in physician assistant education

Rhee et al. (2003) explored the effectiveness of an active learning strategy such as problem-based learning among PA students. They compared the educational outcomes of problem-based learning (PBL) and lecture-based learning among PA students and found no significant differences in the knowledge base, although the students found the PBL learning more meaningful. Lowy (2013) evaluated the overall critical thinking skills (CTS) of PA students using HSRT and found them to exhibit moderate to strong CTS. Likewise, Lowy identified the PA students' style of learning (preferentially concrete sequential learners) and reported that there was no significant difference between preclinical and clinical PA students with respect to learning style or overall CTS.

In summary, mind maps can be easily taught, does not require any expensive equipment, are additional resources that can be added to the study strategy, and helped to organize information (D'Antoni et al., 2010). Mind mapping promoted learning and development of students' critical thinking skills (Rosciana, 2015; Spencer et al, 2013). MM promoted holistic care for patients and patient-centered thinking (Mueller et al, 2002; Kern et al, 2006). Mind mapping aided in recalling information and encouraged a deeper level of thinking and offered a creative way for information processing (Farrand et al., 2002). Mind maps helped in understanding the concept of critical care nursing (Boley, 2008). Moreover, Vilela et al. (2013) suggested that meaningful learning through mind mapping promotes analytical skills and effective treatment of patients. However, while mind mapping has been studied in a variety of educational settings, there is currently no data on its use or impact on the critical thinking skills of physician assistant students. PA students, like the nurses, medical students, and physical therapy students need to learn, understand and apply concepts essential for patient-centered care.

Critical thinking is needed in healthcare delivery, accurate diagnosis, and treatment, analyzing and managing health risks, using and managing information systems, explaining policy and protocols, and understanding treatment implications. Thus, mind mapping as a learning strategy and its impact on the critical thinking skills of physician assistant students form the conceptual framework for this study (see Figure 6. Conceptual Framework).

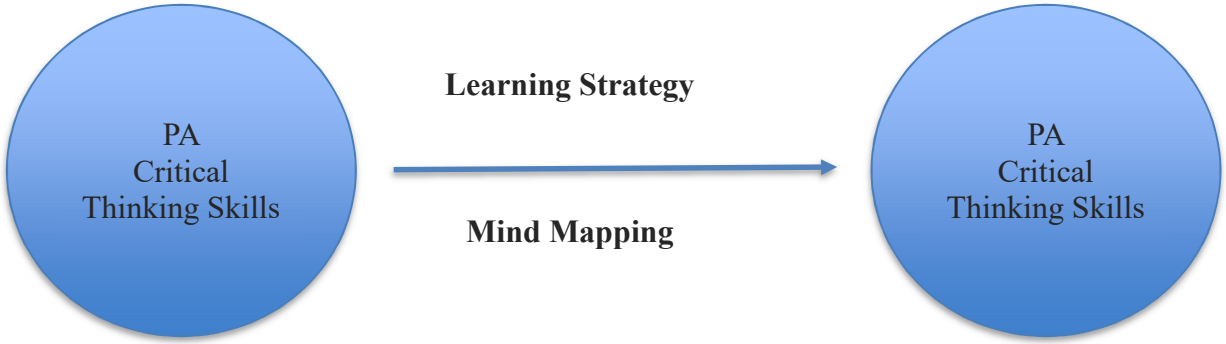
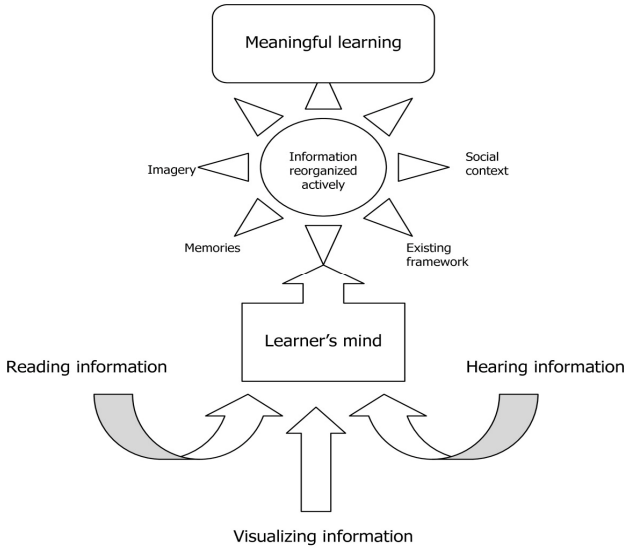


Figure 6. Illustration of Conceptual Framework

Establishing a Theoretical Framework

Learning strategies (e.g. mnemonics, maps, charts) may differ in their efficacy and applicability, but they all are based on the conceptual framework called the constructivist theory of learning, which states that meaningful learning or learning with understanding occurs when adult learners assimilate new information within their existing framework (Ausubel, 1978; Bodner, 1986). Meaningful learning, as opposed to rote memory, requires an in-depth understanding of material where facts are not isolated but rather interrelated, and newly learned concepts are directly associated with those previously learned concepts (Shuell, 1990). Rote learning, on the other hand, happens when the new information cannot be related to the previously learned content in any substantive manner. If there was nothing in the person's existing cognitive structure to

which she or he can relate the new information to form meaning, then it can only be learned rotely (Hay, Kinchin, & Lygo-Baker, 2008). The theoretical basis of constructivism is depicted in figure-7.



(Ausubel, 1978).

Figure 7. Constructivist theory of learning

Information is available to the students through reading, visualizing or listening. Irrespective of the mechanism, information enters the mind of the student who actively tries to make sense of the information (Mezirow, 1981). David Ausubel, an educational psychologist saw the primary responsibility of the educator as the presentation of learning materials in a meaningful form, not as a list of facts. He indicated that educators must find procedures that allow the learners to tie new knowledge into their prior cognitive structure. He proposed visual mapping as a tool par excellence to promote meaningful learning (Santiago, 2011). One of the assumptions underlying the constructivist theory is that the student will integrate information into his/her mental models to make sense, and that results in meaningful learning (Muirhead, 2006).

Constructivism is based on the work of Lewin, Vygotsky, and Piaget. The theory was founded on the principle that knowledge is not "discovered" but constructed in the mind of the learner by integrating learning activities and reflecting on his/her own experiences. Learning is thus an internal cognitive activity, and the learner plays an active role in the construction of the knowledge (Dennick, 2012). The cognitive process of meaning-making was emphasized as both an individual mental activity and a socially interactive interchange. Constructivism views learning as a process of constructing meaning. People actively construct their own subjective representation of the objective reality (Hrynchak & Batty, 2012).

Each person has a different interpretation and construction of the knowledge process. The learners are not a blank slate (tabula rasa) but bring experiences and cultural factors to the situation. New information is linked to prior knowledge; thus, mental representations are subjective (Hrynchak & Batty, 2012). Ausubel (1978) stated that knowledge is hierarchically organized; that new information is meaningful to the extent that it can be related to what is already known. The locus of learning in this perspective is to develop meaning and deepen understanding, as opposed to rote or surface learning (memorizing poorly related facts) (Torre, Daley, Sebastian, & Elnicki, 2006).

The various attributes associated with meaningful learning, such as active, constructive, reflective, intentional, and contextual factors, are exemplified in mapping learning strategies. In MM and concept mapping learners actively identify main ideas and create links between them; they interpret, relate and incorporate new information into their previous knowledge, resulting in meaningful learning. Ultimately, meaningful learning allows for flexibility in solving problems and critical thinking (Pudelko et al.,

2012). Especially, in MM since the student creates the mind map without a template, and the map represents the student's own interpretation and integration of ideas, and this results in meaningful learning (D'Antoni et al., 2010). In MM, the meaningful illustration expounded by the mind mapper assists in a richer and deeper integration of the information that can nurture both declarative (explicit) and implicit knowledge associated with critical thinking and long-term learning (Ambrose et al., 2010).

Overall, mapping allows the presentation of new material to build upon existing knowledge (Davies, 2011). Empirical evidence indicates that mapping is effective in promoting meaningful learning (Pudleko et al., 2012). Meaningful learning is necessary for critical thinking (D'Antoni et al., 2010). Critical thinking is the ability of the individual to evaluate and interpret information, identify assumptions and draw conclusions from data. Visual mapping allows the learner to explicitly explore, analyze, synthesize, and share ideas (Santiago, 2011). Likewise, knowledge is necessary for critical thinking. While critical thinking involves higher order thinking skills, these cannot be utilized without knowledge (Stalheim-Smith, 1998). Willingham (2007) stated that critical thinking occurs when a student goes beyond the surface structure of the problem and recognizes how the problem can be solved and in addition possesses the content knowledge integral to solving the problem. Since critical thinking is dependent upon content (domain) knowledge and problem familiarity, MM may facilitate critical thinking because it fosters retention of factual information, as well as relationships between concepts (Ferrand et al., 2002).

Constructivist theory is supported by empirical evidence that the development of an elaborate and well-structured framework of knowledge determines, at least in part,

how knowledge is used for decision-making and problem solving (West, Park, Pomeroy, & Sandoval, 2002). Peters (2000) stated adult students, and many of them with considerable life experience, have accumulated significant bodies of knowledge about many different things. Some of this learning has been formal and some informal, but it has been continuous and extensive.

Constructivist epistemology offers an alternative to traditional pedagogy in that it is student-focused and considers previous learning done by the students as a foundation upon which to modify, build, and expand new knowledge. Constructivism also appears to be congruent with adult education theory and therefore offers great potential for the enhancement of self-directed learning. Constructivism enhances learning because of the consideration of prior knowledge and the ownership of learning by the students. Implicit in this is the development of metacognitive skills that are an important facet of active and self-directed learning (Peters, 2000).

Additionally, the constructivist theory of learning is the basis for several active learning strategies such as case-based learning, problem-based learning, concept mapping, and mind mapping which are used to promote critical thinking in students (D'Antoni et al., 2009; Noonan, 2012). With increasing dependence on PAs for primary care delivery and their projected growth in the future, PA educators preparing their students will benefit from identifying learning strategies that promote critical thinking. Therefore, the constructivist theory of learning was used as the theoretical foundation to explain mind mapping as an effective learning strategy to promote critical thinking in this study.

Chapter III: METHODS

Design

The study was designed as an experimental cross-sectional analytical study. The purpose of this study was to determine the overall critical thinking scores of PA students using mind mapping as a learning strategy as measured by HSRT and to determine if there is a significant difference in the critical thinking skills between students who used mind mapping versus standard note-taking in their learning environment. Descriptive, quantitative, and qualitative data were obtained to (1) identify the specific characteristics of the PA students (2) to determine the overall critical thinking scores of the mind mapping and the standard notetaking students and (3) to understand the different aspects of promoting critical thinking in PA students. The specific approach used was a mixed methods approach (Figure 8) with concurrent data collection for both qualitative and quantitative analysis.

