THE EFFECTS OF USING CONCEPT MAPPING AS AN ARTIFACT TO ENGENDER METACOGNITIVE THINKING IN FIRST-YEAR MEDICAL STUDENTS’ PROBLEM-BASED LEARNING DISCUSSIONS: A MIXED-METHODS INVESTIGATION

A Dissertation in
Instructional Systems
by
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Submitted in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

August 2012
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ABSTRACT

Attention in medical education is turning toward instruction that not only focuses on knowledge acquisition, but on developing the medical students’ clinical problem-solving skills, and their ability to critically think through complex diseases. Metacognition is regarded as an important consideration in how we teach medical students these higher-order, critical thinking skills.

This study used a mixed-methods research design to investigate if concept mapping as an artifact may engender metacognitive thinking in the medical student population. Specifically the purpose of the study is twofold: (1) to determine if concept mapping, functioning as an artifact during problem-based learning, improves learning as measured by scores on test questions; and (2) to explore if the process of concept mapping alters the problem-based learning intragroup discussion in ways that show medical students are engaged in metacognitive thinking.

The results showed that students in the problem-based learning concept-mapping groups used more metacognitive thinking patterns than those in the problem-based learning discussion-only group, particularly in the monitoring component. These groups also engaged in a higher level of cognitive thinking associated with reasoning through mechanisms-of-action and breaking down complex biochemical and physiologic principals. The students disclosed in focus-group interviews that concept mapping was beneficial to help them understand how discrete pieces of information fit together in a bigger structure of knowledge. They also stated that concept mapping gave them some time to think through these concepts in a larger conceptual framework. There was no significant difference in the exam-question scores between the problem-based learning concept-mapping groups and the problem-based learning discussion-only group.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF FIGURES</th>
<th>viii</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>ix</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>x</td>
</tr>
</tbody>
</table>

## CHAPTERS

1. INTRODUCTION TO THE STUDY ........................................... 1
   - Introduction .................................................. 1
   - Problem Statement ........................................... 2
   - Theoretical Framework for the Study ..................... 5
   - Purpose of the Study ......................................... 7
     - Concept Mapping ........................................... 8
     - The Context ............................................... 9
   - Working Premise ............................................. 10
   - Research Question ......................................... 11
   - Methodology ................................................ 12
   - Significance of the Study .................................. 13
   - Working Definitions ...................................... 14
   - Summary ..................................................... 18

2. REVIEW OF THE LITERATURE ........................................ 20
   - Introduction ................................................ 20
   - Literature Review Process ................................ 20
   - Theoretical Foundations of Metacognition ............... 21
     - John Flavell: The Evolution in Defining Metacognition 23
     - Ann Brown’s Definition and Components of Metacognition 30
     - Rainer H. Kluwe’s Definition and Components of Metacognition 32
   - Conclusion .................................................. 34
   - Reflection and Metacognition ................................ 35
   - The Cognition-Metacognition Relationship ................ 41
   - Pedagogical Implications of Metacognition ............... 42
   - Summary ..................................................... 46
   - Concept Mapping ............................................ 49
     - Foundations of Concept Mapping .......................... 49
     - Duality of Concept Mapping: Cognition and Metacognition .. 50
       - Knowledge Structure .................................. 50
       - Reflection-in-Action ................................ 51
     - Characteristics of Concept Maps ....................... 51
Application of Concept Mapping in Medical Education .......... 52
Relevant Research on Concept Mapping ................................ 53
Problem-based Learning .................................................. 56
Conclusion ................................................................. 60

3. RESEARCH DESIGN ....................................................... 62
Methodology ............................................................... 62
Introduction ............................................................... 62
Studies Leading up to the Proposal ................................. 62
Study #1: Metacognitive Awareness and Metacognitive
Question Prompts ...................................................... 62
  Phase One .............................................................. 63
  Study Population ...................................................... 63
  Measurement Instrument ........................................... 63
  Procedure ............................................................. 66
  Data Analysis and Findings ........................................ 66
  Conclusions ............................................................ 70
  Phase Two ............................................................ 71
  Study Population ...................................................... 71
  Procedure ............................................................. 72
  Data Analysis and Findings ........................................ 72
Study #2: Concept Mapping Perspectives .......................... 77
  Introduction to the Study ........................................... 77
  Research Design ...................................................... 78
  Study Population ...................................................... 78
  Data Collection and Analysis ..................................... 79
  Findings ................................................................. 80
  Conclusion ............................................................... 83
Dissertation Study: Mixed-Methods Investigation .................. 84
  Introduction ............................................................ 84
  Research Design ...................................................... 86
  Context of the Study ............................................... 87
  Location of the Study ............................................... 89
  Entering the Field of Study ........................................ 89
  Institutional Review Board Approval .............................. 90
  Population of Interest ............................................... 90
  Procedures for Random Assignment .............................. 90
  Sampling Method ..................................................... 91
  Participants .............................................................. 92
  Qualitative Investigation: Case Study Perspective .............. 92
    Unit of Analysis .................................................... 94
    Choosing the Artifact ............................................. 95
    Development of the Instructions and Instrument .......... 96
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Sources</td>
<td>97</td>
</tr>
<tr>
<td>Methodology</td>
<td>97</td>
</tr>
<tr>
<td>Qualitative Data Analysis: Outcome Measures</td>
<td>99</td>
</tr>
<tr>
<td>Phase I: Description</td>
<td>99</td>
</tr>
<tr>
<td>Phase II: Categorical Aggregation</td>
<td>100</td>
</tr>
<tr>
<td>Phase III: Establishing Patterns</td>
<td>101</td>
</tr>
<tr>
<td>Phase IV: Naturalistic Generalizations</td>
<td>103</td>
</tr>
<tr>
<td>Ethical Considerations</td>
<td>104</td>
</tr>
<tr>
<td>Quantitative Investigation: Experimental Study</td>
<td>107</td>
</tr>
<tr>
<td>Sample Size</td>
<td>108</td>
</tr>
<tr>
<td>Development of the Test Questions</td>
<td>108</td>
</tr>
<tr>
<td>Factors and Treatments</td>
<td>108</td>
</tr>
<tr>
<td>Quantitative Data Analysis: Outcome Measures</td>
<td>109</td>
</tr>
<tr>
<td>Conclusion</td>
<td>109</td>
</tr>
<tr>
<td>4. RESULTS</td>
<td>111</td>
</tr>
<tr>
<td>Phase IV: Naturalistic Generalization</td>
<td>111</td>
</tr>
<tr>
<td>Research Question #1</td>
<td>111</td>
</tr>
<tr>
<td>Introduction</td>
<td>111</td>
</tr>
<tr>
<td>Concept-mapping Groups</td>
<td>113</td>
</tr>
<tr>
<td>Group 1</td>
<td>113</td>
</tr>
<tr>
<td>Group 2</td>
<td>116</td>
</tr>
<tr>
<td>Group 3</td>
<td>119</td>
</tr>
<tr>
<td>Discussion-only Group</td>
<td>121</td>
</tr>
<tr>
<td>Group 4</td>
<td>121</td>
</tr>
<tr>
<td>Focus-group Interview</td>
<td>124</td>
</tr>
<tr>
<td>Research Question #2</td>
<td>125</td>
</tr>
<tr>
<td>Summary</td>
<td>127</td>
</tr>
<tr>
<td>5. DISCUSSION</td>
<td>128</td>
</tr>
<tr>
<td>Qualitative Findings</td>
<td>128</td>
</tr>
<tr>
<td>Concept-mapping Groups</td>
<td>131</td>
</tr>
<tr>
<td>Discussion-only Groups</td>
<td>133</td>
</tr>
<tr>
<td>Quantitative Findings</td>
<td>140</td>
</tr>
<tr>
<td>Limitations</td>
<td>141</td>
</tr>
<tr>
<td>Future Research</td>
<td>143</td>
</tr>
<tr>
<td>Conclusions</td>
<td>145</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>147</td>
</tr>
</tbody>
</table>
APPENDICES

 Appendix A: IRB-Approved Consent Form .......................... 162
 Appendix B: Concept-Mapping Instructions ......................... 169
 Appendix C: Focus-Group Interview Guide .......................... 172
 Appendix D: Phase II Descriptive Data Sample ...................... 175
 Appendix E: Salicylate Intoxication Test Questions .................. 177
 Appendix F: Six Emergent Themes: Examples of Coding ............. 180
LIST OF FIGURES

Chapter 1

Figure 1.1: List of Wisconsin Men's Henmon-Nelson IQ occupational distributions from 1992-1994 ................................................................. 8

Chapter 2

Figure 2.1: John Flavell’s Components of Metacognition ........................................ 29
Figure 2.2: Ann Brown’s Components of Metacognition ............................... 31
Figure 2.3: Rainer H. Kluwe’s Components of Metacognition .................... 34
Figure 2.4: Reflection Informs Metacognition ............................................. 39
Figure 2.5: Metacognition Feedback Loop.................................................. 40

Chapter 3

Figure 3.1: Distribution of Mean MAI Scores................................................... 67
Figure 3.2: Student Concept Maps of the Autonomic Control of the Heart Rate... 73
Figure 3.3: An Expert’s Map of the Autonomic Control of the Heart Rate....... 74

Chapter 4

Figure 4.1: Emergent Themes: Phase II ...................................................... 113

Chapter 5

Figure 5.1: Model of Emergent Themes Collapsed: Metacognition and Cognition 129
LIST OF TABLES

Chapter 2
Table 2.1: Summary of Metacognitive System .......................... 48

Chapter 3
Table 3.1: Three Components Related to the Knowledge of Cognition...... 64
Table 3.2: Five Components Related to the Regulation of Cognition.......... 65
Table 3.3: Frequency Distribution of the MAI Mean Scores.................. 66
Table 3.4: Results of the Independent t-test Comparing End-of-Year GPA Scores Between the Top 25% and Bottom 25% MAI scores.... 68
Table 3.5: Coefficient of Reliability on the Subcomponents of the MAI...... 68
Table 3.6: Coefficient of Reliability on the Components of the MAI.......... 69
Table 3.7: Example of Concept Map Scoring Criteria.......................... 74
Table 3.8: Results of the Independent t-test Comparing Mean Scores Between the control group and the treatment group.......... 75
Table 3.9: Group-participant List............................................... 92
Table 3.10: Criteria to Choose a Case Study................................... 95
Table 3.11: Phase II Sample Codes .......................................... 101
Table 3.12: Phase III Emergent Themes ....................................... 103

Chapter 4
Table 4.1: Problem-based Learning Group Description ...................... 112
Table 4.2: Distribution of Emergent Themes ................................ 124
Table 4.3: Rank Order of Emergent Themes .................................. 124
Table 4.4: Results of Independent t-test ....................................... 126

Chapter 5
Table 5.1: Prevalence of Metacognitive Thinking .......................... 132
Table 5.2: Prevalence of Cognitive Thinking ................................. 132
ACKNOWLEDGMENTS

My highest gratitude goes to my dissertation advisor and mentor, Dr. Susan Land, for her unwavering commitment, time, steady encouragement, and sincere support to help me reach this goal. I wish her all the best. I am also extremely grateful to my committee members. They are incredible individuals, and I feel very fortunate and honored that they agreed to serve on my committee. To Dr. Roy Clariana who remained steadfast in his support and encouragement over the years, and who was always willing to lend me advice and time when I sought his help. Dr. Clariana became my role model early in my admission to the program. To Dr. Priya Sharma who agreed to serve on my committee despite her heavy workload, and who always made me feel assured that she was there for me when I needed advice. To Dr. Paul Eslinger who I feel privileged to work with over the years, and who guided me in the research on metacognition that led up to this dissertation. He remained committed to my successful completion of this Ph.D., and provided me his support and patience as I worked through the preliminary studies on metacognition and concept mapping.