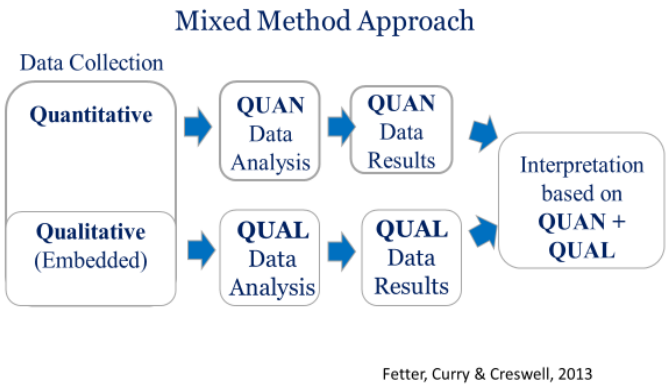


Figure 8. Mixed methods design

The mixed methods approach combines elements of quantitative and qualitative viewpoints, data collection, analysis, inference techniques for breadth and depth of

understanding. Specifically, for this study an embedded experimental mixed methods design was employed, in which, the qualitative data was embedded within a quantitatively designed inquiry. The qualitative data provide a supplemental or secondary role for the study based primarily on the quantitative data (Creswell & Clark, 2003).

The quantitative approach utilized a randomized control design. The participants were randomly assigned to either the Mind Mapping Group (MMG) or the Standard Note Taking Group (SNTG) by the principal investigator (PI). The PI was blinded to participant group assignment. The randomized control design was used to determine whether mind mapping improved critical thinking more in the mind mapping students when compared to the standard note-taking group (RQ 5). The overall critical thinking scores at baseline inform RQ2.

The qualitative approach of the mixed methods design used open-ended questions. Open-ended questions were designed to use the participants' views to further understand the quantitative data in the mixed methods approach. The open-ended questions sought to aid in identifying trends and generalizations regarding learning strategies prevalent among PA students (RQ1) as well as their perceptions on critical thinking, factors that promote critical thinking, faculty's contributions to aid in critical thinking among students and the students' proclivity for a new learning strategy. Since active learning methodologies are recognized strategies used to promote critical thinking in students (D'Antoni et al., 2009; Noonan, 2012), it is pertinent to recognize strategies predominant among PAs that they employ to learn and integrate information and also understand how students define critical thinking skills.

Variables

Independent Variable

The independent variable in this study was the method of study: Mind Mapping (MM) and Standard Note Taking (SNT).

Dependent variable

The dependent variables in this study were the students' HSRT scores.

Instrumentation

The instrument used in this study was the HSRT for measuring critical thinking aptitudes. This instrument was purchased by the PI with permission for student testing from Insight Assessment.

The HSRT, developed by Facione and Facione in 2006, measures high-stakes reasoning and decision-making processes. The HSRT is specifically calibrated for trainees in health sciences educational programs (undergraduate and graduate) and for professional health science practitioners**.** The HSRT does not test domain knowledge. 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 several vignettes (Facione & Facione, 2006). According to the HSRT Manual 2018, the instrument has an overall reliability of 0.8 (Cronbach's alpha) and test-retest reliability of 0.8. The HSRT reports an overall numerical score and 5 subscales: analyses, inference, evaluation, inductive and deductive reasoning.

The scores derived for each of the subscales was classified as either strong moderate, or not manifested, while the overall score was identified as either superior, strong, moderate, or not manifested (See Table 2: Scores of HSRT). While the HSRT instrument is commonly used to determine critical thinking aptitudes, it has also been

used to measure changes in critical thinking based upon a learning intervention (D'Antoni et al., 2010).

The classifications of the six scores can be divided into three categories. For the subscales of analysis, inference, and evaluation, a score of five or above is classified as strong, a score ranging between three and four is considered moderate and a score of less than two is classified as not manifested. For the subscales of deductive and inductive reasoning, a score of eight or above is strong, 5-7 is moderate and less than or equal to 4 is categorized as not manifested. Finally, for the overall score, greater than or equal to 26 is classified as superior, 21-25 is strong, 15-20 is moderate, and a score of less than or equal to 14 is labeled as not manifested (See Table 2: Scores of HSRT). Not manifested indicates that the skills being measured were not demonstrated or expressed.

Table 2

Scoring of HSRT

	Superior	Strong	Moderate	Not Manifested
Analysis	--	≥5	3-4	≤2
Inference	--	≥5	3-4	≤2
Evaluation	--	≥5	3-4	≤2
Inductive	--	≥8	5-7	≤4
Deductive	--	≥8	5-7	≤4
Overall	26-33	21-25	15-20	0-14

Adapted from HSRT data from HSRT Manual (2018).

Setting

The study was conducted at three accredited Physician Assistant programs in New Jersey: Rutgers University PA program, Seton Hall University PA program, and Monmouth University PA program.

Sample

A sample of convenience was utilized. Participant selection was based on meeting four criteria: Male or Female, 18 years of age or older, PA program students and PA majors and students who have not used mind mapping as a learning strategy. Excluded were students enrolled in other programs in the mentioned institutions and those who have used mind mapping as a learning strategy.

Procedure

Upon obtaining approval from the IRB at Seton Hall University (see Appendix), first-, second-, and third-year PA students in all three institutions were recruited for the study (see Figure 9). Participants were recruited via on-site recruitment following an oral presentation by the principal investigator (PI) discussing the study protocol, following which the PI (blinded) then randomly assigned volunteer study participants to either the MMG or the SNTG (by odd/even index cards). The SNTG was the control group and the MMG was the experimental group**.** Standard note taking refers to strategies that do not resemble concept or mind mapping in the organization of information includes notes that are arranged from top to bottom or from left to right, index cards & using study methods that students have been using in their academic career. Mind Mapping technique refers to a visual non-linear representation of a network of connected and related concepts.

Index cards had email links for the appropriate pre-HSRT for the assigned groups. The index cards also had participant code numbers which were used on all future

study correspondence. The participants were asked to list their emails and group assignment in a study participant data sheet that was pre-coded. Participants were given a week to complete the demographic survey and pre-HSRT at their convenience in a quiet location with access to a computer, following which the MMG was invited back for an instructional session on how to construct mind maps given by the PI. MMG participants were instructed to create mind maps weekly and drop of their mind maps at a drop-off box in their PA department every three weeks for the next nine weeks. The SNTG was asked not to mind map and to maintain a log of their learning strategies used and email their log every three weeks to the PI. After nine weeks, the PI emailed both groups the link to the appropriately coded post-HSRT and instructions for completion within six days. Following this, the data was compiled with respect to demographic data and critical thinking scores.

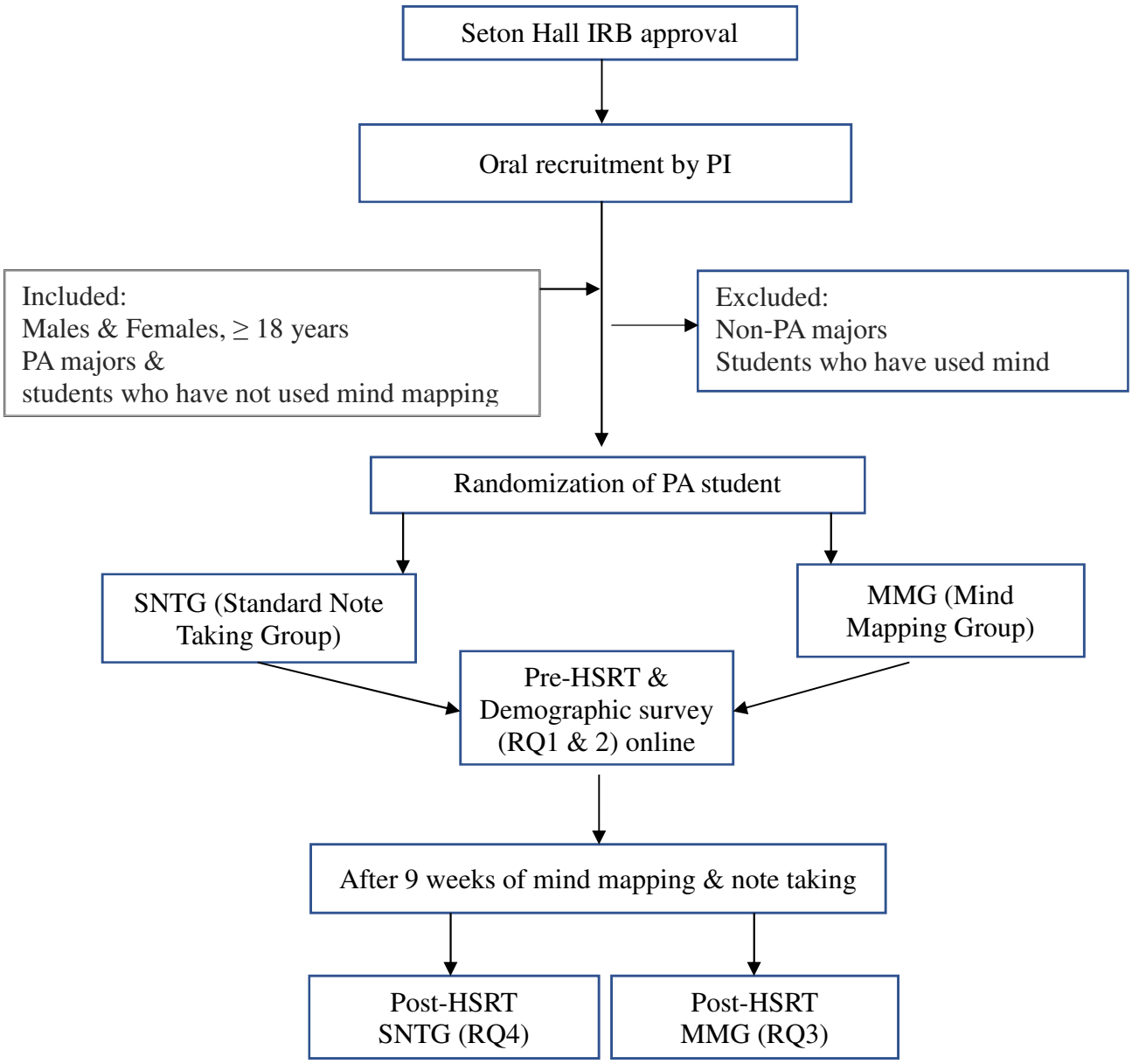


Figure 9. Study Process

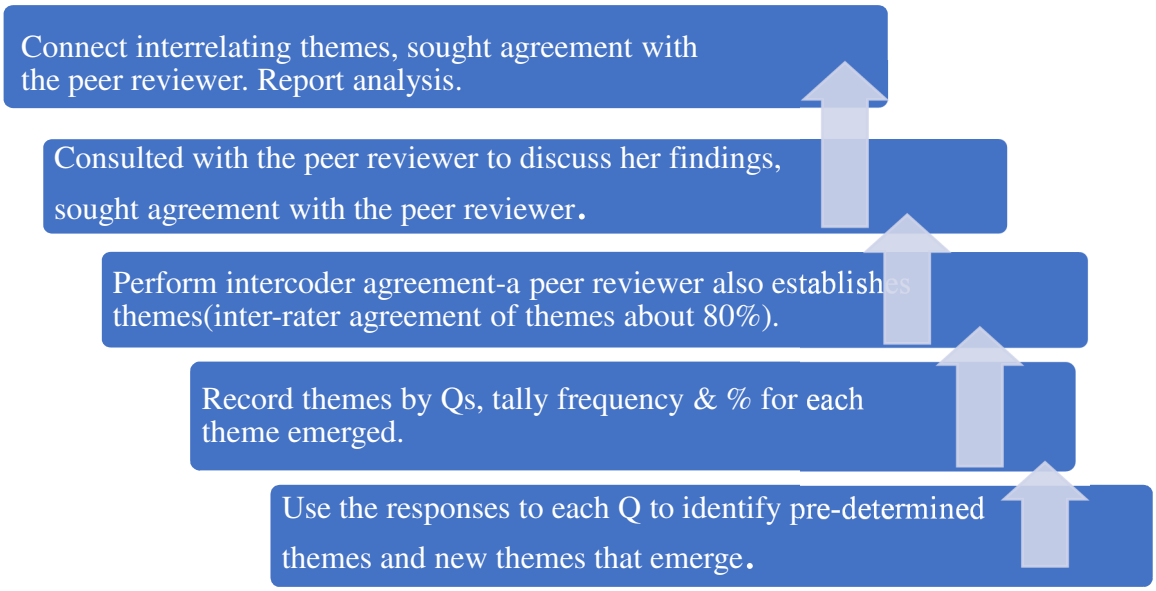
Data Analysis

Using data from the convenience sample, comparative (descriptive, comparison of means) and selected analysis (independent t-test and dependent/paired t-test) were utilized to identify the learning strategies prevalent among PA students (RQ1), the overall critical thinking skills of the PA students before the infusion of mind mapping as a

learning strategy (RQ2), if mind mapping improved the critical thinking scores in the MMG (RQ3) post-nine weeks intervention,if SNTG improved critical thinking post-nine weeks intervention (RQ4) and if there is a significant difference in overall critical thinking skills between the MMG vs the SNTG (RQ 5) post-nine weeks intervention. Content analysis was utilized for the open-ended questions.

Likert-type questions were employed to ascertain the knowledge the MMG had acquired regarding the technique(mind mapping) following their nine weeks exposure. Responses to the Likert-type questions were analyzed using frequencies.

The content analysis and theme generation, illustrated in Figure 10, was utilized to review the open-ended questions.



(Creswell & Clark, 2011)

Figure 10. Content analysis of open-ended questions

In **Quantitative Analysis** the descriptive statistics depicted the demographic characteristics of the participants and the Likert questions were explained by frequencies. The inferential statistics involves

- **Independent T-test**- examined the differences in means between groups (MM & SNT) post-nine weeks intervention.
- **Dependent** T test analyzed the differences in means between the pre-and post-overall HSRT scores of the MMG and the differences in means between the pre-and post-overall HSRT scores of the SNTG.

Specifically, the research questions were analyzed as follows and all appropriate assumptions were tested and met, to use the proposed statistical tests.

RQ1 What learning strategies do PA students use to support their learning in PA school?

- Performed content analysis of open-ended questions on the use of learning strategy among PA students following steps illustrated in Fig 10.

HA2: There is no difference in the overall level of critical thinking skills of PA students as measured by HSRT, regardless of group assignment **at baseline**.

- Descriptive statistics for the overall critical thinking score and subscale scores of all the participants.
- Independent T-test was performed to ascertain that there was no significant difference in the overall critical thinking scores between the two groups at baseline.

HA3: There is a significant difference between pre-and post-overall critical thinking scores for the MM group as measured by HSRT post-nine weeks intervention, with scores being higher at the post.

- Dependent T-test was used to analyze if there is a significant difference in means between the pre-and post-overall HSRT scores of the MMG.

HA4: There is a significant difference between pre-and post-overall critical thinking scores for SNT group as measured by HSRT post-nine weeks intervention, with scores being higher at the post.

- Dependent T-test was used to analyze if there is a significant difference in means between the pre-and post-overall HSRT scores of the SNTG.

HA5: There is a significant difference in critical thinking as measured by HSRT overall score between SNT and MMG, post-nine weeks with MMG presenting with higher scores in CT.

- Independent T-test was employed to determine if there is a significant difference between the means of two independent groups.
- The post-HSRT overall (mean) scores of the MMG and Post-HSRT overall scores (mean) of the SNTG were compared to determine if the MMG had significantly higher scores than the SNTG.

Chapter IV: RESULTS

The purpose of this study was to determine the overall critical thinking scores of PA students using mind mapping as a learning strategy as measured by HSRT and to determine if there is a significant difference in the critical thinking skills between students who used mind mapping versus standard note-taking in their learning environment.

The analysis had two major components. First, a quantitative analysis of the overall critical thinking score of the PA students based on group assignment was completed. The demographic characteristics of the respondents were also identified. This included relevant sample statistics and meaningful graphic display of central tendency, dispersion, and shape of the distribution.

Dependent and independent t-tests were conducted to determine if there was a significant difference between the pre-test and posttest overall critical thinking scores for MMG and the SNTG as well as a significant difference in overall critical thinking scores between the MMG and the SNTG respectively, post-nine weeks as measured by HSRT. For all statistical analyses an alpha of 0.05, with a power of .80 was performed using SPSS software version 24.

The second component reviewed the qualitative data using content analysis as outlined in Creswell & Clark (2011). In this study, the qualitative data was not used to cross-validate data but rather capture a different dimension of the same phenomenon. Using a content analysis approach from the open-ended questions, the PI was able to categorize open-ended questions based upon frequently used words and phrases and develop themes.

Quantitative Findings: Descriptive Statistics

Characteristics of Sample

74 participants met the inclusion criteria. They comprised first-, second-, and third-year PA students from 3 PA schools in New Jersey. The study participants were predominantly female (82%), with a mean age of 26 (SD 2.72) and with 85 % enrolling in the PA school with a bachelor's degree (See Table 3). 50% of the participants were second-year students.

Table 3

Study Demographics

Demographics	Value
Gender	
Male	18%
Female	82%
Age	
Mean	26
Minimum	20
Maximum	38
Education	
Bachelor's Degree	85%
Master's Degree	15%

In response to the first Research Question (RQ): What learning strategies do PA students use to support their learning in PA school?

The learning strategy prevalent among the PA students were determined by utilizing the results compiled from the open-ended questions using content analysis and theme generation as outlined in Creswell & Clark (2011). For most of the subjects, the preferred learning strategy was a combination of visual, auditory and verbal (49%) components followed by visual (35%) and verbal (16%). Table 4 illustrates the three

themes obtained for the "learning strategies employed by the PA students" and the interrater reliability score.

Table 4

Learning strategies employed by PA students (N-74)

Theme 1: Visual Based on VARK (Chick, 2018) Prefer using flash cards, highlighting, graphs, map, charts, notes, pictures and images	Theme 2: Verbal Based on VARK (Chick, 2018) Prefer using words, written and spoken, use study groups, benefit from oral and written reports, use mnemonics and read aloud	Emergent Theme 3: Combination Based on VARK (Chick, 2018) and emergent theme Visual, Auditory & Verbal
"Making notes"	"Textbook reading and flashcards"	"Outlines, flashcards, question banks, videos, & PowerPoints"
"Tables, graphs, flow charts, & pictures"	"Reading, writing, & repetition,"	"Flashcards and diagrams"
"Flashcards, color coding, & charts"	"Writing notes and reading textbook"	"Notes, flashcards, outlines, & videos"
Percentage of respondents providing comments for each of the identified themes		
35%	16%	49%

Note: Interrater reliability = 87%

RQ2: What is the overall level of critical thinking skills of the PA students at baseline as measured by the HSRT based on group assignment?

The overall critical thinking (CT) score of the PA students at baseline was measured by HSRT based on group assignment. The instrument provided separate scores for six parameters identified by the instrument as analysis, inference, evaluation, deduction, induction and overall (see Table 2: Scoring of HSRT). For each of these parameters the median, mean and standard deviation were calculated, and these scores

were utilized to classify each parameter as either superior, strong, moderate or not manifested (see: Table 5 Pre-HSRT Scores of MMG and Table 6: Pre-HSRT Scores of SNTG).

Table 5

Pre-HSRT Scores of Mind Mapping Group (N=47)

Parameter	Mean	Median	Classification
OVERALL	21.1 ± 5.2	22	Strong
Induction	7.0 ± 1.9	7	Moderate
Deduction	6.5 ± 2.5	7	Moderate
Analysis	4.1 ± 1.5	4	Moderate
Inference	3.9 ± 1.6	4	Moderate
Evaluation	4.4 ± 1.6	4	Moderate

In the MMG (N=47) the overall score (Mean = 21.1.8 ± 5.2, Median=22) was identified as strong; Induction (Mean =7.0 ± 1.9, Median=7), Deduction (Mean=6.3 ± 2.5, Median=7), Analysis (Mean=4.1 ± 1.5, Median=4), Inference (Mean=3.9 ± 1.6, Median=4), and Evaluation (Mean=4.4 ± 1.6, Median=4) were identified as moderate. There were no parameters that were identified as “not manifested”.

In the SNTG (N=43) (Table 6) overall score was identified as strong (Mean=21.5 ± 4.0, Median 21), and the rest of the five parameters, Induction (Mean=7.4± 1.5, Median 8), Deduction (Mean=6.5 ± 1.9 Median=7), Analysis (Mean=4.1 ± 1.2, Median=4), Inference (Mean=3.7 ± 1.2, Median=4), and Evaluation (Mean=4.7 ± 1.2, Median=5) were identified as moderate. Figure 11 represents the Box-plot of the pre-HSRT overall score of MMG & SNTG.

Table 6

Pre-HSRT Scores of Standard Note Taking Group (N=43)

Parameter	Mean	Median	Classification
OVERALL	21.5 ± 4.0	21	Strong
Induction	7.4 ± 1.5	8	Moderate
Deduction	6.5 ± 1.9	**7**	Moderate
Analysis	4.1 ± 1.2	4	Moderate
Inference	3.7 ± 1.2	4	Moderate
Evaluation	4.7 ± 1.2	5	Moderate

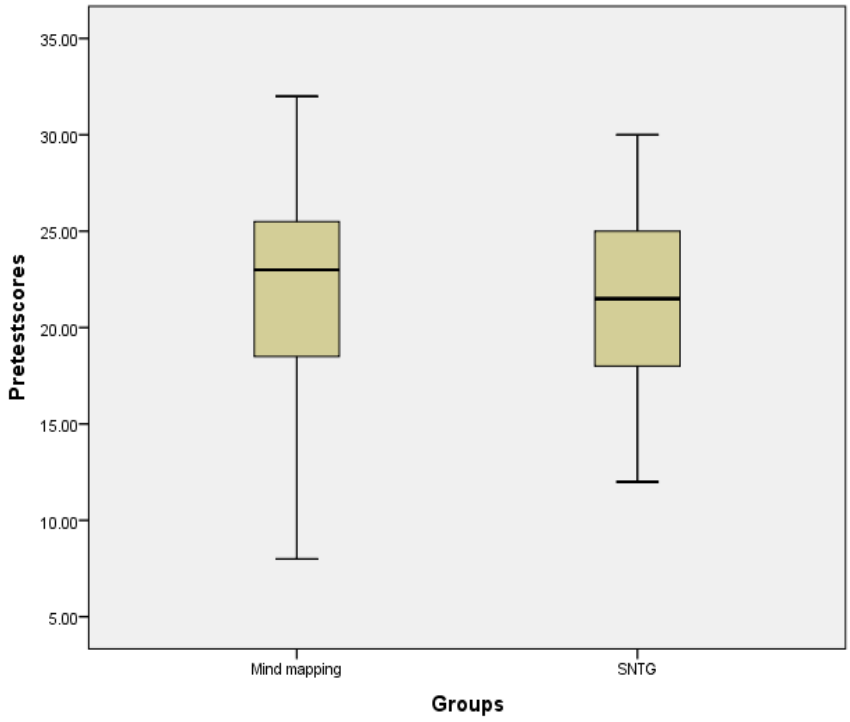


Figure 11. Boxplot of Pre-HSRT overall scores for MMG and SNTG.