To my dearest and closest family and friends who never left my side. They were always there with their support, reminding me of the confidence and determination needed to persevere, and encouragement to continue toward my personal goal of achieving a Ph.D. My deepest heartfelt gratitude goes to Bill Shoop, Dr. Kit Hume, Dr. Robert Jones, Dr. Linda Kanzleiter, Dr. Steven Melnick, Dr. Carol Whitfield, Dr. James Ziegenfuss, and Tasna and Jay Kitch. And lastly, to my devoted and trustworthy friend, Dr. Richard Conrad Pees, who never stopped believing that I could achieve this remarkable goal, and who was always there to share smiles and wipe tears.
Chapter One

INTRODUCTION

The ability to solve complicated, undifferentiated clinical problems is essential for physicians to give quality patient care leading to optimal patient outcomes. This complex problem solving requires higher-order thinking skills for clinical analysis, synthesis, reasoning, and judgment. Therefore, commencing in the first year of medical school and extending across the continuum of medical education, medical educators must shape educational experiences that instill a desire within students to gain knowledge, reflect on actions, critically think through clinical problems, and judge what is or is not known. Success in getting to this end may lie, in some way, with metacognition as suggested in academic writings found in the medical education literature (Cooke, Irby, & O’Brien, 2010; Croskerry, 2003a, 2003b, 2003c, 2011; Quirk, 2006). In an extensive review of the literature on metacognition (Brown, 1980, 1987; Flavell, 1963, 1971, 1976, 1979, 1987, 2004; Flavell & Wellman, 1977; Flavell, Miller, & Miller, 1977, 2002; Hacker, 1998; Kluwe, 1982, 1987; Sternberg 1985, 1998; Tarricone, 2011) there was sufficient evidence to suggest that metacognitive skills are essential to higher-order thinking, and linked to effective learners and the development of an expert student (Hacker, Dunlosky, & Graesser, 1998; Kluwe, 1987; Osman & Hannafin, 1992; Sitko, 1998; Sternberg, 1985, 1998).

Metacognition is knowing how you think and making yourself pause to ask the why, how, or what questions: Why should I make that decision? How should I approach studying? What could I do better? If you’re engaged in metacognitive thinking, you consider how you come up with answers to make decisions and make choices to get to
those answers; understand how you process information; reflect on how biased thinking may mislead you in those decisions; and know what you need to do to self correct.

A medical student who is thinking metacognitively will, for example, *contemplate* how he will approach studying the complex anatomy of the knee because he knows how he best learns, or *weigh his options* for decisions to solve a patient’s renal failure, or *evaluate* how he successfully learned the hemoglobin molecule, or *monitor* his thinking and reasoning processes as this relates to treating a patient’s complaint of shortness of breath. These examples of metacognitive thinking demonstrate the complex thinking skills necessary for medical students to be competent at patient care. The success at which these skills are cultivated is not clear, and unfortunately incompetent clinical decisions are being linked with lapses in cognitive function as it relates to critical thinking, rather than to a medical knowledge deficiency.

**Problem Statement**

A seminal publication in 1999 by the Institute of Medicine titled, *‘To Err is Human: Building a Safer Health System,’* established a national focus on medical error and patient safety (Kohn, Corrigan, & Donaldson, 2000). The Institute’s report concluded that between 44,000 to 98,000 people die each year as a result of preventable medical errors. Shojania, Burton, McDonald, and Goldam (2003) reported that a major diagnosis was clinically undetected in at least 8.4% of individuals dying in hospitals (71,400 out of 850,000 deaths), and approximately 4.1% (34,850 out of 850,000) may have survived to discharge had a misdiagnosis not occurred. Regrettably, these medical errors are being associated with cognitive errors – faults in the thinking process leading to
mistakes in reasoning through a clinical problem, making a diagnosis, and managing the clinical problem (Croskerry, 2003a).

One grasps the seriousness of the situation and the implication of cognition in a 2005 report published in the Archives of Internal Medicine that described cognitive error as the most common cause of diagnostic errors made by internists (Graber, Franklin, & Gordon, 2005). This report, based on a diagnostic-error study by Graber and his colleagues, showed that of the 100 clinical cases in their investigation, 74 of the cases had greater than 300 cognitive errors. The three most common cognitive errors were (1) faulty synthesis of knowledge, (2) flawed processing of the available information, and (3) faulty data gathering. Graber et al. concluded that internists generally have sufficient medical knowledge, and that the errors overwhelmingly reflect inappropriate cognitive processing, and/or poor skills in monitoring one’s own cognitive processes (metacognition).

The focus on quality improvement in patient care and the reduction in errors are, in part, why an extensive study of physician education by the Carnegie Foundation for the Advancement of Teaching, titled ‘Educating Physicians’, calls for a major overhaul in the present approach to medical education (Cooke, Irby, & O’Brien, 2010). The report urges medical educators to provide learning experiences that best facilitate the development of critical thinking skills, which are closely related to metacognition (Cooke, et al., 2010).

The close relationship between metacognition and critical thinking is clear (Black, 2005; Halpern, 1989, 1998; Kuhn & Dean, 2004; Magno, 2010). Brown (2004) asserts that critical thinking cannot be achieved without metacognition, and the results of a recent study by Magno (2010) indicate a significant relationship between the factors of metacognition and critical thinking. If metacognition is a precursor to critical thinking,
and critical thinking is necessary for good medical practice, then the extent to which metacognition is developed and supported in medical training is an important issue.

Getting to this end, however, is not straightforward given all the demands and challenges placed on medical education, such as a proliferating volume of information, the rapid pace of instruction, students’ jam-packed schedules, and the limited empirical evidence for instructional interventions used in medical schools that promote such thinking. To some degree, medical education itself may conspire and work against itself to limit the extent to which opportunities for metacognitive thinking skills are used, thus limiting the extent to which deep mental processing, and any meaningful emphasis on reflection, are practical. The temptation is great for medical educators to add more content to an already packed curriculum. Therefore, I believe exploring ways to strategically increase the quantity and quality of instructional time that allows students time to think about what is being learned is desirable. Yet despite the challenges, the responsibility lies with medical educators to require medical students to develop complex thinking skills that are essential to integrate large, complicated knowledge structures and retrieve them from memory, and accurately solve complex, ill-structured clinical problems.

Medical education should move toward strategies whereby students are given various opportunities to engage in metacognitive thinking, so that as physicians they are able to use the same patterns of thought to think through complex clinical conditions, and solve complicated, ill-defined problems. The presumption that metacognition plays an important role in making accurate clinical decisions, creates the need to understand
metacognition and how it applies to the medical student population from an empirical position.

**Theoretical Framework for the Study**

Flavell (1976, 1979), Hacker, Dunlosky and Graesser (1998), Kluwe (1982), and Sternberg (1985, 1998) build a framework of definitions and theories that describe metacognition. In sum, the essence of metacognition appears to be the capacity and capability of an individual to monitor and regulate learning, the ability to discern what is known and not known, and the propensity to reflect and monitor one’s actions. As I untangle the concept, I believe that metacognition must be an essential component to learning and performing complex cognitive functions such as critical thinking and problem solving.

The function of metacognitive thinking in the care of patients is supported by writings from leading medical educators such as Cooke et al. (2010), Crookerry (2003a, 2003b, 2003c, 2011), Gordon et al. (2000), Talbot (2004), and Quirk (2006). These educators suggest that medical schools need to provide extensive opportunities to support a student’s metacognition, improve the students’ ability to learn and integrate the extensive bodies of basic science and clinical science knowledge, and develop the higher-order thinking skills needed to reason through and accurately solve clinical problems. Although having a strong, deep foundation of factual knowledge is essential for a deep understanding of a subject (Bransford, Brown, & Cocking, 2000), the information must be organized and situated around conceptual frameworks and within contexts of use in order for that knowledge to be ‘usable’. Norman (2002) suggests that the higher-order mental processes involved in metacognition facilitate integration and the transfer of
conceptual knowledge to new problem situations. When metacognitive strategies are introduced into instruction, the learners become active participants by focusing their attention on critical elements of the instruction, pulling out common themes and principles, and evaluating their own progress of understanding specific areas of knowledge (National Research Council, 2000).

Reflection is a major component of metacognition (Carr & Biddlecomb, 1998), and according to the National Research Council (2000), reflection on performance is as important to metacognition as having the cognitive ability to regulate learning. Giving medical students time to pause and think within the existing pedagogical framework of a medical school’s content-packed curriculum may explicitly focus learning at the metacognitive level. Medical students need opportunities to think about what they know, comprehend how this vast body of factual knowledge connects and is integrated, experience how complex conceptual knowledge structures relate to safe patient care, and contemplate how they will approach learning to fill in any knowledge gaps. Since clinical practice should improve over time, metacognitive skills are critical for lifelong learning. Hence, finding the most effective instructional strategies that give students time to pause and think metacognitively is valuable to medical education. The challenge, however, for medical educators is to discover the most appropriate types of experiences that engender metacognition, and where best to apply these experiences in the medical school curriculum.
Purpose of the Study

The focus of this study was to investigate concept mapping as an artifact that may engender metacognitive thinking in the medical student population. Specifically the purpose of the study was twofold:

1. To determine if concept mapping, functioning as an artifact during problem-based learning, improves learning as measured by scores on test questions.
2. To explore if the process of concept mapping alters the problem-based learning intragroup discussion in ways that show medical students are engaged in metacognitive thinking.

I chose to study the medical student population because the students selected to matriculate into medical school are highly intelligent, academically successful, and high achievers. Kole and Matarazzo (1965), using the Wechsler Adult Intelligence Scale I.Q., reported the mean Full Scale I.Q. of medical students was 126.18 (n=80; S.D. 6.32; range was 111 to 149). According to the study, the average medical student scores at the 96th percentile relative to the general adult population (Kole & Matarazza, 1965). Hauser (2002) used the Henmon-Nelson IQ score in his investigation of cognitive ability across occupations and reported the physician (M.D. or equivalent) occupation ranked highest in the spectrum of I.Q.s. (The women’s I.Q. distributions across occupational groups did not include the occupation of physician.) Figure 1.1 shows the distribution of Henmon-Nelson IQ scores across occupations. The fact that medical students go through an arduous pre-medical undergraduate training, undergo a rigorous selection process before matriculation, and sit at the top echelon of intelligence, makes them a unique population of students to investigate.
Concept Mapping

Concept maps, strategically used in the curriculum, might be one method to prompt metacognitive thinking, by providing the learning space for students to think at a level beyond facts, rote memorization and recall. In this investigation, concept mapping
was used as the artifact in problem-based learning to give the students a space of time to engage in a level of metacognitive thinking.

Daley and Torre (2010) reported from their analytical review of concept maps in medical education that the use of concept mapping is increasing. Studies conducted on concept mapping in the specific context of problem-based learning have been reported in the medical and nursing literature (August-Brady, 2005; Hsu, 2004; Kassab & Hussain, 2010; Kinchin & Hay, 2005; MacNeil, 2007; Rendas, Fonseca, & Rosando Pinto, 2006). However, I have found no systematic exploration on the impact of concept mapping on metacognition in problem-based learning. In the research that has been conducted, the concept map was being used primarily as an assessment instrument rather than an artifact for metacognitive thinking. Generally, the results of these studies show that those students who map the concepts show higher scores on propositions and integration of concepts, but are inconclusive if concept mapping affects overall test-question scores.

**The Context**

The context of the investigation was problem-based learning. This is a popular instructional method at the Penn State College of Medicine. The medical students are introduced to problem-based learning in the fall semester of their first year in medical school. In the spring semester of their first year, the students’ time in problem-based learning increases to approximately 30% of their total time in class, and by the second year of medical school, problem-based learning accounts for 45-50% of instructional time.

Problem-based learning sessions are used to provide clinical relevance for the topic being studied. Thus, students interact with the topic in a much different way than
they do sitting in a lecture. A dilemma in the problem-based learning process comes during the last session of a problem-based learning case when much of the students’ time is spent discussing the learning objectives in lockstep sequence to correct deficits rather than taking time to carefully think how they learned that everything in the clinical case fits together.

**Working Premises for the Study**

The working premises that guide my thinking about this project are as follows (Presidential Task Force on Psychology in Education and American Psychological Association, 1993; McAleese, 1998; Bransford, Brown, & Cocking, 2000; Novak & Cañas, 2008):

- Metacognition is an essential component of thinking and cognitive performance
- Reflection is an essential component of metacognition
- Concept mapping provides a space for reflection, giving the students time to pause and think about what they know, and contemplate how the pieces of information fit together
- Concept mapping provides a means for students to map what they know in terms of conceptual frameworks of knowledge
- Prior knowledge is not a confounding variable because all first-year medical students go through the same instruction and receive the same material in the same manner prior to the problem-based learning session.
**Research Questions**

The following two research questions guided the literature review and directed the study design:

**Question #1:** How does concept mapping, used as an artifact in a problem-based learning session during the Cellular and Molecular Basis of Medical Practice, influence the intra-group discussion compared to the problem-based learning group that does not use concept mapping.

**Question #2:** Do first-year medical students who draw group concept maps during their end-of-case discussion in a problem-based learning session in the Cellular and Molecular Basis of Medical Practice course achieve higher scores on test questions than the first-year medical students who did not draw a group concept map during the end-of-case discussion?