An independent sample t-test was conducted to compare the overall pretest critical thinking score between the MMG (M= 22.11, SD=4.7) and the SNTG (M=21.42,

SD=4.4) at baseline (Table 7). There was no significant difference between the groups in the overall critical thinking scores (t (72) =.656, p=.514 >.05). The results suggest that the two groups did not differ significantly in overall critical thinking scores at baseline (the beginning of the study).

Table 7

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Pretest scores	Mind mapping	36	22.1111	4.69515	.78253
	SNTG	38	21.4211	4.35351	.70623

t (72) = .656, p=.514 >.05

RQ3: Is there a significant difference between pre- and post-test overall critical thinking scores for MMG as measured by HSRT post-nine weeks?

In response to research question three, a dependent t-test or a paired t-test was conducted to compare the overall critical thinking score of the MMG before and after nine weeks of mind mapping. There was no significant difference in the pre-test overall critical thinking score (N=36, M=22.1 SD=4.7) and the post-test overall score (M=22.8. SD=3.9) following nine weeks of mind mapping (Table 8) t (35) =1.22, p=.23>.05.

RQ 4: Is there a significant difference between pre- and post-test overall critical thinking scores for SNTG as measured by HSRT post-nine weeks?

A paired sample t-test of the SNTG was also conducted to compare the overall critical thinking score of the SNTG before and after nine weeks of standard note-taking strategy. There was no significant difference in the overall pretest score (M=21.4, SD=4.4, N=38) and the overall post-test score (M=20.6, SD=4.3) following nine weeks of standard note-taking strategy (t (37) = 1.356, p=.183 >.05) (Table 9).

Table 8

MMG statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	posttest	22.8056	36	3.90472	.65079
	Pretest	22.1111	36	4.69515	.78253

t (35) =1.22, p=.23>.05

Table 9

SNTG statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	21.4211	38	4.35351	.70623
	Posttest	20.6316	38	4.28965	.69587

t (37) = 1.356, p=.183 >.05

RQ 5: Is there a significant difference in the overall critical thinking score as measured by HSRT between SNTG and MMG, post-nine weeks?

In response to research question four, an independent t-test was conducted to compare the overall critical thinking score between the MMG and the SNTG post-nine weeks (Table 10) of mind mapping and standard note taking respectively. Figure 12 illustrates the Box-plot of the post-HSRT overall score of MMG & SNTG.

Table 10

Group Statistics

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Postscores	Mind mapping	36	22.8056	3.90472	.65079
	SNTG	38	20.6316	4.28965	.69587

t (72) = 2.276, p =.026

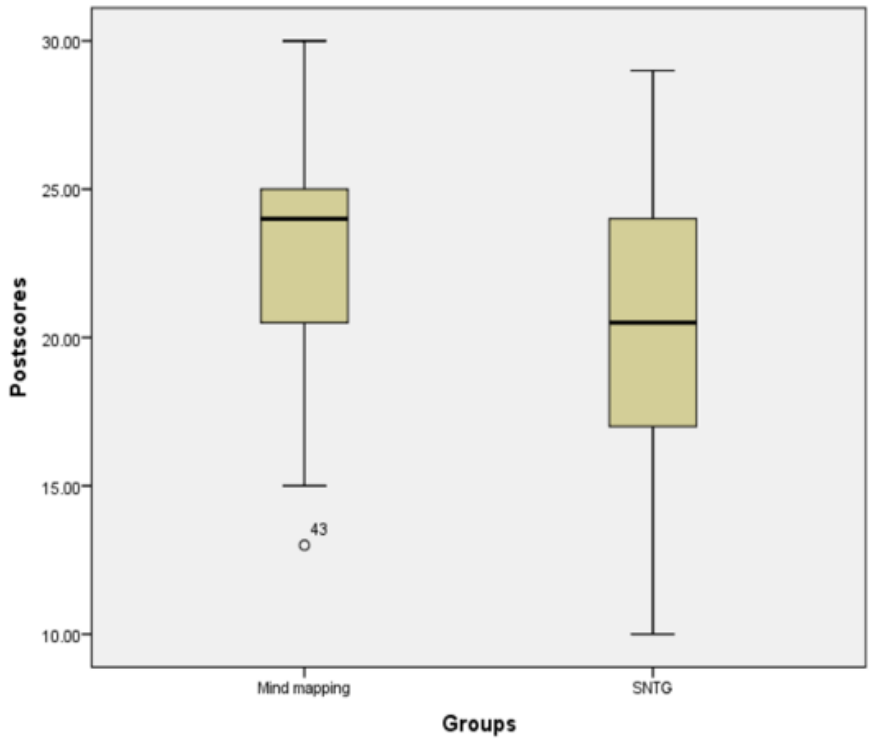


Figure 12. Box-plot of Post-HSRT overall score between MMG and SNTG.

There was a significant difference in the overall critical thinking score post nine weeks between the MMG (M=22.80, SD=3.90) and the SNTG (M=20.63, SD =4.29) $t(72) = 2.276$, $p = .026 < .05$) with the mind mapping group presenting higher scores.

Qualitative Data Results

The qualitative part involved content analysis and theme generation for the five open-ended questions as outlined by Creswell & Clark (2011) illustrated in Figure 10. This was to ascertain a more complete picture of the different aspects of promoting critical thinking in PA students. Two OED questions were included in the pre-test and three OED were included in the post-HSRT test as part of the qualitative data collection. Of the five OED questions, four (2 pre- and 2 post-) questions were directed to both groups and one question was addressed to the SNTG. These questions followed the HSRT pre- and post-tests.

The following were the **Pre-test** questions for both groups:

1. How would you define critical thinking?
2. What contributes to the development of your critical thinking skills?

The following were the **Post-test** question for both groups:

1. What persuades you to be interested in a new learning strategy?
2. How can faculty contribute to critical thinking in students?

The following was a posttest question to the SNTG ONLY:

1. What do you know about the use of mind mapping as a learning strategy?

For the MMG an additional posttest Likert-Type questionnaire developed by the PI (Principal Investigator) was used to assess statements regarding mind mapping following nine weeks of mind mapping. The scale offered a choice of five pre-coded responses ranging from strongly agree to agree, uncertain, disagree, and strongly disagree. The Likert questionnaire evaluated items like “Mind mapping can help organize information” and “Mind mapping helps in integration of information”. The Likert questionnaire had positive statements of mind mapping.

Results of Open-Ended Questions (content analysis**)**

Data analysis of open-ended questions consisted of coding and organizing information from the responses into themes by the PI. Microanalysis or line -by -line analysis by reading through the entire text was first employed. Next data from each line of text were then used with the comment tool in Microsoft Word to identify themes within the text. Some themes were pre-determined based on literature, while others emerged from the data. Depending on the responses some questions had pre-determined and emergent themes, while others had only emergent themes. The responses were

divided into the control group and intervention group first and then analyzed. The same process was followed by the interrater.

Intercoder reliability is a critical component of the content analysis of open-ended survey questions, without which the interpretation of content analysis cannot be considered objective and valid. Intercoder agreement was ensured by two researchers independently coding like statements and establishing themes (Creswell & Clark, 2011). Cohen's kappa was used to report the intercoder reliability. Cohen's kappa is an index that measures interrater agreement for categorical (qualitative) items. Cohen's kappa considers the possibility of the agreement occurring by chance. A kappa value of .70 is generally considered satisfactory (McHugh, 2012).

Q1. How would you **define critical thinking**?

Q2. What **contributes to the development** of your critical thinking?

Qualitative responses were included from 74 respondents for Q1 & Q2. The text from OED was examined for aspects of critical thinking within the messages so that common themes could be generated. There were three themes established in "Defining critical thinking" in question 1 shown in Table 11. The themes included those defined by Facione (2013), themes defined by Facione and additional emergent themes, and those with emergent themes only. The interrater reliability was 91%.

Table 11

Definition of critical thinking by the PA students (N=74)

Theme 1:	Theme 2:	Emergent Themes 3:
Components of Critical thinking (Facione,2013): Induction, Deduction, Analysis, Evaluation, Inference, problem-solving, decision making & reasoning	Components of critical thinking (Facione,2013) + Additional (emergent) themes: Application, memory, synthesis, understanding, and judgment	Synthesis, application understanding and interpretation
"Evaluation and analysis of a specific matter"	"Problem-solving with a true understanding of all aspects"	"Using your knowledge and applying it to a situation in which the knowledge can be integrated"
"Deep analysis of a given topic"	"Analyzing and applying knowledge to come up with a solution/outcome"	"Integration of information to see the big picture when assessing a situation"
"Evidence-based, analytical solving of a problem"	"Being able to form conclusions based on multiple sources of information and putting them all together"	"Being able to think about a topic in a greater context than the individual topic itself."
Percentage of respondents providing comments for each of the identified themes		
36.6%	16.2%	47.3%

Note: Interrater reliability = 91%.

Table 12 highlights the four themes established for "the development of critical thinking": Attitudes & Knowledge, Active learning strategies, Understanding & active learning strategies & Understanding.

Table 12

Development of critical thinking themes (N=74)

Theme 1: Attitudes and Knowledge (based on Bloom's taxonomy, 2001) Rest, & receptive	Theme 2: Active Learning Strategies (based on Bonwell & James, 1991) Situational experiences, writing, discussion, & problem-solving	Theme 3: Understanding (based on Bloom's taxonomy 2001)	Emergent Theme 4: Active learning strategies and Understanding
"Knowledge of concepts"	"Problem-solving skills, searching and analyzing of literature"	"How well you understand the information"	"Understanding the topic and being able to use context to answer"
"Sleep"	"Experience in situations where it is necessary to think quickly and make decisions"	"Understanding concepts instead of memorizing information"	"Practice questions, understanding of concepts, and being able to relate similar concepts
"Learning"	"Taking knowledge and education from didactic training and apply to clinical training and patient encounters"	"Trying to understand on my own"	"Having a full understanding of the concept in differing scenarios"
Percentage of respondents providing comments for each of the identified themes			
12%	66 %	11%	11%

Note: Interrater reliability = 95%.

Post-HSRT Open-Ended Questions

Table 13 Displays the five emergent themes generated for “What persuades you to be interested in a new learning strategy?”

Five themes were: Improve learning, performance, and retention, efficiency, and quickness, recalling information, novelty and type of leaner.

Table 13

Interest in a new learning strategy (N=74)

Theme 1: Improve Learning, performance & retention: Recall information, improve grades, improve learning, better study habits, & improve knowledge	Theme 2: Efficient & Quick: Volume, quicker, efficient, & effective	Theme 3: Recall Information: recall	Theme 4: Novelty: Curiosity, & try new methods	Theme 5: Type of learner: Visual
"Struggling with new information"	"Efficient with studying	"If it helps to recall the information"	"New strategy could only benefit me when studying".	Visual learner and wanted to learn how to mind map
"To be able to integrate and understand topics better"	"To be more efficient"	"Ease of recall"	"I find normal studying difficult/boring".	"I enjoy art, so it is a satisfying study method for me"
"The ability to retain long-term information"	"My previous methods have not been effective in regard to time and success."	"Possibility to improve my recall"	"Incorporating new learning strategies can help promote mastery of concepts."	"It integrates into my established study technique"
Percentage of respondents providing comments for each of the identified themes				
61%	11%	5%	20%	3%

Note: Interrater reliability = 95%.