Null Hypothesis:  \( H_0: \mu_1 = \mu_2 \)  First-year medical students who drew group concept maps during their problem-based learning session in the Cellular and Molecular Basis of Medical Practice course will score the same on questions related to the problem-based learning topic as students who did not draw concept maps in their problem-based learning group.

The null hypothesis was tested against an alternative hypothesis, denoted as \( H_1: \)

Alternative hypothesis:  \( H_1: \mu_2 > \mu_1 \)  First-year medical students who drew group concept maps during their problem-based learning session in the Cellular and Molecular Basis of Medical Practice course will score higher on questions related to the problem-based learning topic as students who did not draw concept maps in their problem-based learning group.
The null hypothesis was assumed to be correct unless there was sufficient evidence from the sample as tested by the significance level to reject it.

**Methodology**

A mixed-methods study was conducted to address the effect of using concept mapping as an artifact to engender metacognitive thinking in a problem-based learning discussion. A two-phase, embedded, mixed-methods research design was used in which different but complementary data were collected to answer the research questions. In the quantitative phase, exam questions written for the problem-based learning case was used to test if concept mapping in problem-based learning positively influences the scores for first-year medical students at the Penn State College of Medicine. Contemporaneous with this data collection, qualitative data was collected by audio recording the problem-based learning groups to gain insights to the students’ discussions during the concept mapping experience.

The qualitative phase explored the concept mapping process to learn if it did or did not engender metacognitive thinking as interpreted through the discussion among the medical students in the problem-based learning group. The reason for collecting both quantitative and qualitative data is to bring together the strengths of both forms of research to explain the effect of concept mapping in the phenomenon of metacognition. Three suppositions are made in designing the study:

1. Metacognition in a cohort of medical students at the high end of intelligence influences achievement;

2. Concept mapping is an artifact that when used during problem-based learning, provides the time for learners to retrieve information from memory and
organize the concept, show how the new knowledge integrates with prior knowledge, and comprehend the integration of that concept within a large and complex framework of existing knowledge;

3. The process concept mapping allows students the time to engage in a level of metacognitive thinking during the problem-based learning case discussion.

**Significance of the Study**

Lack of hard evidence notwithstanding, I am convinced that currently there is far too little time in the medical school curriculum for medical students to reflect on what and how they are learning and solving clinical problems. What most medical students learn about learning in medical school is to learn fast. Too quickly, students fall into the trap of accumulating vast amounts of facts and principles without knowing how this information forms a conceptual framework of integrated knowledge that is related to providing competent and safe patient care.

If medical educators can discover the most effective and efficient means to help the students develop habits of metacognitive thinking, the discovery could have a significant impact on the students’ success in critical thinking and problem solving. Thinking at a metacognitive level could prove valuable for students to regulate their learning to understand why and how complex biochemical principles and mechanisms are integrated into clinical practice, and monitor how well they are learning the material, weigh options for making clinical decisions, and apply what they learn to the care of patients. However, there’s much research work ahead before one can make these general statements with any degree of certainty.
Working Definitions

There were essential terms that, in some form or another, are important in the discussion about a framework for the investigation. Below are the working definitions of the following: cognition, cognitive error, concepts, concept map, conceptual knowledge structure, critical thinking, executive function, higher-order thinking skills, knowledge, learning, metacognition, metacognitive prompt, problem-based learning, and reflection.

Cognition

Cognition encapsulates all thinking and learning activities, such as how we organize, code, store and retrieve information; build knowledge; make decisions and plan strategies; apply meaning; create ideas; and consciously respond to events (Bruning, Schraw, & Ronning, 1999).

Cognitive Error

Cognitive errors are faults in the thinking process leading to mistakes in reasoning through a clinical problem, making a diagnosis, and managing the clinical problem (Croskerry, 2003a). The cognitive error can occur at all levels of thinking – skill based, rule based, and knowledge based – however, it’s at the highest level of thinking, which is knowledge based, that lead to the most serious types of medical mistakes (Croskerry, 2003a).

Concepts

Concepts are extensive arrangements of critical attributes and facts that we hold in our memory to give meaningful structure to a particular object or abstract idea (Schunk, 2000). These structures represent meaningful categories of information (Bruning,
Schraw, & Ronning, 1999). These mental structures are formed through experiences and provide a foundation to link new information.

**Concept Map**

A tool used in education that allows learners to show their understanding in a domain of conceptual knowledge. The concept map is a two-dimensional diagram of an individual’s conceptual knowledge that shows static and functional relationships between concept labels, and the propositional framework of the concept (Novak, 1977; Novak, 1990; Novak & Gowin, 1984; Novak & Musonda, 1991). The theory behind the concept map is Ausubel’s cognitive view and theory of meaningful learning (Ausubel, 1968).

**Conceptual Knowledge Structure**

A conceptual knowledge structure is an organized, assimilated and integrated cognitive framework that represents what is known about a particular concept. Conceptual knowledge structure is defined by the schema theory (Bartlett, 1932). Conceptual knowledge structure is a mental representation of declarative and procedural information, linked together in a network of propositions (Winn & Snyder, 1996). These knowledge structures, or schemas, are active so that as one experiences a phenomenon, the new information is encoded to what is already in memory (Bruning, Schraw, & Ronning, 1999).

**Critical Thinking**

As defined by the National Council for Excellence in Critical Thinking, critical thinking is “an intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or
generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action” (Scriven & Paul, 1987).

**Executive Function**

Executive function is associated with organizing cognitive processes and controlling behavior (Esslinger, 1996). Butterfield and Albertson’s theory of executive functioning postulates that the brain’s executive function coordinates the cognitive levels and metacognitive levels (Butterfield & Albertson, 1995). Ardila (2008) describes two types of executive function: (1) ‘metacognitive' that includes thought, reasoning, problem solving, planning, developing and implementing strategy, and working memory tasks, and (2) ‘emotional/motivational’ that is associated with impulses and mood affecting behavior.

**Higher-order Thinking Skills**

Higher-order thinking skills are complex goal-directed cognitive skills associated with analytical thinking, creativity, discernment, judgment, purposeful and reasoned thought, reflection, and synthesis of information (Halpern, 1998). These thinking skills are not associated with mastering a large cache of factual knowledge or passive learning.

**Knowledge**

Knowledge is organized around one’s conceptual framework. This framework is a vast accumulation of concepts, principles, beliefs, and truths that are self-organized by the learner in a system of complicated mental associations that are organized to give meaning to what is known about one’s surroundings. Knowledge is dynamic, and changes to fit one’s existing structure of understanding and meaning.
Learning

Learning is an active and dynamic process whereby knowledge is acquired and constructed through meaningful experiences and social interactions.

Metacognition

Metacognition is monitoring and knowing one’s cognitive processes and applying this knowledge to regulate and govern how tasks are executed (Flavell, 1979, 2004; Hacker, 1998). Metacognition is having an awareness of one’s own understanding, and knowing what strategies are needed to acquire additional knowledge, and the ability to reflect on and evaluate what one knows and what one uses to solve problems (Carr & Biddlecomb, 1998). Metacognition has three components: reflection, knowledge, and regulation.

Metacognitive Prompt

A metacognitive prompt is an instructional strategy that guides the learner how to think during a learning experience (Hannafin, Land, & Oliver, 1999). In this particular study, the metacognitive prompt is used to prompt the learner to reflect on what they know or don’t know.

Problem-based Learning

According to Hmelo, Gotterer, and Bransford (1994), and Dahlgren and Dahlgren (2002), problem-based learning puts learning into a context that allows students to construct meaning and knowledge. In medical education, problem-based learning anchors instruction in an authentic clinical case, and provides a framework for the clinical problem. Putting the problem in the context of patient care and its relationship to a clinical situation increases the chance that the learners will find a meaningful connection between basic science concepts, clinical science concepts, and caring for patients. Problem-based learning holds the promise that the experience will promote the students’
understanding of the principles, provide the experience whereby learners can expand their conceptual framework by linking new knowledge to prior knowledge, show how the information is applied to solving clinical problems, and increase the probability that the acquired knowledge will be retained in memory for recall at another time.

**Reflection**

Reflection is a conscious process of introspection (Mead, 1903); taking time to mull over what we know, ponder over our emotional orientation, assess meaning, gain insights, and contemplate outcomes (Moon, 1999, 2004). Hence, reflection is a personal and purposeful engagement in thinking. Reflection is often thinking about what one is doing while doing it, which Schön (1983) describes as reflection-in-action. One engages in reflective conversation to understand the situation (Schön, 1983). Reflection may not always lead to a full resolution of the issue, but one can gain a clearer understanding of the matter at hand (Moon, 1999, 2004). The place of reflection in learning is toward self-development, whereby the individual upgrades learning by making sense of, and finding the meaning in more superficially learned material (Moon, 1999, p. 157).

**Summary**

There is no doubt that medical education is facing significant challenges in a time of rapid growth in scientific knowledge, technologies, and options for patient care. Not only is this rapid growth changing the practice of medicine, but so, too, the growth in our knowledge about learning and cognitive processes is changing our methods for teaching. Thus, attention in medical education is turning toward instruction that not only focuses on knowledge acquisition, but on developing the medical students’ clinical problem-solving skills, and their ability to critically think through complex diseases.
Metacognition is regarded as an important consideration in how we teach medical students these higher-order, critical thinking skills. Medical students get so focused on the sheer volume of information they must learn, that memorization often trumps higher order thinking. Therefore, we need to investigate instructional activities that fold higher order thinking skills associated with metacognition into learning the information needed to understand and recognize disease.

The foundational literature in Chapter Two will show how the concepts of metacognition, reflection, and concept mapping informed the research questions for this study. The goal is to extend the theory and expand the application of what we already know to a new population – medical students. A study on the effects using concept mapping as an artifact in problem-based learning could prove significant for policy and practice decisions made to teach our medical students.
Chapter Two

REVIEW OF THE LITERATURE

Introduction

Patrick Croskerry (2003 a, b, c) brought metacognition to the forefront in medical education in his writings related to the effect of cognitive errors in patient-care decisions. Croskerry proposed that teaching cognitive forcing strategies, which he claimed are highly metacognitive, is the answer to minimize the errors that lead to grave consequences for patients. Consequently, medical educators turned their attention toward metacognition as it relates to learning, problem solving, and critical thinking. Thus, while metacognition is not a new concept to general education and psychology, it is fairly new in the conversation about teaching and learning in medical education.

Literature Review Process

The literature review for this study focuses on the theoretical and practical framework of metacognition, exploring the basis for which concept mapping may play a role in helping medical educators prompt metacognitive thinking in the problem-based learning environment. The literature included in this review was obtained by searching library databases including Penn State’s CAT, CINAHL, EBSCOHost, ERIC, MDConsult, PsychINFO, PubMed/MEDLINE, OVID, and the Theses and Dissertations Catalog. The key terms used in the search were ‘metacognition’, ‘metacognition and medical education’, metacognition and prompts’, ‘metacognition and intelligence’, ‘metacognition and achievement’, ‘metacognition and learning’, ‘concept mapping’, ‘concept mapping and metacognition’, concept mapping and medical education’, ‘concept mapping and PBL’, ‘concept mapping and learning’, ‘problem-based learning’
and ‘problem-based learning and metacognition’, and ‘problem-based learning and constructivism’.

**Theoretical Foundations of Metacognition**

On a global scale, relevant and theoretical literature on metacognition is abundantly available, and seminal works provide a clear definition and empirical foundation to our understanding of the concept. These theories about metacognition are extremely interesting, and help move us away from the dominant view in medical education that learning focuses primarily on how fast and how much medical students acquire knowledge and skills. Many scholars, such as John Flavell (1971, 1976), Ann Brown (1980, 1987), Ranier Kluwe (1987), and Robert Sternberg (1985, 1998) take the view that metacognition is an important factor in learning, problem solving, and achievement.

Long before the name metacognition was given to these higher-order thinking skills, educational psychologists such as John Dewey (1910), Lev Vygotsky (1978), and Jean Piaget (1952, 1969) theorized how the mind works, writing about thinking skills that are characteristically metacognitive in nature. In 1910, Dewey’s writings speak extensively to areas specifically related to thought and reflection as he focused much of his attention on the need for reflective thinking. Dewey felt reflection originates in a problem that at some point makes reflection necessary to “consciously inspect and examine this familiar background” in a form of “reflective inquiry” (Dewey, 1910, p. 214-215). Thus, Dewey believed a trained mind has mental discipline and habits of inquiry and reasoning that can be cultivated in the educational process (Dewey, 1910). Reflection, conscious control, and mental discipline are all common attributes of thinking
in Dewey’s writings, and are general characteristics of metacognition as we now know the concept.