Table 14 demonstrates the three emergent themes that characterized responses to: "How can faculty contribute to critical thinking in students?"

Table 14

Faculty's contribution to critical thinking

Theme 1	Theme 2	Theme 3
Case studies/real situations/practical problems, team-based learning: demonstrate the integration of information, & synthesizing	Practice Questions & Answers: Pre/post, & guided questions	Innovative strategies: Ways of presenting information, mind mapping, & learning from different sources
"They can show how topics are intertwined by helping us integrate them"	"Pre/Post questions during lecture are also helpful"	"Assign each student to make a mind map and present it to the rest of the class."
"They could go over problems with the class and discuss the manner in which students should think and problem solve"	"Provide resources that guide you through the process of critically thinking through a question"	"By presenting information simply first and then adding the details"
"Do concept analysis exercises in class"	"Class discussion with guided questions about in-depth topics"	"By educating students on new learning techniques"
Percentage of respondents providing comments for each of the identified themes		
27%	20%	53%

Note: Interrater reliability = 93%.

Table 15 highlights the five emergent themes obtained from the SNTG for the question:

"What do you know about the use of mind mapping as a learning strategy?"

Table 15

Knowledge of mind mapping in the SNTG (N=38)

Theme 1 Not much, & none	Theme 2 Organizational tool: helps write, organize thoughts, & an organized way of studying	Theme 3 Integration tool	Theme 4 Visual tool	Theme 5 Memory Tool
"I don't know much about it".	"Helps in organizing the content and helps visual learners."	"It encourages you to use different parts of your brain to learn material"	"Provide a visual of a lot of different pieces of information"	"It helped to remember information better"
"Not much"	"Mind mapping is an effective way of organizing topics and learning new material"	"It helped me to write papers"	"More visual way to remember information that works better usually than traditional study habits"	
"None"	"An organized way of studying"	"Good learning strategy to help incorporate Everything"	"Uses visuals to assist with studying"	
Percentage of respondents providing comments for each of the identified themes				
37%	18 %	16%	16%	13%

Note: Interrater reliability was 86%.

Responses to OEQ were further analyzed based on groups assignment. That would help in identifying if there were differences between the groups and may offer insight into their respective overall critical thinking score.

Table 16 illustrates the responses of the MMG and the SNTG for RQ1 “What learning strategies do PA students use to support their learning in the PA school?”

Table 16

Learning strategies among the MMG and SNTG

Theme 1: Visual Based on VARK (Chick, 2018) Prefer using flash cards, highlighting, graphs, map, charts, notes, pictures and images	Theme 2: Verbal Based on VARK (Chick, 2018) Prefer using words, both in written and spoken, use study groups, benefits from oral and written reports, use Mnemonics and read aloud	Emergent Theme 3: Combination Based on VARK (Chick, 2018) and emergent theme Visual, Auditory & Verbal
	MMG	
6	5	18
	SNTG	
20	7	18

More participants in the SNTG use visual aids as learning strategies compared to the participants in the MMG.

Table 17 represents the responses of the groups to “Definitions of critical thinking”

Table 17

Components of critical thinking skills

Theme 1 Components of Critical thinking (Facione,2013): Induction, Deduction, Analysis, Evaluation, Inference, problem-solving, decision making & reasoning	Theme 2 Components of critical thinking (Facione,2013) + Additional(emerging) themes: Application, memory, synthesis, understanding, and judgment	Theme 3 Emergent Theme: Synthesis, application understanding and interpretation
	MMG	
10	3	21
	SNTG	
17	9	14

In terms of the definition of critical thinking, the two groups did not differ considerably. Table 18 addresses the question “What contributes to the development of your critical thinking skills?”

Table 18

Development of Critical thinking Skills

Theme 1 Attitudes and Knowledge: (based on Bloom's taxonomy, 2001) Rest, & receptive	Theme 2 Active Learning Strategies: (based on Bonwell & James., 1991,) Situational experiences, writing, discussion, & problem-solving	Theme 3 Understanding:(based on predetermined Bloom's taxonomy, 2001)	Theme 4 Emergent Theme: Active learning strategies and Understanding
	MMG		
3	24	5	5
	SNTG		
6	25	3	3

The two groups do not differ widely in the elements that contribute to the development of their critical thinking skills.

Table 19 portrays the responses to the post question "What persuades you to be interested in a new learning strategy?"

Table 19

Interest in a new learning strategy

Theme 1 Improve Learning, performance & retention: recall information, improve grades, improve learning, better study habits, & improve knowledge	Theme 2 Efficient & Quick: Volume, quicker, efficient, & effective	Theme 3 Recall Information: recall	Theme 4 Novelty: Curiosity try new methods	Theme 5 Type of learner: Visual
		MMG		
30	4	1	11	2
		SNTG		
15	4	3	4	0

All themes were generated from responses. More MMG participants were interested in improving learning, performance & retention compared to SNTG participants. Likewise, MMG indicated novelty and curiosity influencing their persuasion in exploring a new learning strategy.

Table 20 depicts the role of the faculty in promoting critical thinking among PA students.

Table 20

Faculty's contribution to critical thinking

Theme 1 Case studies/real situations/practical problems, team-based learning: demonstrate the integration of information, & synthesizing	Theme 2 Practice Questions & Answers: Pre/post, & guided questions	Theme 3 Innovative strategies: Ways of presenting information, mind mapping, & learning from different sources
	MMG	
18	2	18
	SNTG	
2	13	21

All themes were generated from responses. A greater proportion of MMG identified case-based learning that faculty can utilize to promote CT compared to SNTG. Both groups desired innovative strategies to present and learn information.

Results of Likert Questions

Following nine weeks of mind mapping, a Likert questionnaire was used to determine the attributes of mind mapping among the participants in the MMG. Frequencies (percentages of responses in each category) were used to analyze the responses

Figures 13-19 illustrate the responses to positive statements on mind mapping.

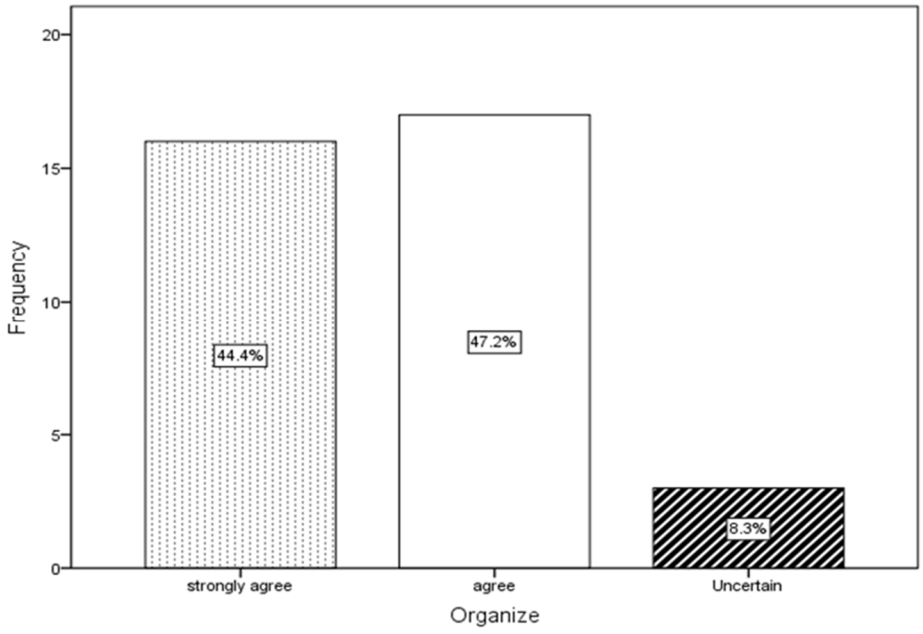


Figure 13. Bar graph displaying responses to organization

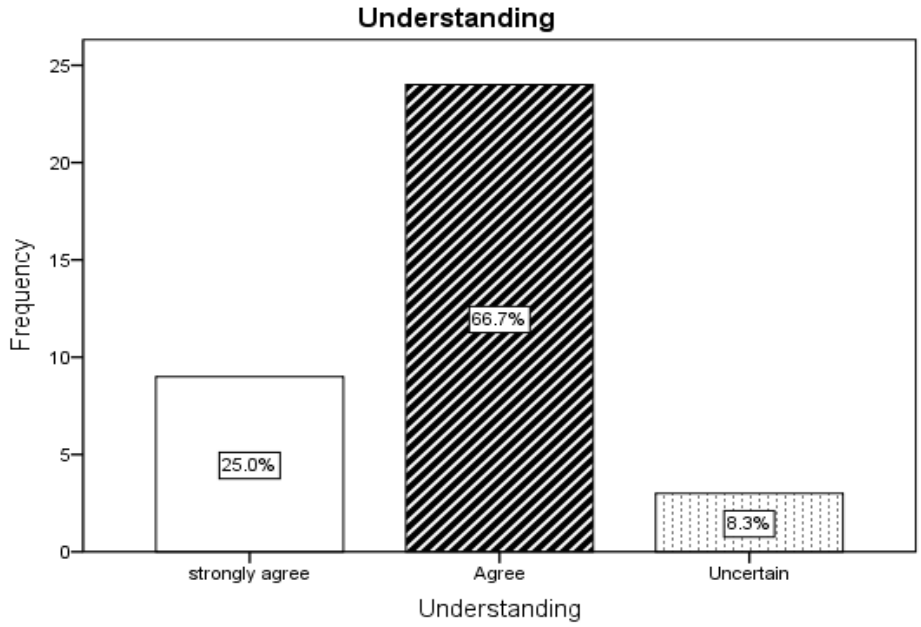


Figure 14. Bar graph displaying the responses to understanding

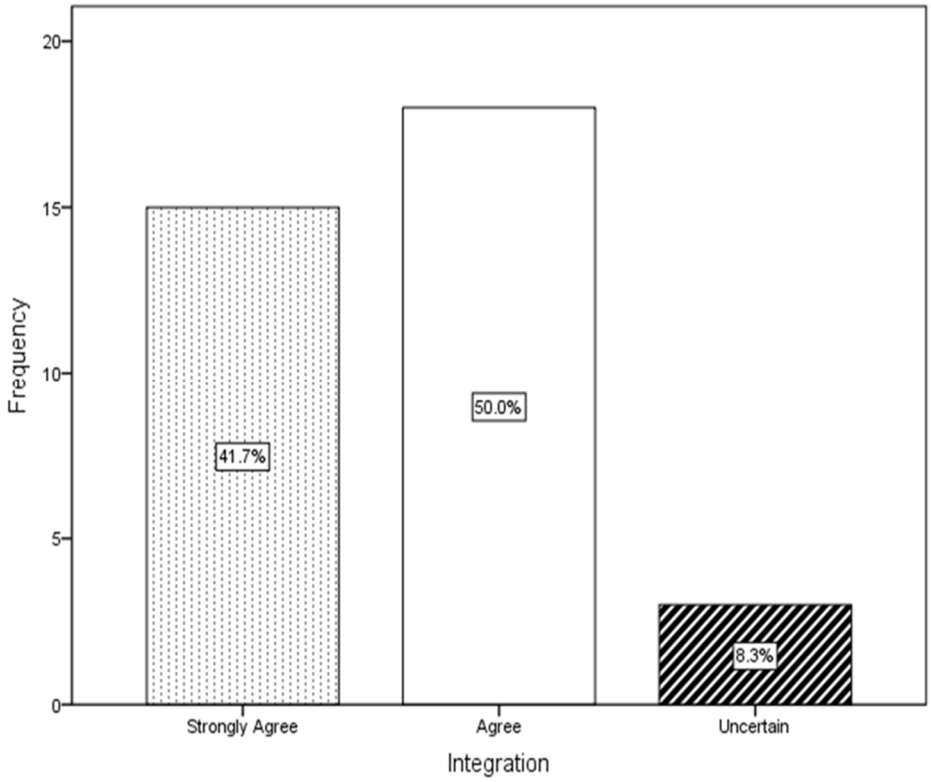


Figure 15. Bar graph displaying responses to integration

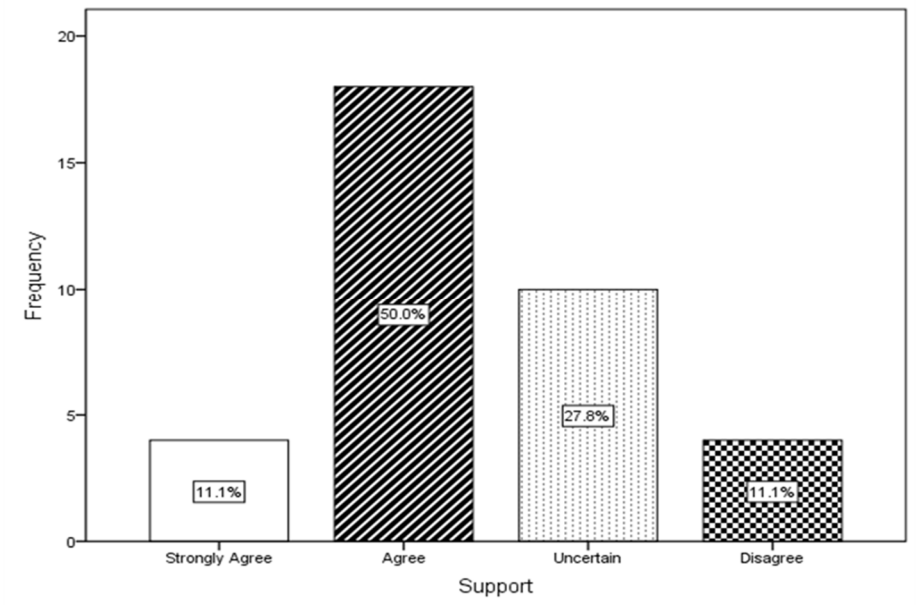


Figure 16. Bar graph displaying responses to support

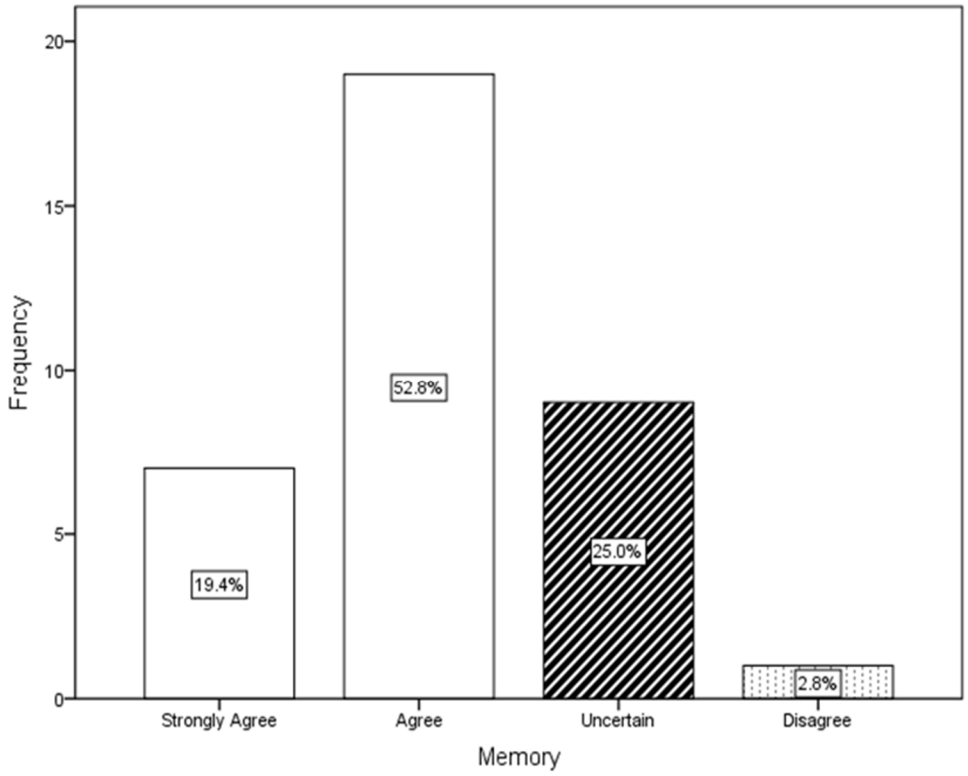


Figure 17. Bar graph demonstrating responses to memory

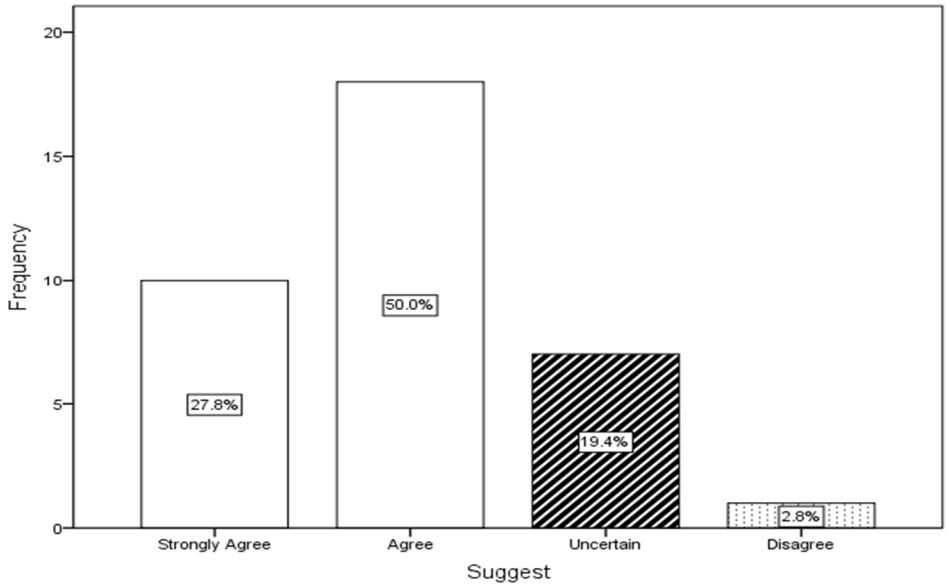


Figure 18. Bar graph presenting responses to suggest

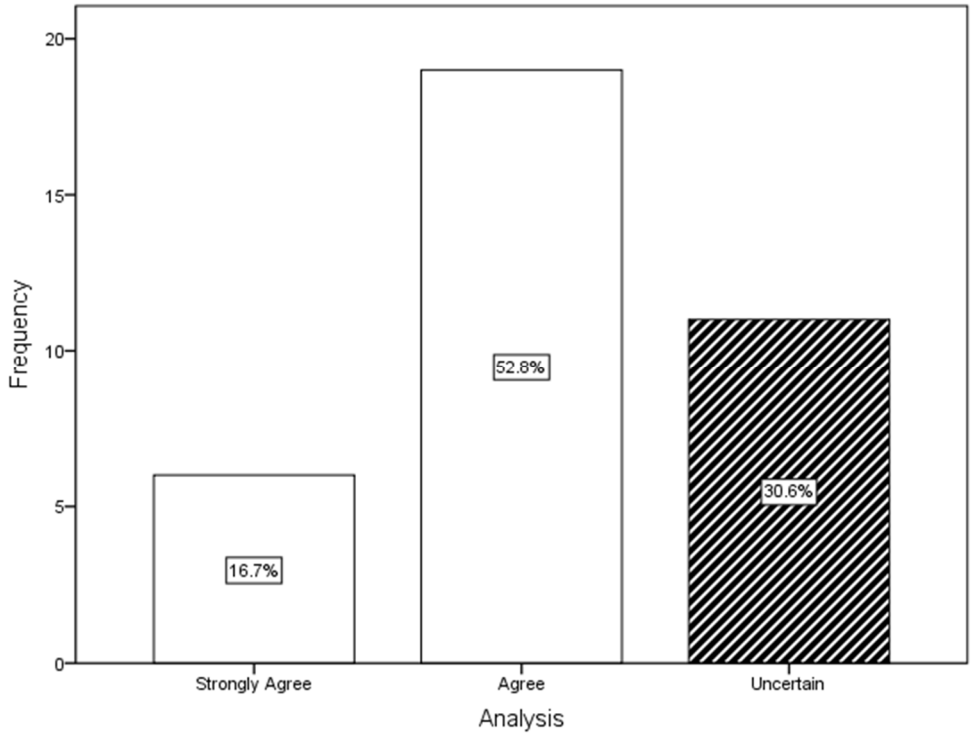


Figure 19. Bar graph demonstrating responses to analysis

More than half of the MM participants indicated that MM assists in the analysis; understanding, organization and integration of information; aids in memory and supports their learning. Additionally, they would suggest MM to other students to bolster their learning in PA school.

CHAPTER V: DISCUSSION

In today's healthcare system, taking care of patients is often a team effort. The team involves nurses, technicians, and therapists. One vital member of the health care team is the PA. Working in all specialties and all settings, PAs play a key role in the healthcare team and offer a solution to the expanding need for primary care providers in the US. The contributions of PAs to primary care involve effectiveness, safety, patient satisfaction, and outcomes of care comparable to a physician. The addition of PAs to primary care teams' aides in providing comprehensive, coordinated patient care and helps to maintain continuity of care (Hooker & Evertte, 2012). Given the crucial role of the PA in healthcare delivery, it is the inherent responsibility of the PA educators to prepare students for today's clinical practice, ensuring that their students develop and utilize effective critical thinking skills to make sound clinical decisions (Day & Hale, 2005).

Critical thinking is an essential cognitive skill that PAs must engage in daily, to provide effective patient treatment and patient management. Critical thinking skills must be developed and fostered in their academic career by incorporating them into a variety of contexts and using multiple methodologies. PA educators can optimize learning that fosters critical thinking using methods like mind mapping, concept mapping, problem-based learning, and case-based studies (Day & Hale, 2005; Rosciano, 2015). Mind mapping allows the learners to draw upon prior knowledge and apply this knowledge to specific situations (Buzan & Buzan, 1996; Davies, 2010; Spencer et al., 2013). Use of mind mapping in care plans, collaborative learning, differential diagnosis, and the process of managing acute and chronic diseases provides an opportunity to practice critical thinking skills and develop clinical judgment (Spencer et al., 2013).