The works of Soviet psychologist, Lev Vygotsky, who is best known for his theory on the zone of proximal development as the basis for instruction (Vygotsky, 1978) proposed that higher order mental functions first develop through social interactions, at an interpersonal, more introspective level in relationships with other people, then move to an intrapersonal level (Vygotsky, 1978; Wertsch, 1985). In contrast to Dewey’s theory that focused on the individual, Vygotsky’s theory suggests that intellectual activity occurs in a social context before it moves inward. Upon moving inward, the intellectual activity becomes a reflective process whereby the individual engages in planning and self-regulation processes. Vygotsky writes of ‘natural’ and ‘higher’ mental functions (Vygotsky, 1978) that, interpreted by Wertsch (1985), have two important distinctions that I believe speak directly to metacognition: (1) there is a shift in mental function from the interpersonal to intrapersonal, and (2) there is a shift in a conscious realization of mental processes. This implies that once intellectual activity turns inward at the intrapersonal level, the individual is consciously engaged in what is happening in the thought process.

The cognitive development theory of Jean Piaget (1952) also informs the definition and elaboration of metacognitive thinking (Fox & Riconscente, 2008; Tarricone, 2011). Piaget was interested in changes in cognition and the structure of thought, and gave us a four-stage theory of cognitive development to help us understand his idea. He was making a distinction between different cognitive processes in the following four stages: (1) sensori-motor period – birth to age 2; (2) pre-operational stage
– stage 2-6; (3) concrete operational stage – age 6-12; and (4) formal operational stage – age 12 and up. The characteristics of metacognition lie in Piaget’s fourth stage of cognitive development – formal operations (Piaget, 1952, 1969).

Piaget’s discussion of formal operations focuses on the development of abstract thinking, reasoning, and logic (Tarricone, 2011). Flavell argues that Piagetian formal thinking is primarily metacognitive because the person is engaged in thinking about cognitive objects such as propositions and hypotheses, and imagining possibilities (Flavell, Miller, & Miller, 1977). The individual would have to reach this stage to engage in scientific reasoning, systematically making a hypothesis, and reflecting on different options.

While Dewey, Vygotsky, and Piaget contributed to our understanding of thought and cognitive development, one must turn to the seminal work of John Flavell to fully understand how the definition of metacognition evolved. Flavell was a scholar who pioneered the theoretical definition and gave us a foundation for metacognitive research. Flavell’s conceptualization of metacognition was influenced by his relationship with Piaget (Hacker, 1998), for it was Flavell who introduced the United States to Piaget’s theory in his 1963 publication. Flavell focused on Piaget’s fourth stage – formal operations – referring to a kind of ‘metathinking’ where one thinks about thinking, rather than a particular object that the cognitive activity is focused on at the time (Flavell, 1977, p. 107).

**John Flavell: The Evolution in His Definition of Metacognition**

The idea of ‘meta’ in cognition was introduced in 1971 when Flavell’s work in memory development laid the groundwork for ‘metamemory’, a term Flavell used to
describe a person’s intellectual ability. Flavell felt metamemory gave a person the ability to (1) structure and store information; (2) search and retrieve information; and (3) demonstrate intelligent monitoring and knowledge of these storage and retrieval processes. More specifically, metamemory, defined by Flavell, was a person’s “knowledge about variables affecting memory performance and especially their knowledge and use of memory” (Flavell, 2004, p. 275). In a subsequent article on the development of memory, Flavell and Wellman (1977) suggested metamemory improves during the course of early childhood, involving intelligent structuring and storage of knowledge, and intelligent search and retrieval.

Throughout Flavell’s writings, he draws a distinction to two levels of cognition. One level is the brain’s cognitive system of Information Recall coming in from the environment, such as how the brain stores, organizes, compares, manipulates, and retrieves information. The second level is ‘meta’ implying that there was another state of cognition situated with the information processing role of cognition. The prefix of ‘meta’ before cognition provides a vocabulary to discuss a certain level of cognition that goes beyond memorizing facts, calculating numbers, and retrieving information from memory. This level of cognition, hence metacognition, “includes any knowledge or cognitive activity that takes as its object, or regulates, any aspect of any cognitive enterprise” (Flavell, Miller, & Miller, 1977, p. 170).

Similarly to his distinctions in the levels of cognition, Flavell makes a clear distinction in the function of cognitive and metacognitive strategies in this statement. The main function of a cognitive strategy is to help you achieve the goal of whatever cognitive enterprise you are engaged in. In contrast, the main function of a metacognitive
strategy is to provide you with information about the cognitive enterprise or your progress in it. We might say that cognitive strategies are invoked to make cognitive progress, metacognitive strategies to monitor it (Flavell, Miller, & Miller, 1977, p. 154). To demonstrate what Flavell is saying, the cognitive strategies are the thinking processes that lead an individual toward a specific goal. An example of a cognitive strategy is to write a chemical equation that changes sodium hydroxide and hydrogen chloride into salt [sodium chloride] and water. The metacognitive strategies are used as tactics to meet the goal. For example, if the chemical equation you wrote to change sodium hydroxide and hydrogen chloride into salt and water didn’t balance, you decide you’re lacking knowledge and choose to read the step-by-step instructions to gain a better understanding of the problem.

In 1976, Flavell formally introduced the term in his chapter titled, *Metacognitive Aspects of Problem Solving*. Flavell at this point is more articulate about the differences in cognitive activity, describing problem solving at two levels. The one level is a cognitive transaction in which a variety of information processing activities occur to reach a goal and come to a resolution. The second level refers to metacognition, in which he defines metacognition as

One’s knowledge concerning one’s own cognitive processes and products or anything related to them (...) [and] refers as among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective (Flavell, 1976, p. 232).
In the development of metacognitive thinking as it relates to problem solving, Flavell (1976) was making the case that a child must develop a growing sense that “such and such situations call for active, deliberate attempts to store, retrieve, and apply what is information to a problem and make deliberate, systematic searches for whatever problem-relevant information happens to be available for retrieval” (p. 232).

In this particular writing, Flavell (1976), through the frequent use of the term deliberate begins to draw the attention to the conscious nature of metacognition. Flavell wrote of intelligent monitoring that suggests metacognitive thoughts are deliberate, planful, intentional, goal-directed, and future-oriented mental behaviors that can be used to accomplish cognitive tasks. Flavell’s definition of metacognition implies it functions at an explicit level whereby there is a deliberate process aimed at a particular purpose, suggesting that there is a conscious control over how you plan, monitor, and evaluate your learning. Conscious or volitional control is also suggested years later by Shimamura (2000), because metacognition refers to one’s evaluation and control of cognitive processes. Thus, the notion of conscious attention to selecting and choosing strategies makes metacognition unique and personal to the individual.

In 1979, Flavell advanced his definition of metacognition in his formal model of cognitive monitoring. This model was an expansion in his work on cognitive development, and brought more clarity to his interpretation of metacognition as he defined it at this point in his findings. Flavell’s model explained cognitive enterprises through the actions and interactions of (1) metacognitive knowledge, (2) metacognitive experiences, (3) goals or tasks, and (4) actions or strategies (Flavell, 1979).
Flavell (1979) defined metacognitive knowledge as the “knowledge or beliefs about what factors or variables act and interact in ways that affect the course and outcome of cognitive enterprises” (p. 907). He broke the factors into three interacting categories: person, task, and strategy. The person category includes everything you know and have come to believe about your own thinking and learning, and your epistemological belief about yourself and others in terms of cognitive activities. The task category is “one’s knowledge about how to manage a cognitive activity, knowing how difficult or demanding the cognitive activity will be, and how successful you are likely to be in achieving its goal” (Flavell, 1979, p. 907). The strategy category is the knowledge one has about cognitive strategies that will likely lead to a successful outcome in achieving the goals of a cognitive activity.

Flavell made reference to the fact that regardless how metacognitive knowledge is activated, it enters consciousness and gives rise to the metacognitive experience (Flavell, 1979; Flavell, Miller, & Miller, 1977). These metacognitive experiences are important to our understanding of metacognition because they are the internal responses to the person’s metacognitive knowledge, goals, and strategies. In some regard, the metacognitive experiences are linked to the affective nature of metacognition. For example, the metacognitive experience of an individual engaged in solving a problem is the uneasiness felt when there are several options to solve the issue.

These metacognitive experiences provide the cues that make the person aware of the need to change strategy or stay on course for a particular cognitive activity (Efklides, 2006). To show how this works, think of a medical student learning about acid-base balance. The student encounters a metacognitive experience when she feels confused and
knows she isn’t grasping the idea. The student pauses to analyze the learning situation based on her existing metacognitive knowledge, knowing she has problems remembering physiologic mechanisms and pathways. At this point, the student applies metacognitive strategies to control and regulate her learning by rereading the chapter on kidney function, and decides to draw a picture of the kidney’s role in acid-base regulation.

According to Flavell (1979), “these metacognitive experiences activate metacognitive strategies and can occur before, during, and after a cognitive activity and generally occur in situations that stimulate a lot of highly conscious thinking” (p. 908). In the example of reading a tricky passage in a novel, the individual is quite able to read the words, which is the mechanics of reading, and moves rather easily from paragraph to paragraph (the cognitive activity); however, the person feels ill at ease with understanding the passage (the metacognitive experience), and goes back to reread the entire passage (the metacognitive strategy). The metacognitive strategy leads to the feeling of making progress (the metacognitive experience), because the individual learns that rereading a passage is helpful to learn (gains metacognitive knowledge). Flavell, Miller, and Miller (1977) stated “metacognitive monitoring was closely related to the metacognitive experiences, and served a variety of useful functions by instigating various cognitive strategies to achieve a goal” (p. 154).

A description of Flavell’s model of metacognition is shown in Figure 2.1. As Flavell suggests, metacognition functions to monitor and regulate cognition. A cognitive goal (i.e., learn the hemoglobin molecule), initiates cognitive activity to gain knowledge by gathering facts that lead to a conceptual understanding of the molecule. At this point metacognition monitors and regulates how that goal will be accomplished. This function
is not a linear process; rather it becomes a complex interaction between the two types of brain activity: cognition and metacognition.

Most notable to Flavell’s (1979) thinking about metacognition up to this point in time are the following:

- Under conscious control, metacognition actively monitors and regulates cognitive processes.
- Metacognition provides the “quality control” for the thoughts and feelings about your own thinking (p. 908).
- Metacognitive strategies are transferrable to quite different tasks.

*Figure 2.1*: A description of the components in John Flavell’s definition of metacognition. The figure shows the function of metacognition through the dynamic role of metacognitive knowledge, experiences and strategies.
• Teaching children and adolescence to monitor their cognition in communication and social settings is important, particularly those related to persuasion and making wise and thoughtful life decisions (p. 910).

• Metacognitive experiences are the affective component of metacognition and give rise to the decisions to change course in how one is learning material, recalling something from memory, or solving a problem.

As Flavell’s thinking about metacognition matured, his theory and definition evolved, and in 1987 he began to expand his interpretation of the metacognitive experiences as developmental tools, and suggested that metacognition can improve with practice. Flavell (1987) felt schools should be the ‘hotbeds’ for metacognitive experiences and opportunities to gain metacognitive knowledge, thus developing metacognition by giving students repeated opportunities to monitor and regulate their cognition (p. 27).

**Ann Brown’s Definition and Components of Metacognition**

Ann Brown (1987) defined metacognition as “one’s own knowledge and control of one’s cognitive system” (p. 66). Her contribution to metacognitive theory was her distinction between two related forms of metacognition: the knowledge of cognition and the regulation of cognition as illustrated in Figure 2.2 (Brown, 1980, 1987).
Figure 2.2: The figure shows the components in Ann Brown’s (1987) model of metacognition. The figure distinguishes two important metacognitive components: knowledge of cognition and the regulation of cognition.

According to Brown, the knowledge of cognition is the bank of understanding and insights one develops over time about one’s own cognitive processes (Brown, 1987), and this “knowledge bank develops late because it requires the learner to step back and reflect on their cognitive processes in terms of objects of thought and reflections” (p. 68).

According to Brown, one’s knowledge of cognition has the characteristics of being stable (little change), fallible (not perfect), and statable (can be described). Declarative, procedural and conditional knowledge are three different categories of metacognitive awareness associated with metacognitive knowledge (Brown, 1987; Jacobs & Paris, 1987; Schraw & Moshman, 1995). Declarative knowledge refers to one’s knowledge of how one learns and what processes are associated with how best to store information into memory (Schraw, 1998). Procedural knowledge is knowing what strategies you have
available, and when to use them to effectively learn and solve problems (Schraw, 1998). Conditional knowledge gives the learner the ability to know how to systematically allocate specific strategies to learn and solve problems (Schraw, 1998). Metacognitive knowledge is unique to metacognition. This knowledge bank, stored in long-term memory, contains facts on various learning and problem solving strategies that were accumulated over years of experience, information on how the individual learns best in various situations, knowledge about successful approaches to a learning or problem-solving task, and knowledge about how much time should be allocated to one learning situation versus another.