Although mind mapping (MM) has been evaluated in other health-related professions, there has been no prior research on whether MM is a useful learning strategy to employ to develop PA students' critical thinking. Hence, the purpose of the study was to assess the critical thinking skills (CTS) of the PA student using mind mapping as a learning strategy as measured by HSRT and to determine if there is a significant difference in the CTS between students who used MM versus Standard Note Taking (SNT) in their learning environment.

HSRT Assessment of Critical Thinking Skills

HSRT was utilized to assess the overall critical thinking skills of the PA students at baseline, irrespective of group assignment. The overall critical thinking score was 21, which is in the strong category. The result obtained was consistent with previous results observed among PAs (Lowy, 2013) and in medical students (D' Antoni et al., 2010; Huhn et al., 2013). Given the rigorous admittance requirements of these programs as well as the amount of information to be learned throughout the curriculum, a score of strong for critical thinking was expected. The subscales (inductive, deductive, inference, analysis & evaluation) were all moderate. Similar findings have been noted with nursing students and physical therapy students for all the subscales except evaluation (Greener, 2013). Surprisingly, no parameter was identified as "not manifested" (they did not exhibit the skills that they were tested for). Despite the group's strength in overall score, the PA students were predominantly in the moderate range with respect to the subscale scores, therefore there is a need for further development of their CTS. Acknowledging these findings will pave the way to improving the learning process given the importance for PA students to develop their CTS.

Comparison of Pre- and Post-Overall CT Score in the Mind Mapping Group

Comparison of pre- and post-critical thinking overall score was performed to determine if there was a significant difference in overall CTS post-nine-week intervention in the Mind Mapping Group (MMG). The results indicate ($t(35) = 1.22$, $p = .23$) that there is no statistically significant difference between pre-and post-overall critical thinking scores as measured by HSRT in the MMG post nine weeks intervention. The mean overall total score on the posttest for subjects in the MMG was 22.8 (SD=3.9), and the mean overall total score on the pretest for subjects in the MMG was 22.1(SD=4.7); while the difference was not significant, the posttest overall score was higher. The majority (61%) of the MMG participants, however, observed an increase in their individual overall critical thinking (CT) score. Improvements in their critical thinking score can be classified into 5 categories:

Students who moved up in the strong category (21-25 overall CT score) =14

Students who moved up in the moderate category (15-20 overall CT score) =2

Students who moved from moderate to strong category =2

Students who moved from strong to superior (26-30) category=2

Student who moved up in the superior category=1

Improvements in critical thinking scores ranged from an increase of one point to an increase of five points. According to insight assessment, an improvement of a single point in overall critical thinking is educationally significant, suggesting that mind mapping improved critical thinking compared to SNT strategies in the PA students. Student improvements in the overall CT score noted in this study are like those obtained by Zipp, Maher & D'Antoni (2015) between pre- and post-CT overall and subscores during one semester of MM infusion for PT students. Huhn et al. (2013) evaluated the

overall CT score and subscale scores as measured by HSRT of DPT (N=63) students at 3 points in their education: upon entry into the program, prior to final affiliation, and prior to graduation. They observed a significant change (Table 21) in the total score as well as deductive and analytical subscale scores between times 1 and 2 (between entry & prior to affiliation). Surprisingly, the greatest changes in reasoning occurred during the didactic portion of the student's education and not during their clinical period.

Table 21

HSRT Total and Sub-Scale Means at Time 1, 2, and 3 and ANOVA Statistics

	Time 1	Time 2	Time 3	F	P
Total Score	22.39	23.74	23.42	7.81	.007*
Inductive	7.9	8.14	8.27	2.27	.13
Deductive	7.15	7.87	7.5	11.14	.001*
Analysis	4.23	4.71	4.73	9.25	.003*
Inference	3.57	3.63	3.42	0.891	.69
Evaluation	5.2	5.33	5.39	1.03	.31

* $P < .05$

(Huhn, Black, Jensen & Deutsch, 2013)

This finding is contrary to the findings of Bartlett and Cox (2002) who reported a greater change in CT scores during the clinical portion of their DPT program relative to the didactic portion. Williams et al. (2011) reported findings like Huhn's in the study of medical school curriculum describing a steady improvement in reasoning across the years of medical school but failed to identify greater improvements during the clinical portion of the program compared to didactic portion.

The results in the difference between the pre- and post-overall critical thinking scores in the MMG along with the results of Huhn (2013) suggest that the students need to make mind maps for a longer period to observe a significant change in their critical thinking. Additionally, earlier studies by D'Antoni et al. (2010) and Srinivas et al. (2008) indicate that multiple MM sessions or multiple maps may be necessary for students to gain proficiency in the technique before significant changes in critical thinking emerge. The participants in this study, on the other hand, created one mind map per week for a total of nine weeks. Therefore, multiple mind maps over a longer period may be a necessary requisite to better test whether the use of mind mapping significantly increases critical thinking as measured by HSRT. Additionally, the results may be impacted by the structure of the medical curricula (D'Antoni et al, 2009). Moreover, insight assessment (2018) also signifies that with an adequate size sample, the difference between the pre- and post-overall critical thinking scores will be statistically significant when the average change is about +2. The average change in this study for the MMG was .69 (9-week intervention) coupled with an inadequate sample size could be additional factors that influenced overall critical thinking scores. Furthermore, the participants had a strong overall score at baseline, reinforcing that longer time may be necessary to observe significant changes in overall critical thinking scores.

Comparison of Pre- and Post-Overall CT Score in the SNTG

Comparison of pre- and post-overall CT score in the SNTG was conducted to identify if there was a significant difference in overall CT score post-nine-week intervention. The result showed that there was no significant difference ($t(37) = 1.356$, $p=.183$) in the overall CT score of the SNTG post-nine-week intervention. The mean

overall score on the pre-test for subjects in the SNT group was 21.42(SD=4.4), and the mean overall score on the post-test was 20.63(SD=4.3). Although the subjects in the SNTG had the benefit of using their preferred method of study, there was some regression observed at post-test. A possible reason for this type of change could be low motivation when completing the post-test. Additionally, issues with testing conditions (preventing focus on the assessment), increased cognitive fatigue or physical illness (Insight Assessment Manual, 2018) could also contribute to the observed regression. However, results in the SNTG highlight the impact of learning strategies in promoting critical thinking. A *post hoc* analysis of the study logs of the SNTG subjects revealed that none of them used strategies resembling mind mapping or concept mapping. It is possible that the strategies that were employed were not effective/weak in the development of critical thinking.

Comparison of Post Overall CT Score between the MMG and the SNTG

Comparison of post-overall CT score between the MMG and the SNTG was performed to ascertain if there was a significant difference in critical thinking as measured by HSRT overall score between SNT and MMG, post nine weeks. The mean overall score on the post-HSRT for subjects in the SNTG was 20.6(SD=4.3) and mean overall score on the post-HSRT for subjects in the MMG was 22.8(SD=3.9). The difference was statically ($t(72) = 2.276$, $p = .026$) significant. The subjects in the MMG scored higher than those in the SNTG. This important finding suggests the strength of mind mapping, even after a brief exposure of nine weeks, in promoting critical thinking in the novice learner and supports the notion of adult learner capability (Ausubel,1978). It

is likely that mind maps encourage a deeper level of processing than that obtained with the other conventional study techniques adopted in the SNTG (Farrand et al., 2002). Mind mapping is thus a viable active learning strategy to promote critical thinking in PA students.

In curriculum design, educators must simultaneously consider teaching methods, materials, the nature of the subject area, and the characteristics of the student audience. In healthcare, the student is the product of the educational program and the future of that profession (Noonan, 2013). PA students and future PAs need to critically analyze and synthesize new and complex information from diverse sources to effectively treat their patients. Decision making regularly takes place in the healthcare environment and should, therefore, be based on sound critical thinking skills (Vilela et al., 2013).

Qualitative Findings Discussion

To further understand the quantitative findings of the study, open-ended questions (OEQs) were embedded in the qualitative part of the mixed methods design. The responses to the OEQs allowed for greater insight on promoting CTS in the PA students. Themes were established for the six OEQs. The first question sought to understand the learning strategies PA students use to support their learning in PA school. For most of the subjects (49%, N=74, IRR 87%), the preferred learning strategy was a combination of visual, auditory and verbal components, followed by visual (24%) and verbal (14.8%). In this scenario, the possibility arises of adding mind maps (a visual technique) to their study strategy repertoire, and it can appeal to a wide variety of learners (D'Antoni et al., 2010).

The second question queried the student on the definition of critical thinking. There were three themes established in "Defining critical thinking". The pre-determined themes included those defined by Facione (2013), themes defined by Facione and emergent themes, and those with emergent themes only. Emerging themes formed a greater portion of the definition of critical thinking among the PA students. Emerging themes included synthesis, application, understanding, and interpretation. The results illustrate that the students are conversant of aptitudes of critical thinking and its requirement and development to be a successful PA. The critical thinking themes identified are espoused by Kotcherlakota et al. (2013) and Davies (2011).

In response to OEQ three "what contributes to the development of your critical thinking skills?" a priori themes were established based upon themes noted in Bloom's taxonomy (2001) and Bonwell & James (1991). Sixty-six percent of the students identified active learning strategies as contributing to the development of CT; this finding supports the findings of Popil (2011), Noonan (2013), Vilela et al. (2013), and Davies (2011). Active learning encourages interconnectivity and engages the learner in activities that foster meaningful learning (Gage & Berlinger, 1998). Meaningful learning is essential for critical thinking (D'Antoni et al., 2010). Active learning has resulted in improved critical thinking skills, increased retention, transfer of new information, increased motivation and improved interpersonal skills (Wittrock, 1992). Interestingly, attitude (12%) and knowledge and understanding (11%) were noted as contributing to CT as well, but to a lesser extent. This supports Stalheim-Smith's (1998) view that although critical thinking involves higher order thinking skills, it cannot be utilized without

knowledge. Since critical thinking is dependent upon content (domain) knowledge and problem familiarity, MM may facilitate critical thinking because it fosters retention of factual information, as well as relationships between concepts (Ferrand et al., 2002). The skills and attitudes of critical thinking include retention, comprehension, application, analysis, and evaluation (Day & Hale, 2005). It is important to note that critical thinking attitude identified by the PA students not only demonstrates their insight, but it is an essential skill for problem-solving, decision-making processes, and reasoning as PAs continue to function as frontline medical generalists.

Five themes emerged in reply to "What persuades you to be interested in a new learning strategy (LS)?". Majority (61%) of the students were interested in a new LS to improve their learning, performance, and retention, followed by curiosity (20%) to learn new methods and assimilate volume of information quickly, efficiently and effectively (11%). The responses aid in understanding the motivation behind considering a new learning strategy among the PA students. PA educators should seek to motivate students by utilizing teaching and LS that facilitate reflection, knowledge building, problem-solving, inquiry, and critical thinking skills (Rosciano, 2015).

Additionally, the students indicated novelty and curiosity influencing their persuasion in exploring a new learning strategy. Faculty members who are responsible for organizing learning activities should present innovative strategies like mind mapping not only as an alternative strategy to traditional methods of learning but as a tool to promote the integration of information and critical thinking. The students are also curious as to the applications of the new learning strategy in terms of ability to organize and remember information. D'Antoni et al. (2010) specified that mind mapping assists in the

organization of information, and in memory. They reported that the use of colors, pictures, and dimensions helps to convert information from short-term to long-term memory. The above-mentioned attributes of mind mapping are all borne out in this study. The observed significant differences in the overall CTS between the MMG and the SNTG in this study underscores the effectiveness of mind mapping as an active learning strategy to enhance critical thinking skills in the PA students.