The regulation of cognition is accomplished through planning, monitoring, evaluating and self-regulating the cognitive actions during learning. The metacognitive activities used to regulate cognition are relatively unstable, not always statable, and age dependent (Brown, 1987). According to Brown, the interlinked issues that pertain to the definition of metacognition as it relates to the knowledge and regulation of cognition are reflection, executive control, self-regulation, and other-regulation fostered by interactions in a social setting. While Brown’s model is easy to understand and brings more definition to metacognition, her model doesn’t show the dynamic interrelationships between the knowledge of cognition and the regulation of cognition, nor show how the sequence of interactions relate to the cognitive processes.

**Rainer H. Kluwe’s Definition and Components of Metacognition**

Kluwe (1987) brings the focus to the procedural aspects of metacognition, examining metacognition as a component of cognitive activity rather than as aspect of knowledge. Kluwe’s important contribution to understanding metacognition was in his
attachment of metacognitive thinking to the executive function of the information processing system.

Generally, executive function is linked with reasoning, problem solving and abstracting skills. The brain uses this system to carry out the important executive functions of thinking as it plays a critical role in an individual’s ability to keep track of two or more different kinds of tasks, draw from a neural web of schemata to assimilate and synthesize knowledge, analyze tasks, strategically plan an approach to a problem, make strategic selections, and form educated decisions (Borkowski, Chan, & Muthukrishna, 2000; LeDoux 2002). Kluwe describes metacognitive activity through the role of the executive processes that lead to the executive decisions needed for problem solving and executive regulation (Kluwe, 1987). Kluwe claimed that cognitive activities during problem solving tasks are controlled and regulated through executive decisions.

Kluwe’s other contribution to our understanding of metacognition was in his distinction between what was, and what was not, metacognition in terms of declarative and procedural knowledge (Kluwe, 1987; Hacker, 1998). Metacognitive declarative knowledge is made up of the stored bank of knowledge that includes facts, assumptions, and beliefs about your thinking. In contrast, the non-metacognitive declarative knowledge comprises the accumulated facts and understandings in specific domains, such as the number of valves in a heart, the calculation for measuring flow rate, the equation for energy, and the letters of the alphabet. Metacognitive procedural knowledge is that which monitors and regulates thought processes. In contrast, the non-metacognitive procedural knowledge is used to multiply 12 by 10, or calculate the circumference of a circle.
Kluwe describes executive decisions in terms of metacognitive procedural knowledge because the decisions direct the flow of our own thinking (Kluwe, 1987). However, these decisions are based on the availability of metacognitive declarative knowledge (Kluwe, 1987).

![Figure 2.3: Rainer H. Kluwe’s components of metacognition. Figure shows metacognitive activity through the role of the executive processes.](image)

**Conclusion**

As one begins to dissect the concept of metacognition, its characteristics very much seem like the ‘mission control’ of the cognitive system; whereby metacognition, by directing attention, enables students to “coordinate the use of extensive knowledge and many separate strategies to accomplish a single goal” (Bruning, Schraw, & Ronning, 1999, p. 95). This higher-order thinking skill is defined in terms of the self-monitoring and self-control of one’s own cognitive processes (Nelson & Rey, 2000, p. 147) that are
needed for learning, reasoning, solving problems, and making decisions. As suggested by research conducted by Meijer, Veenman, and van Hout-Wolters (2006), there are interdependencies among the various metacognitive activities, and the number of activities that occur in a learning or problem-solving task, may not be as important as the sequence of those activities that may give us clues into what contributes to learning.

**Reflection and Metacognition**

There is a strong association between reflection and metacognition, and considering one in isolation of the other is almost impossible. Scholars (Schön, 1987; Moon, 1999; Schraw, 2001; and Tarricone, 2011) have given us theoretical and practical descriptions of this relationship, and both perspectives are important to our understanding.

Dewey (1910, 1933) was very specific in describing the specific function of reflection as purposeful thought in learning and problem solving. In Dewey’s description, reflection was the basis for conscious control and monitoring, and these two attributes have a striking resemblance to metacognitive components. In fact, reflection is so tightly connected to metacognition that, according to Schraw (2001), it is necessary for the construction of metacognitive knowledge and metacognitive regulation. Moon (1999) also described reflection as a purposeful mental process for metacognition. However, Moon’s focus on the reflective process rested in the change of meaning that was assigned to complicated and unstructured ideas, and the relationship of new material to that which was already in memory. In Moon’s map of learning (1999, pg. 154) the association between reflection and metacognition is made in the transformative stage of learning. Moon says reflection functions in the manner of metacognition at this stage,
whereby the reflective process brings about a change in self knowledge, the assignment of deep meaning to learning, and the integration of new material into the existing cognitive structure (Moon, 1999). Tarricone (2011) views reflection as the ‘quintessence of metacognition’ (p. 11), making a strong case for the reflection-metacognition relationship. Tarricone’s model shows that the self knowledge one gains through the reflective process is essential for metacognition. Schraw (2001) stated that reflection, both solitary and group, plays a crucial role in metacognition, and he included the allowance of time for group discussion and reflection on the list of instructional principles for promoting metacognitive awareness. Moon (1999) also suggested that small-group discussion could facilitate this level of thinking with the appropriate types of support that encourage it.

Metacognitive regulation decisions are also associated with the reflective process. During each stage of the regulatory process of learning and problem solving, Ertmer and Newby (1996) suggest that reflection is necessary for individuals to use their metacognitive knowledge and metacognitive experiences to apply the appropriate metacognitive strategies. Zimmerman (2002) also claims the process of self-reflection is necessary for self regulation, because the prior efforts affect students’ subsequent forethoughts and actions about learning. These regulatory processes include the functions of planning, activation, evaluation, self-correction (Ertmer & Newby, 1996).

Donald Schön (1987) applied the theories of reflection to practice, and has contributed to our understanding of reflection in the terms ‘reflection-in-action’ and ‘reflection-on-action’. The reflection-in-action is bounded by the present; a zone of time when an adjustment in the course of action can still make a difference to the outcome.
(Schön, 1987). This period of reflection refers to thinking deeply and self-examining one’s thoughts and actions during the moment in real time. This real-time reflection gives one the chance to inspect what actions are occurring, decide if adjustments should be made, and make strategic decisions in the course of the action. In a learning experience, the student would reflect-in-action on the thoughts that she has about the problem she was solving, or the material she is learning. How the student interprets these feelings and scrutinizes the situation during the reflective process will determine if she decides to take action and change course. In the context of patient care, reflection-in-action would be seen in the doctor’s reflection for the course of action she chose to take, the feeling for the particular subjective and objective findings that steered her to take that particular action, or the consequences of treatment plans she has to choose from in order to get the best outcome for the patient. She monitors her thinking about the patient’s situation and as a result of that reflective moment, the doctor might decide to stay with the original treatment plan, or change course to another alternative.

If you consider Schön’s reflection-in-action in the context of metacognition, the following would apply: (1) according to Flavell’s theory (1979) the reflection that results from the metacognitive experience will lead to the application of metacognitive knowledge and strategies to meet the goal; (2) according to Brown’s theory (1987), metacognitive regulation would kick in to apply strategies to regulate the cognitive activity; and (3) according to Kluwe’s theory on metacognition (1987), this is the point when executive decisions are made to stay on or change course using the metacognitive procedural knowledge. The focus of reflection-in-action is the outcome.
The reflection-on-action is bounded by the past, referring to the deep introspection one moves into after the occurrence. Time is spent thinking about aspects of the decisions that were made, why certain actions were taken while others were ignored, and the understandings and misunderstandings that were learned in the process. In the case of learning, the student failed the test, and now reflects on the reasons why. In the case of physician care, the patient is not improving, and so the physician might reflect back on the initial decision to implement that particular treatment plan, and for the reason he made that judgment. Conversely, he might prescribe without reflecting, and take a trial-and-error approach. The focus on reflection-on-action is building self knowledge. Therefore, in applying reflection-on-action in the context of metacognition, the following would apply: (1) in keeping with Flavell (1979) and Brown’s (1979) theories of metacognition, the individual would accumulate a bank of metacognitive knowledge – those understandings, insights, and beliefs about the cognitive processes of thinking and learning; and (2) along with Kluwe’s (1988) theory of metacognition, this would be a period of growth in one’s metacognitive declarative knowledge.

The metacognitive system is made up of the metacognitive knowledge, control, and strategies that a person uses in all aspects of life that involve learning, solving problems, and making decisions. Reflection, as I interpret it in the context of the theories set forth of the reflection-metacognition relationship, does not control metacognition, but rather informs metacognition. The reflective process has a role at the front end of the metacognitive system and at the back end of metacognition as shown in Figure 2.4. At the front end, reflection is directed at the development of self knowledge and geared at knowing. The recalibration of self knowledge occurs, which in turn develops the
metacognitive system in terms of metacognitive knowledge (declarative and procedural). Reflection at the back end of metacognition is directed at making choices and choosing metacognitive strategies that would be most effective in tackling the cognitive task, i.e. learning, problem solving, etc. Figure 2.4 shows that when one encounters a cognitive task, the person experiences a feeling of success or failure in moving toward the goal. This feeling in turn initiates a period of reflection whereby the person focuses on what was done wrong (or correct), how did he/she respond, what was done that didn’t work (or did). What the individual is gaining from this reflection is a growth in self knowledge. The person then in monitoring how he/she is working through the task, reflects on what strategies did not (or did) work best and the reflection is geared to regulating the cognitive task. The choices that the person makes on the metacognitive strategies to apply to the task are then directed to the cognitive task.

*Figure 2.4:* Illustrates how reflection informs metacognition at the front end of the system and at the back end of the system.

Applying the principles of the feedback loop is central to the understanding the significance of reflection has in the metacognitive system. The metacognitive feedback
loop that can lead to unlimited growth in a person’s metacognitive system is shown in Figure 2.5. The feedback is a loop wherein the metacognitive knowledge (declarative and procedural) one gains in reflection is fed back into a system of metacognition. The student can take this information and apply it to cognitive tasks that require a robust metacognitive system, such as learning, problem solving, and critical thinking. I believe, the knowledge gained in the feedback loop changes the likelihood of future approaches to learning and solving problems.

*Figure 2.5:* Shows the metacognitive feedback loop that can lead to unlimited growth in the metacognitive system, specifically in the area of metacognitive knowledge.
**The Cognition-Metacognition Relationship**

The cognitive and metacognitive systems are related in such a manner that neither can be ignored in the discussion of learning and problem solving. Flavell, Brown, and Kluwe, by their own interpretation, were differentiating cognition and metacognition in terms of a process that manages and handles information coming into the brain, and a process that monitors and regulates how that processing of information occurs. This relationship is abstract and largely conceptual. However, recent progress has been made in studies of brain function in the disciplines of neuroscience, neuropsychology, and cognitive psychology to advance our understanding of metacognition. With advanced imaging, studies of brain function show that metacognitive abilities are clearly interdependent, and evidence links them to the structure and function of the brain’s frontal lobe, specifically the frontal cortex (Fernandez-Duque, Baird, & Posner, 2000 a, b; National Research Council, 2000; Shimamura, 2000).

In the metacognitive-cognitive framework constructed by Artzt and Armour-Thomas (1992, p. 141), cognition and metacognition co-exist, but depending on the action one is more prominent than the other. When considering this relationship in the context of the Cognitive Information Processing Theory (Miller, Galanter, & Pribram, 1960; Newell, Shaw, & Simon, 1958; Spearman, 1923), cognition is the process of storing and retrieving information; whereas, metacognition is strategically controlling and monitoring the means to direct cognitive processing and regulate thinking.

An influential description of the cognition-metacognition relationship is by Nelson and Narens (1990, 1994) who describe cognition and metacognition on two levels: the object level and the meta level. The object-level system is knowledge-based...
memory and mental representations. The meta-level system monitors and controls the flow of information at the object level. Accordingly, cognitive processes at the object level are monitored by metacognitive processes at the meta level (Shimamura, 2000). Cognition, represented by the object-level system is the manner or method of performing verbal and non-verbal actions that lead to actual information processing, e.g. reading or rehearsing. These cognitive operations are what we use to move information in and out of memory, put information into categories and classifications to build vast knowledge structures, assign meaning, and distinguish among concepts, principles and rules. We need this basic cognitive processing to form the foundation that we use to see relationships among the vast network of concepts and propositions, and manage complicated problems that require complex thinking. Thinking at this level involves finding relationships and rearranging knowledge to solve perplexing situations (Lewis & Smith, 1993). Metacognition, the meta-level system on the other hand, is the executive control in thinking about those cognitive actions in terms of monitoring, understanding, planning, verifying, and evaluating what has been learned. Based on this monitoring and evaluation, there’s a feedback flow of information and adjustments to the object level (Shimamura, 2000).