Three themes emerged in response to: "How can faculty contribute to critical thinking in students?" Fifty-three percent identified innovative strategies that faculty can utilize to improve CT in the students, such as mind mapping, and learning from different sources. The responses highlight the importance of a new learning strategy sought by the students to organize, learn and understand voluminous information. Likewise, they are expecting the faculty to guide and help them in mastering and integrate information via learning strategies. Twenty-seven percent indicated that faculty can plan activities such as case studies, real-life situations, practical problems, and team-based learning. Active learning strategies specified by the students can promote greater learning and contribute to the development of critical thinking (Noonan, 2013). Twenty-percent noted faculty should provide practice questions and questions during the lectures to better understand the material.

To understand if there was any diffusion of MM among the PA students, the SNTG was asked: "What do you know about the use of mind mapping as a learning strategy?" A significant percentage had little or no knowledge of the MM as an LS. Less than 16% identified mind mapping either as an organization, or integrating, or visual or a memory tool. The above responses provide an opportunity for the utilization of mind

mapping as an active learning strategy in the PAs. The MMG, on the other hand, had Likert-type questions (all statements about mind mapping were positively stated) on the use of MM. Likert scale offers a range of answer options to a questionnaire- from one extreme attitude to another, like “extremely likely” to “not at all likely.” Typically, they include a moderate or neutral midpoint. More than half of the MM participants indicated that MM assists in the analysis; understanding, organization and integration of information; aids in memory; supports their learning; and they would suggest MM to other students to bolster their learning in PA school. The responses emphasize the strength of mind mapping as an active learning strategy in PAs.

While the quantitative data provides us with a numerical value for assessing the students CTS, The OEQs give us an understanding of the perceptions of CT among PA students, the aspects that may/can influence the development of CT and the stance of the students toward a new learning strategy along with the role the faculty. The cumulative data provides an enhanced understanding of how to promote CTS in PA students.

The OEQs were further analyzed in terms of specific groups to better understand the difference in the overall critical thinking scores. Slightly different patterns were observed for some questions between the groups. The two groups did not generally differ in terms of the definition of critical thinking, which contributes to the development of critical thinking and use of innovative learning strategies by the faculty. However, the SNTG preferred more of visual aids as learning strategies compared to the MMG. Mind mapping can appeal as a visual learning strategy to the SNTG. A greater proportion of participants in the MMG identified case-based learning that faculty can utilize to promote CT compared to SNTG. More participants of MMG were also interested in improving

learning, performance, and retention compared to SNTG participants. Likewise, they indicated novelty and curiosity influencing their persuasion in exploring a new learning strategy. It is likely that the motivation of the MMG, coupled with the interest in active learning strategies (case-based) contributed to their higher critical thinking scores compared to the SNTG. Farrand et al. (2002) imply that greater and deeper learning with improved memory is achieved via mind mapping when the participants are motivated.

CHAPTER VI: CONCLUSION

The projected 30% growth of employment for PAs from 2014 to 2024, which is much higher than the average for all occupations, underscores the vital role of PAs in today's healthcare system. Keeping in mind that the focus of today's healthcare environment is on the provision of patient-centered care rooted in an inter-professional practice model (Hooker & Evertte, 2012) the expectation is clear, PA students must be prepared to function as members of a patient-centered interprofessional team. To be effective members of the team it is essential that PA students develop the critical thinking skills needed for sound patient-centered care. Therefore, it is incumbent upon the faculty to train and equip future PAs accordingly.

The results of the study indicate that most PA students use a combination of visual, auditory and verbal elements and thirty-five percent use visual components to support their learning in the PA school. Mind mapping as a visual, non-linear representation of related and connected concepts can enhance learning and critical thinking skills (Noonan, 2013; Rosciano, 2015). The overall critical thinking score of 21 irrespective of group assignment as determined by HSRT in this study represent that PA students display strong critical thinking skills. Therefore, with respect to the first postulated hypothesis, the results of this study support the findings of previous studies with other health profession students (Greener, 2013). So, PAs possess the CTS similar to the other health care professionals on the team and thus can contribute effectively to the development of sound patient-centered care plan.

In this study, MMG demonstrated an improvement in their overall post-HSRT score but the SNTG overall post-HSRT score declined. Although there was no significant difference between the pre- and the post-overall critical thinking score in both the mind

mapping and SNTG, there was a significant difference in critical thinking as measured by HSRT overall scores between SNT and MMG, post-nine weeks with the mind mapping scoring higher.

The results of the study signify that nine weeks of mind mapping (MM) by the PA students promoted greater critical thinking (CT) skills compared to PA students who used only Standard Note Taking practices. Based on these findings, MM is a viable active learning strategy to promote CT. Given that, CT is essential for PAs as they seek to accurately diagnosis and treat, analyze and manage health risks, manage health information systems, explain policy and protocols, and understand treatment implications as a medical generalist (Cawley, 2012). PA curricula need to facilitate the development of critical thinking skills in PA students and MM is one viable teaching and learning strategy to employ (Day & Hale, 2005).

The data of the present study build upon those of previous studies (D'Antoni et al., 2010; Wickramsinghe et al., 2007; Farrand et al., 2002) and bolsters the support for using mind mapping in PA education to promote CT. Additionally, this study illustrates that mind mapping can be taught to PAs who have no previous background in mind mapping rather quickly and with little or no additional specific equipment or cost. Clearly, MM is an additional study strategy that PAs have as a resource to enhance their learning and critical thinking skills (D'Antoni et al., 2010).

The results of the open-ended questions on the use of MM as a learning strategy further emphasize that MM assists in analysis; understanding, organization, and integration of information; aids in memory and supports learning. Additionally, the students reported they would suggest MM to other students to bolster their learning in PA

school. MM can be an effective learning strategy for PAs to understand and integrate information.

PA students are knowledgeable that critical thinking is a process of reasoned and reflective judgment. Additionally, most of the PA students reported that active learning strategies contribute to the development of CTS. Active learning promotes meaningful learning and meaningful learning is essential for critical thinking (D'Antoni et al, 2010). Case studies, scenarios, small group discussions, computer-assisted instruction, simulations, and supervised clinical experiences require student participation and active engagement with class content and can simulate the clinical environment (Davies, 2011). Majority of the PA students not only identified most of the above-mentioned activities but specified that they would be better served if faculty would adopt more of active learning experiences and fewer lectures.

PA students emphasized the important role that faculty play in promoting CT by employing active and innovative learning strategies to facilitate learning and reinforce ideas. PA Students are interested in learning new strategies primarily to improve learning, performance, and retention of knowledge. So, educators need to utilize teaching and learning strategies that promote critical thinking among PA students and enable them to emerge as sound clinicians who deliver competent care. The results of the open-ended questions reinforce the pivotal role of the faculty in preparing future PAs. PA educators can utilize innovative strategies like mind mapping to direct and assist PA students in the learning process and promote critical thinking.

Majority of the SNTG participants reported that they did not know much about the use of mind mapping as a learning strategy. Accordingly, the introduction of a mind

mapping as an active learning strategy can benefit PA students and future PAs in the assimilation of voluminous information; enhanced memory; integration of information and development of critical thinking skills.

When MMG and SNTG were compared in terms of responses to open-ended questions slightly different patterns evolved. Interestingly, most MMG participants were interested in improving learning, performance, and retention compared to SNTG participants. Likewise, MMG indicated novelty and curiosity influencing their persuasion in exploring a new learning strategy. Majority of MM participants identified case-based learning that faculty can utilize to promote CT compared to SNTG. Both groups desired innovative strategies to present and learn information.

Considering the essential role PAs have in the evolving healthcare system, PA educators have an inherent responsibility to examine, review, and investigate novel and emerging teaching and learning strategies that develop critical thinking skills, so PA students can emerge as sound clinicians and deliver quality care (Day & Hale, 2005). Critical thinking is a vital skill needed in healthcare professionals in order to make good clinical judgments and deliver appropriate care.MM is a learning strategy that aids in organization, memory, analysis, and integration of information all of which contribute to the development of effective critical thinking skills.

The results of the study provide strong evidence on the utility of mind mapping as an active, innovative learning strategy to promote critical thinking in PAs. MM is a resource that can be utilized to assist students and future physician assistants learn, understand and apply concepts essential for patient-centered care. In turn, PA programs will then achieve their primary goal of preparing qualified professionals who deliver

quality care as part of a healthcare team (Day & Hale, 2005).

Limitations

Several limitations of the study must be acknowledged and addressed in future studies. First is the sample size (N=90), of which 16 did not take the post-HSRT(N=74). Additionally, 20 students dropped out. Attrition rate and incomplete data did not allow for the assessments to be scored, thereby affecting the strength of the findings. The HSRT was a self-administered. Respondents may have a subject bias associated with a self-administered test. Additionally, factors such as when the student took the test, the time of day, after or before an exam may have influenced their score.

It was a convenience sample, from three PA programs in New Jersey, thus limiting generalizability beyond the schools that participated in this study. However, the results of the study provide strong evidence for enhancing critical thinking skills among the PAs via mind mapping as an active learning strategy.

Future Research Directions

The recommendations are that future studies increase sample size (SS). This can be achieved by the inclusion of PAs from other academic institutions beyond New Jersey, and in turn, can enhance the generalizability of results. An increase in SS could also be achieved through the inclusion of students of other healthcare professions. This would allow for an exploration of similarities and differences in critical thinking aptitude between different health professions. It would allow for an assessment of mind mapping in different health professions.

In addition, the study could be expanded to include practicing PAs. A longitudinal study would follow the overall cohort from enrollment through pre-clinical to clinical and

upon graduation and into clinical practice to assess the extended use of mind mapping at different points during the didactic and clinical years in the PA's education. Furthermore, mind mapping can be compared to other active learning strategies such as concept mapping for the promotion of critical thinking among PAs.

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APPENDIX

Seton Hall University Institutional Review Board Approval

SETON HALL UNIVERSITY
1 8 5 6

June 16, 2017

[redacted]

Dear Ms. Israel,

The Seton Hall University Institutional Review Board has reviewed the information you have submitted addressing the concerns for your proposal entitled "Does the Use of Mind Mapping as a Learning Strategy for Physician Assistant Students Promot Critical Thinking as Measured by Health Science Reasoning Test?" Your research protocol is hereby approved as revised through expedited review. The IRB reserves the right to recall the proposal at any time for full review.

Enclosed for your records are the signed Request for Approval form and the stamped original Consent Form. Make copies only of this stamped form.

The Institutional Review Board approval of your research is valid for a one-year period from the date of this letter. During this time, any changes to the research protocol must be reviewed and approved by the IRB prior to their implementation.

According to federal regulations, continuing review of already approved research is mandated to take place at least 12 months after this initial approval. You will receive communication from the IRB Office for this several months before the anniversary date of your initial approval.

Thank you for your cooperation.

In harmony with federal regulations, none of the investigators or research staff involved in the study took part in the final decision.

Sincerely,

Mary F. Ruzicka, Ph.D.

Mary F. Ruzicka, Ph.D.
Professor
Director, Institutional Review Board

cc: Dr. Genevieve Pinto Zipp

Office of Institutional Review Board
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