**Pedagogical Implications of Metacognition**

Knowing how to learn is as important as the knowledge itself in being a successful student (Sternberg, 1998). Whether one thinks of metacognition and cognition as distinct, parallel, or overlapping processes, the relationship is critical to thinking and learning, and has implications for instructional decisions.
The Triarchic Theory of Human Intelligence (Sternberg, 1984, 1986a, 1986b) explicitly emphasizes the importance of metacognition in intelligence. Sternberg describes intelligence through the relationship of three major mental components: metacomponents, performance components, and knowledge acquisition components. These components make possible the ability to deal with novel situations, learn and think within new conceptual systems, know when to adapt and when to leave to a different situation, capitalize on one’s strengths and use compensatory strategies to offset the weaknesses, and know when to engage select strategies and processes for learning, and to be able to automatize information processing (Sternberg, 1986b). Metacognition lies in the metacomponents that are described by Sternberg (1986b) as the “executive processes, in that they essentially tell the other kinds of components what to do” (p. 24). Sternberg considers metacomponents an “essential ingredient of intelligence” and goes as far to say, “…any effort to improve our intelligence must necessarily involve metacomponential skills” (Sternberg, 1986b, p. 42). Sternberg associates metacognition with the brain’s executive function, connecting intellectual and cognitive processes.

Brand, Reimer, and Opwis (2003) concluded that evidence suggests “even just stimulation to engage in metacognitive thinking, and the shift from the cognitive to the metacognitive level this initiates, can enhance problem-solving performance” (p. 252). The researchers subsequently conducted a study in which the findings supported this claim for problem solving and the transfer of knowledge. Azevedo (2005) reported that the successful students used more metacognitive monitoring processes and strategies to regulate their learning. The students’ ability to determine the important skills and information they need, know how to go about getting it, and then reflect on why they
need to know it lies in their ability to regulate and direct their learning, and is intimately
tied to metacognition (Derry & Murphy, 1986).

In an extensive review of the literature on metacognition, there was sufficient
evidence to suggest that metacognitive skills are essential and linked to effective learners
and the development of an expert student, the improvement in problem solving, and the
transfer of knowledge (Azevedo, 2005; Brand, Reimer, & Opwis 2003; Desoete, Roeyers
& De Clercq, 2003; Ertmer & Newby, 1996; King, 1991; Osman & Hannafin 1992; Sitko,
1998; Sternberg 1985, 1998; Swanson, 1990). In support of this literature review,
subsequent articles written in a 1998 issue of *Instructional Science* (Vol. 26, No. 1-2)
made a compelling argument that metacognition plays an important role in a student’s
accomplishments.

Binet and Simon (1973) describe intelligent thought by knowing what needs to be
done and how to do it, the ability to select a strategy and monitor it during problem
solving, and the ability to reflect and critique those actions, then make adjustments to self
correct. Veenman, Wilhelm, and Beishuizen (2004) sought to understand the extent
intelligence is associated with metacognitive skills and whether metacognitive skills are
general or domain and knowledge specific. The participant pool included students from
fourth grade, sixth grade, eighth grade, and university students. Each participant took an
intelligence test and was instructed to perform four computerized inductive learning tasks
– two in the domain of biology and two in the domain of geology. The results showed
that intellectual ability, learning performance, and metacognition increased with age.
Metacognition significantly contributed to learning performance over intellectual ability
in those participants from grades four, six and eight, but correlated rather poorly with the
university students. The investigators discussed this difference based on the threshold of problematicity (Elshout, 1987). They speculated that there comes a certain point when the complexity of the task is so low that the demand for metacognitive skills to solve the problem lessens. However, when all groups were aggregated, the scores showed a high correlation amongst intellectual ability, metacognition and learning performance. The investigators concluded from the results of this study that metacognition contributed more to learning in this study than intellectual ability. Veenman, VanHout-Wolters, and Afflerbach (2006) suggested that metacognitive skills contribute to learning performance despite intellectual ability, and may compensate for a student’s cognitive limitations based on intelligence. This application of metacognitive skills was also found to be specific to general, person-related characteristics across age groups rather than domain-specific areas of knowledge. Therefore, metacognitive thinking applies across the domains of knowledge.

What research has told us about metacognition is compelling and supports the theoretical framework of Flavell, Brown, and Kluwe. My conclusion from the literature is there are four important pedagogical implications for medical educators to consider across the continuum of medical education support and promote students’ metacognitive thinking:

1. Attention to the role and appropriateness of various instructional methods, in different instructional domains, and across levels of medical education which are most effective in developing metacognition.

2. Making strategic, evidence-based decisions to create metacognitive experiences for the students.
3. Consideration to the impact that each method has on improving the metacognitive monitoring, control, and regulatory processes.

4. Deliberate efforts in the instructional environment to shift students thinking between the cognitive and metacognitive levels.

Until very recently in the conversations about curricular design, little emphasis has been placed on the need to promote metacognitive thinking, and it is essentially absent in the vast majority of medical school classes. Thus, medical schools should become pedagogically aware to provide opportunities for the medical students to reflect on and assess their experiences as learners, and to help the students become more deliberate, intentional, and integrative thinkers.

For example, medical educators should build instructional methods into the curriculum that provide space for reflection, dialogue, and exploration. Special consideration should be applied to developing instructional experiences that trigger the metacognitive experience and encourage metacognitive thinking. Flavell felt that the emergence of feelings that one gets during the metacognitive experience is significant in the implication of activating metacognitive strategies (Flavell, 1987). Efklides (2006) reports the implications of these metacognitive experiences on the learning process receives little attention.

**Summary**

With the growing advocates for metacognition’s importance within the context of educational contexts, metacognition has been placed high on the agenda for educational research as one can see by the plethora of studies that were designed to study and advance the theory. Flavell’s theory of metacognition spurred a large number of studies
– particularly in cognitive psychology – which were based on the promise that metacognition was the answer to learning and academic achievement.

Metacognition is a higher-order thinking skill that serves two functions in a human’s thinking process: a monitoring function and a control or regulatory function. Based on the review of the literature, taking away some of the ambiguity of metacognition, I believe that a definition of metacognition should include, at least, five elements:

1. Knowledge: the knowledge regarding one’s own thinking that helps interpret success or failure of the task and strategy variables
2. Regulation: the ability to monitor and regulate this knowledge of thinking by using specific strategies
3. Deliberate: the process of conscious monitoring to deliberately make adjustments and employ strategies
4. Reflective: a reflective component that is necessary for discovering how, when, and why to change course
5. Feeling: the conscious or unconscious affective experiences that occur during the monitoring process that motivates decisions to change strategy or stay on course.

In bringing together what was learned in this section of the literature review, cognition is monitored and controlled by metacognitive knowledge, metacognitive experiences, and by regulating and employing metacognitive strategies. Table 2.1 provides a framework to show the important components of metacognition as they have been discussed in the theoretical review of metacognition.
Table 2.1: Summarizes the metacognitive system, showing the components and features of each: metacognitive experiences, knowledge, and regulation.

<table>
<thead>
<tr>
<th>Components of the Metacognitive System</th>
<th>Metacognitive Knowledge</th>
<th>Metacognitive Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affective Metacognitive Experiences</td>
<td>• Affective feelings</td>
<td>• Monitoring</td>
</tr>
<tr>
<td></td>
<td>• Emotional response</td>
<td>- Analysis of cognitive processing by way of assessment and reassessment</td>
</tr>
<tr>
<td></td>
<td>• Activates the employment of metacognitive strategies in the regulation of cognitive activity</td>
<td>- Associated with making judgments about knowing, learning</td>
</tr>
<tr>
<td></td>
<td>• Sets off metacognitive knowledge and metacognitive strategies</td>
<td>- Enables metacognitive control</td>
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<tr>
<td></td>
<td></td>
<td>- Time and effort check on cognitive task</td>
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<tr>
<td></td>
<td></td>
<td>• Control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Conscious planning, evaluating, and self-regulating cognitive activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Deliberate application of metacognitive strategies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Executive control in operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Dependent on metacognitive knowledge and monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Self correction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Self assessment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Decisions on when/how to employ strategies rely on reflective thinking</td>
</tr>
<tr>
<td></td>
<td>• Declarative knowledge</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Person – what you know about yourself</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Task – what you know about your ability to manage a cognitive task and meet the goal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Procedural knowledge</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Strategy – what you know about the strategies you have to achieve a cognitive goal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Conditional knowledge</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Regulation – what you know in terms of your ability to employ specific strategies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Develops over time through reflective thinking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Stored in long-term memory</td>
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</tr>
</tbody>
</table>
The metacognitive monitoring processes keep a check on the cognitive activity, and when the individual experiences discourse at the cognitive level a metacognitive experience is initiated that activates the metacognitive control processes, and by way of the executive control regulate the cognitive activity with the metacognitive strategies. Reflection’s contribution to this metacognitive system is to develop knowledge and decide on strategies.

**Concept Mapping**

**Foundations of Concept Mapping**

John Novak and his colleagues introduced concept mapping in the 1970’s when they were studying how children learn science concepts. The researchers were seeking to understand the changes in children’s knowledge structure (Novak, 1977; Novak & Gowin, 1984). The theoretical base for understanding concept maps is Ausubel’s theory of meaningful learning and assimilation (Ausubel, 1968). The fundamental idea behind Ausubel’s theory is that an individual develops an elaborate knowledge structure through the assimilation of new concepts into the existing conceptual knowledge structure. Key principles that apply to concept mapping, described by Cañas and Novak (2006), and based on Ausubel’s work in cognitive psychology (Ausubel, 1968; Ausubel, Novak, & Hanesian, 1978) are

- The development of conceptual understanding is based on meaningful learning, (sometimes described as deep and dynamic) as opposed to rote learning (described as surface and static).
- Meaningful learning occurs when new information is attached to the existing learner’s existing knowledge structure; therefore, learning is idiosyncratic to the
learner and progresses over time. With time, the learner builds a linked network of declarative and procedural knowledge.

- Learning abstract concepts is done through appropriate props and didactic instruction.
- Meaningful learning leads to a construction of well integrated cognitive structures that facilitate new learning and allow one to solve problems.

**Duality of Concept Mapping: Cognitive and Metacognitive**

Cognition and metacognition are complementary in the process of concept mapping. The roles they play are not interchangeable, but essentially work together during the process. The duality of concept mapping can be explained through the role of knowledge structure (cognition), and Schön’s (1983,1987) reflection-in-action (metacognition), and will be subsequently discussed.

**Knowledge Structure**

Concept mapping is a procedure for the learner to plot their visual representation of internal knowledge, as information and facts are drawn from memory to answer a focused question within a domain of knowledge. The learner may draw the answer on a sheet of paper or use computer software such as CmapTools (Cañas, Hill, Carff, Suri, Lott, Eskridge, et al., 2004). This map is a two-dimensional diagram of an individual’s conceptual knowledge that shows static and functional relationships between concept labels, and the propositional framework of the concept (Novak, 1977; Novak & Gowin, 1984; Novak, 1990; Novak & Musonda, 1991). Concepts are extensive arrangements of critical attributes and facts that we hold in our memory to give meaningful structure to a particular object or abstract idea (Schunk, 2000). These mental structures are formed
through experiences and provide a foundation to link new information. These structures represent meaningful categories of information (Bruning, Schraw & Ronning, 1999) that we hold in memory. The map is made up of words or phrases that refer to and explain concepts. These words and phrases are placed in boxes that are linked together with lines that show the relationships between them. Jonassen (1994), and later Jonassen, Reeves, Hong Harvey, and Peters (1997) suggest that the concept map is a representation of how one constructed their understanding of knowledge within a particular domain, showing the interrelationships among ideas and terms. Thus, this concept map becomes a conceptual knowledge structure, which is an organized, assimilated and integrated cognitive framework that represents what the learner knows about a particular concept.

**Reflection-in-Action**

McAleese (1994; 1998) applies Schön’s theory of reflection-in-action, and the role of reflection in general to concept mapping, and doing so, McAleese also associates reflection to metacognition. There comes a personal interaction between the external representation and the internal understanding while the mapper is interpreting and organizing personal knowledge in the mapping process (McAleese, p. 19). Reflection-in-action occurs during the concept mapping process through self regulation and self confrontation (McAleese, 1998). These are metacognitive thinking patterns associated with monitoring, assessing success, deciding when and how to respond, diagnosing misunderstanding, and self correcting.

**Characteristics of Concept Maps**

All concept maps have common characteristics (Cañas, Coffey, Carnot, Feltovich, et al., 2003). First, two or more concepts can be linked to form a meaningful statement,
called a proposition or semantic unit, and the map shows the spatial arrangement of these concepts and linking relationships (Cañas & Novak, 2006; Novak & Gowin, 1984). These concepts are a group or class of things that hold something in common – patterns or regularities – and are designated by a label, usually a word. The conceptual knowledge structure is defined by the schema theory (Bartlett, 1932), and as seen in the concept map, is a mental representation of declarative and procedural information, linked together in a network of propositions (Winn & Snyder, 1996). Second, the context for the map is through some problem, situation, or event that the mapper is trying to understand through the organization of the knowledge held in memory about the event. Therefore, starting with a focused question that one seeks to answer is an important consideration in the concept map instructions. Third, the inclusion of cross links shows the concepts in one semantic unit on the map is related to another unit on the map.

**Application of Concept Mapping in Medical Education**

Based on literature review of concept maps in medical education, Daley and Torre (2010) concluded that concept maps function in four areas: (1) promote meaningful learning, (2) provide an additional resource for learning, (3) use as a feedback mechanism, and (4) assess learning and performance. Daley and Torre drew articles published on medical and health professions education; qualitative and quantitative studies on dentistry students, medical students, nursing students, science students, and veterinary students were included in their analysis.

In looking more closely at the thirty-five studies cited by Daley and Torre, there seems to be a growing body of evidence indicating that concept mapping may have a role in the instructional decisions made in medical education, despite the limitations in each
study. The following section presents and critically analyzes the most significant writings that are relevant to the proposed study in my dissertation.

**Relevant Research on Concept Mapping**

Research conducted by Hsu (2004) reported a study on developing concept maps from problem-based learning scenarios. The population in this experimental design was ninety-two first-year nursing students. Hsu was exploring the effects of adopting concept mapping in problem-based learning. The students were randomly assigned to either a control or experimental group. The students assigned to the control group received traditional training while the students in the experimental group drew concept maps in six PBL scenarios. The traditional training for the control group was not defined, which leaves one to assume that the training consisted of didactic lectures. At the end, each student in the study was asked to draw a concept map after watching a video that focused on two sisters’ relationship after one sister was diagnosed with a serious illness. The students were instructed to apply four concepts in the map: physical function, self-concept, role-function, and interdependence. The maps were scored by measuring concept links, hierarchies, cross links, and examples. The results showed that the experimental group achieved significantly higher proposition, hierarchy, and total scores in their concept maps than the control group. No significant differences were found in the cross links and the examples. Making sound conclusions about the results in this investigation is difficult because the significance in the scores could be merely explained by the practice the experimental group had in drawing concept maps. The control group may have had the same knowledge, especially since there was a correlation in the cross links among the concepts on the map, however they were less able to clearly articulate it
through propositions. The students were not presented with a focused question as the starting point for drawing the map, and the maps that were included in the report appeared to be flow diagrams of four concepts, with no cross links between the four concepts.

August-Brady (2005) published the results of a study that explored the effect of concept maps on approach to learning and the self regulation of learning (August-Brady, 2005). The investigator was using concept mapping as a metacognitive intervention in her quasi-experimental, pretest-posttest design study. A convenience sample of eighty nursing students from four geographically separate nursing programs participated in the study. The decision to assign the students to a control or treatment group was based on the program (not randomization) to minimize the effect of diffusion within the sample, and to establish control over the intervention. Students in the treatment group were asked to draw six concept maps on six assigned patients during the fifteen-week semester. The findings suggest that concept mapping (the metacognitive intervention) had a significant effect on increasing a deep approach to learning, and increasing adaptive control beliefs indicating flexibility in learning strategies. Despite the limitations in this study, such as a convenience sample and lack of control in how the treatments were implemented at geographically separate programs, the findings begin to suggest that using concept mapping as a metacognitive intervention might be beneficial to facilitate learning.

Rendas, Fonseca, and Rosando-Pinto (2006) published results from a study conducted in academic year 2003-2004 that investigated the effect of concept mapping on meaningful learning within a medical school’s problem-based learning pathophysiology course. The investigators took a single group of fourteen medical students from a class
of 199 students who were taking the problem-based learning pathophysiology course. During the six blocks of problem-based learning sessions, concept maps were given in advance to the students. A certain number of key nodes were hidden on the map. The students were asked to fill in the gaps on the map and bring it to the following session. At the end of each block, the students were asked to complete a questionnaire, sharing their opinions about the usefulness of the concept maps and about the learning objectives related to the process. The results showed that 100% of the students agreed that concept maps improved their ability to identify key concepts, organize the concepts into hierarchies, and establish relationships among the concepts. While the results are interesting, the sample group was too small to make any reasonable conclusions.

In 2010, Kassab and Hussain published the results of their investigation focused on concept map assessment in a problem-based medical curriculum. All one hundred fourteen medical students in Year 2 and all one hundred fourteen medical students in Year 4 participated in the study. Every student received training in concept mapping and participated in drawing concept maps during problem-based learning. There was no control group that did not participate in the mapping exercise. Students were encouraged to construct a concept map for each problem they studied in the problem-based learning sessions. At the end of the problem-based learning unit, the students were required to submit concept maps on any two problems in the unit. The maps were assessed and this score became a small percentage of the end-unit summative score. The results showed that comparing the two groups, the Year 4 students scored higher on the concept maps in areas for valid concepts, hierarchy, integration, relation to context, and degree of creativity. The analysis also showed that there was no significant difference between the
students’ concept map scores and their scores on multiple-choice question summative examinations. The lack of a control group (the group of students who did not draw concept maps) makes the interpretation of these findings difficult to formulate.

The findings that concept map scores do not highly correlate with in-training examinations are supported by a study conducted on 21 pediatric residents in a university-based training program (West, Pomeroy, Park, Gerstenberger, & Sandoval, 2000). However, data analyzed in a study conducted by Johnstone and Otis (2006) showed that there was a significant difference in the mean scores of conventional course examinations between groups of medical students who used concept mapping during problem-based learning and a group of medical students who did use concept mapping during problem-based learning. The debate to which concept mapping does or does not affect scores on conventional course exams seems to be still unsettled.

**Problem-based Learning**

Supported by the general theoretical principles of cognitive psychology and grounded in the epistemology of constructivism, problem-based learning is a popular instructional method in the Penn State College of Medicine. According to the cognitive perspective, problem-based learning offers the following to medical education (Bruning et al., 1999; Winn & Snyder, 1996):

- A mechanism to teach complex problems that have well-defined goals
- Learners can adopt mental representations to organize the information so that relationships are made between their existing knowledge to newly-acquired knowledge
- Puts the information in a real-life context which makes learning purposeful and meaningful and stimulates the desire and curiosity to seek more information
- Gives an organizational framework, through the clinical case, so the students can link new knowledge in ways that it can be stored in long-term memory
- The learner is a fully-engaged participant in all stages of the learning process
- The teacher guides the learning process, creating the appropriate environment that stimulates learning and allows the student to build on existing knowledge.

Approximately thirty percent of a first-year medical student’s instructional time is spent in the problem-based learning environment, and this increased to approximately fifty percent in the students’ second year of school.

Problem-based learning in the College of Medicine is a teacher-constructed experience. Through carefully-designed clinical cases, small groups of medical students work together with coaching from a faculty member to determine what they need to know for successful diagnosis and treatment of the patient. Information about the clinical problem is disclosed to the students in a progressive fashion, guiding the learners through information to be explored, investigated, hypothesized, and solved. By definition, the cases can be considered representational models of a real-life clinical situation because the cases are used to depict a patient care phenomenon (Shoop, Nordstrom, & Clariana, 2008). These are ill-structured clinical problems where students actively participate to seek new information that links to their existing knowledge base, and make clinical decisions based on this knowledge.
The problem-based learning experience gives students the opportunity to integrate the basic science concepts and principles into the presentation of a disease. In a sense, the problem-based learning case functions as an instructional tool that becomes – as suggested by Jonassen (1996) – the intellectual partner that engages the learners’ higher-order thinking skills. The idea is to use these cases to maximize the pedagogical power that helps students construct conceptual models that lead to a greater degree of retention and overall recall of information (Shoop et.al., 2008).

Problem-based learning functions well from a constructivist view of learning because it ties in with doctrine of beliefs that that knowledge is constructed by the learner through experiences and direct participation with the environment (Cobb, 1994; Duffy & Cunningham, 1996; Jonassen, 1999). According to Duffy and Cunningham (1996) the environment plays a critical role because the central focus of constructivism is on the creation of meaning through learning experiences involving a community of learners. This social interaction is important from the social constructivist viewpoint that takes as its belief that knowledge is created when individuals engage in discussion and activity about shared problems and experiences (Cobb, 1994). Through this interaction, information is organized and understood in such a way that it takes on a new meaning. Meaning will differ among the learners because meaningfulness is an individual interpretation based on the interactions and experiences. These experiences are uniquely understood by the learner through personal reflection and dialogue with others as they gain a shared understanding of the complexity of the concept being explored.

The contextual learning experience embedded in the problem-based learning session is especially important to the students understanding of knowledge. Coles (1990)
described problem-based learning in terms of three phases of contextual learning: (a) provide the context, (b) give relevant information related to the context, and (c) relate the new information with existing information through elaboration. According to Hmelo et al. (1994), and Dahlgren and Dahlgren (2002), problem-based learning puts learning into a context that allows students to construct meaning and knowledge. In medical education, problem-based learning anchors instruction in an authentic clinical case and provides a framework for the problem. The chance that the medical students will find a meaningful connection between basic science concepts and clinical care for patients increases when the clinical problem put in the context of patient care and its relationship to a clinical situation. Contextual learning promotes the medical students’ understanding of the principles, the application of those principles, and increases the probability that the acquired knowledge will be retained in memory for recall at another time.

One principle supporting problem-based learning is connected with the elaboration of knowledge. By its design, problem-based learning gives students the opportunity to discuss issues, teach each other, and provide critique on what is said to be known. This process of elaboration is important for students to assemble their thoughts so that it can be recalled and shared with others, test out their understanding of the concepts, and commit the information to memory (Albanese & Mitchell, 1993; Dahlgren & Dahlgren, 2002). Elaboration also gives students the chance to build on simpler, pre-existing concepts and work out in detail a more elaborate knowledge base than they had when they started the process.
Conclusion

Based on what I know, I am now of the opinion that metacognition plays a significant role in the self-management of many human experiences, including learning, problem solving, decision making, critical thinking, and self correction. Metacognitive knowledge, experiences, regulation, and strategies are bundled into a sequence of thinking that lead to purposeful self management. I also have come to believe that reflection is an important component of metacognition.

The precise application of metacognition in the function of learning and its role in critical thinking has not been clearly established. In analyzing metacognition and the medical education research associated with it in the literature, it became apparent that there are gaps, and more work needs to be done in this area before confident evidence-based decisions on its application can be made in medical education programs. Though they serve different purposes, the published contributions can be regarded as systematic attempts to conceptualize metacognition. The research focused on metacognition either at the theoretical level or at the application level, investigating how to apply the concept in various degrees to learning, problem solving, achievement, and decision making.

The theoretical frameworks of metacognition have been taken up, adapted, and extended to explore metacognition in a variety of educational contexts. The intent of this proposed investigation is to build on the existing body of knowledge and explore areas of metacognition that are curiously intriguing, and has moved me into this area of research for the following four reasons:
1. There is a growing body of literature in medicine that links cognitive errors to unsafe patient care decisions, and developing metacognitive thinking skills is thought to be one answer to reduce cognitive errors.

2. The relationship between metacognition and critical thinking is ill-defined.

3. The pedagogical need in medical education is isolating and so defining the instructional strategies that are most effective in medical training is necessary to advance the medical students’ metacognition; and

4. Concept maps may be one learning activity that employs medical students’ to use their metacognitive thinking skills and promote the development of these skills.

The study is the next step in a series of investigations on metacognition in the medical student population at the Penn State College of Medicine in Hershey, PA. Chapter Three describes the study, and explains the design and methods that were followed to complete the investigation.
Chapter Three

METHODOLOGY

Introduction

Chapter Three describes the methodological approach to this investigation, and speaks to the research design, specifying the details by which the study will be conducted. The specific intent of the study was to learn if using concept mapping as an artifact during problem-based learning engenders metacognitive thinking and affects achievement as measured by scores on test questions written specifically for the problem-based learning case.

Studies Leading Up to the Proposal

The proposed study for my dissertation was the next in a series of investigations that were conducted between 2007 and 2010. The studies were conducted to answer specific questions about metacognition in the medical student population at the Penn State College of Medicine. Each study informed the next and provided related pieces of information leading to my dissertation. Two studies leading up to the proposed study will be subsequently summarized in order of investigation.

Study #1

STUDY #1: The Influence of Metacognition on a First-year Medical Student’s Academic Achievement, and the Effect of Using a Metacognitive Question Prompt on Test-question Scores. IRB Protocol #26254. Funded by a grant from the Penn State College of Medicine’s Woodward Endowment for Medical Sciences Education.

This study was conducted in two phases. Phase I of the investigation was conducted to measure the relationship of the patterns of medical students’ perceptions of metacognitive awareness to their academic achievement. Phase II was conducted to
measure the effect of using a metacognitive prompt on the first-year students’ test-question scores and their representation of knowledge. The two-phase study was designed to answer the following questions:

1. Is there a correlation between a first-year medical student’s level of metacognitive awareness and overall grade-point-average at the end of their first year in medical school?

2. Is there a significant difference in the sample means for the overall grade-point-average at the end of the academic year for medical students with high or low metacognitive awareness?

3. How do the items on the metacognitive awareness inventory load together as factors?

4. What effect do metacognitive question prompts during the study of the autonomic control of the heart rate have on first-year medical students’ representation of knowledge as seen on concept mapping scores and multiple-choice-question scores?

**Phase one.**

**Study population.**

Four-hundred twenty-nine first-year medical students enrolled in the Penn State College of Medicine’s educational program leading to an M.D. degree between August 2007 and August 2009 participated in the study measuring metacognitive awareness.

**Measurement instrument.**

A 52-item metacognitive awareness inventory scale developed by Schraw and Sperling-Dennison (Schraw & Dennison, 1994) was used for the study. Permission to
use the instrument was obtained from Dr. Rayne Sperling at the Pennsylvania State University in State College, PA. Schraw and Sperling-Dennison (1994) tested the instrument with one hundred and ninety-seven undergraduate students. The theoretical foundation of the instrument was previously validated, and a decision was made to use it with the medical student population. Each item dealt with one of the attributes of metacognition as was predicted from the literature (Schraw & Dennison, 1994). All items included in the instrument were grouped in categories to measure eight subcomponents related to the two components of metacognition: knowledge of cognition and the regulation of cognition. The eight subcomponents include conditional knowledge, declarative knowledge, procedural knowledge, debugging strategies, evaluation, information management strategies, comprehension monitoring, and planning as shown in Table 3.1 and Table 3.2 (Schraw and Dennison, 1994).

Table 3.1: Three components related to the knowledge of cognition and their items.

<table>
<thead>
<tr>
<th>Component</th>
<th>Item Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditional Knowledge</td>
<td>I learn best when I know something about the topic.</td>
</tr>
<tr>
<td></td>
<td>I use different learning strategies depending on the situation.</td>
</tr>
<tr>
<td></td>
<td>I can motivate myself to learn when I need to.</td>
</tr>
<tr>
<td></td>
<td>I use my intellectual strengths to compensate for my weaknesses.</td>
</tr>
<tr>
<td></td>
<td>I know when each strategy I use will be most effective.</td>
</tr>
<tr>
<td>Declarative Knowledge</td>
<td>I understand my intellectual strengths and weaknesses.</td>
</tr>
<tr>
<td></td>
<td>I know what kind of information is most important to learn.</td>
</tr>
<tr>
<td></td>
<td>I am good at organizing information.</td>
</tr>
<tr>
<td></td>
<td>I know what the teacher expects me to learn.</td>
</tr>
<tr>
<td></td>
<td>I am good at remembering information.</td>
</tr>
<tr>
<td></td>
<td>I have control over how well I learn.</td>
</tr>
<tr>
<td></td>
<td>I am a good judge of how well I understand something.</td>
</tr>
<tr>
<td></td>
<td>I learn more when I am interested in the topic.</td>
</tr>
<tr>
<td>Procedural Knowledge</td>
<td>I try to use strategies that have worked in the past.</td>
</tr>
<tr>
<td></td>
<td>I have a specific purpose for each strategy I use.</td>
</tr>
<tr>
<td></td>
<td>I am aware of what strategies I use when I study.</td>
</tr>
<tr>
<td></td>
<td>I find myself using helpful learning strategies automatically.</td>
</tr>
</tbody>
</table>
Table 3.2: Five components related to the regulation of cognition and their related items.

<table>
<thead>
<tr>
<th>Component</th>
<th>Item Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Debugging Strategies</strong></td>
<td>I ask others for help when I don’t understand something.</td>
</tr>
<tr>
<td></td>
<td>I change strategies when I fail to understand.</td>
</tr>
<tr>
<td></td>
<td>I reevaluate my assumptions when I get confused.</td>
</tr>
<tr>
<td></td>
<td>I stop and go back over new information that is not clear.</td>
</tr>
<tr>
<td></td>
<td>I stop and reread when I get confused.</td>
</tr>
<tr>
<td><strong>Evaluation</strong></td>
<td>I know how well I did once I finish a test.</td>
</tr>
<tr>
<td></td>
<td>I ask myself if I have considered all options after I solve a problem.</td>
</tr>
<tr>
<td></td>
<td>I ask myself if there was an easier way to do things after I finish a task.</td>
</tr>
<tr>
<td></td>
<td>I summarize what I have learned after I finish.</td>
</tr>
<tr>
<td></td>
<td>I ask myself how well I accomplish my goals once I am finished.</td>
</tr>
<tr>
<td></td>
<td>I ask myself if I learned as much as I could have once I finish a task.</td>
</tr>
<tr>
<td><strong>Information Management</strong></td>
<td>I slow down when I encounter important information.</td>
</tr>
<tr>
<td><strong>Strategies</strong></td>
<td>I consciously focus my attention on important information.</td>
</tr>
<tr>
<td></td>
<td>I focus on the meaning and significance of new information.</td>
</tr>
<tr>
<td></td>
<td>I create my own examples to make information more meaningful.</td>
</tr>
<tr>
<td></td>
<td>I draw pictures or diagrams to help me understand while learning.</td>
</tr>
<tr>
<td></td>
<td>I try to translate new information into my own words.</td>
</tr>
<tr>
<td></td>
<td>I try to break studying down into smaller steps.</td>
</tr>
<tr>
<td></td>
<td>I focus on overall meaning rather than specifics.</td>
</tr>
<tr>
<td><strong>Comprehension Monitoring</strong></td>
<td>I ask myself periodically if I am meeting my goals.</td>
</tr>
<tr>
<td></td>
<td>I ask myself if I have considered all options when solving a problem.</td>
</tr>
<tr>
<td></td>
<td>I periodically review to help me understand important relationships.</td>
</tr>
<tr>
<td></td>
<td>I find myself analyzing the usefulness of strategies while I study.</td>
</tr>
<tr>
<td></td>
<td>I find myself pausing regularly to check my comprehension.</td>
</tr>
<tr>
<td></td>
<td>I ask myself questions about how well I am doing while I am learning something new.</td>
</tr>
<tr>
<td></td>
<td>I consider several alternatives to a problem before I answer.</td>
</tr>
<tr>
<td><strong>Planning</strong></td>
<td>I pace myself while learning in order to have enough time.</td>
</tr>
<tr>
<td></td>
<td>I think about what I really need to learn before I begin a task.</td>
</tr>
<tr>
<td></td>
<td>I set specific goals before I begin a task.</td>
</tr>
<tr>
<td></td>
<td>I ask myself questions about the material before I begin.</td>
</tr>
<tr>
<td></td>
<td>I think of several ways to solve a problem and choose the best one.</td>
</tr>
<tr>
<td></td>
<td>I read instructions carefully before I begin a task.</td>
</tr>
<tr>
<td></td>
<td>I organize my time to best accomplish my goals.</td>
</tr>
</tbody>
</table>
**Procedure.**

The metacognitive awareness inventory was administered and collected at the time of the medical students’ matriculation into medical school. Each student consented to participate. For each item on the inventory, students responded using a six-point Likert scale from strongly agree (1) to strongly disagree (6).

**Data Analysis and Findings.**

The frequency and distribution of the Metcognitive Awareness Inventory (MAI) mean scores (N=429) are presented in Table 3.3. On a six-point Likert scale from strongly agree (1) to strongly disagree (6), the mean was 2.12, the median was 2.12, and the mode was 1.79.

*Table 3.3: Frequency distribution of the MAI mean scores.*

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.12</td>
</tr>
<tr>
<td>Median</td>
<td>2.12</td>
</tr>
<tr>
<td>Mode</td>
<td>1.79</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>0.38</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.21</td>
</tr>
<tr>
<td>Maximum</td>
<td>3.31</td>
</tr>
<tr>
<td>Range</td>
<td>2.10</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.29</td>
</tr>
<tr>
<td>SE of Skewness</td>
<td>0.12</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>0.00</td>
</tr>
<tr>
<td>SE of Kurtosis</td>
<td>0.24</td>
</tr>
</tbody>
</table>

The histogram shows a normal distribution of the mean scores as shown in Figure 3.1. The skewness was .29 (SE=.12), and kurtosis was .004 (SE=.24). The distribution of scores is tightly dispersed in the range of 1.21 to 3.31. While the histogram shows a normal distribution of scores on a three-point scale, the scores are heavily weighted and
tightly clustered on the high end for metacognitive awareness. Plotting these means on a six-point scale would show a positively skewed distribution of scores.

Figure 3.1: The distribution of mean MAI scores. Minimum mean was 1.21 maximum mean was 3.31, with a range of 2.10.

Research Question #1: Is there a relationship between a first-year medical student’s level of metacognitive awareness and overall grade-point-average (GPA) at the end of their first year in medical school?

A Pearson’s correlation coefficient (two-tailed) was used to measure the relationship between the MAI mean score and the first-year students’ end-of-year GPA. The results showed no significant relationship between the MAI mean score and the end-of-year GPA, $r = -.04, p > .05$.

Research Question #2: Is there a significant difference in the sample means for the overall GPA at the end of the academic year for medical students with high or low metacognitive awareness?

An analysis was done to compare the means in the top 25% for metacognitive awareness and the bottom 25% for metacognitive awareness. Levene’s test of homogeneity of
variance is nonsignificant (p > .05), therefore the null hypothesis is retained, meaning the variances appear to be the same across treatment groups. On average, students in the top 25% for metacognitive awareness had higher end-of-year GPAs (M = 82.18, SE = 5.75) than those students in the bottom 25% for metacognitive awareness (M = 81.40, SE = 5.94). However, the results of the independent samples T test, as displayed in Table 3.4 showed the difference in the mean GPAs was not significant t(97) = .61, p > .05.

Table 3.4: Results of the independent samples T test that was used to analyze the comparison of end-of-year GPA mean scores between the top 25% for metacognitive awareness and the bottom 25% for metacognitive awareness.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Top 25%</th>
<th>Bottom 25%</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>End-of-year GPA Mean (SE)</td>
<td>82.18 (5.75)</td>
<td>81.40 (5.94)</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>N=66</td>
<td>N=33</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at p = < .05

Research Question #3: How do the items on the metacognitive awareness inventory load together as factors?

Cronbach’s alpha, a coefficient of reliability, was used as the measure of internal consistency to determine how closely related the set of items were in each subcomponent on the MAI. The intent was to evaluate the reliability of the scales already in use on the MAI. The results are shown in Table 3.5.

Table 3.5: Coefficient of reliability on the subcomponents of the Metacognitive Awareness Inventory.

<table>
<thead>
<tr>
<th>Subcomponent Scale</th>
<th>Number of Respondents</th>
<th>Number of Items</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditional Knowledge</td>
<td>429</td>
<td>5</td>
<td>0.41</td>
</tr>
<tr>
<td>Declarative Knowledge</td>
<td>429</td>
<td>8</td>
<td>0.66</td>
</tr>
<tr>
<td>Procedural Knowledge</td>
<td>429</td>
<td>4</td>
<td>0.64</td>
</tr>
<tr>
<td>Debugging Strategies</td>
<td>429</td>
<td>5</td>
<td>0.65</td>
</tr>
<tr>
<td>Evaluation</td>
<td>429</td>
<td>6</td>
<td>0.58</td>
</tr>
<tr>
<td>Information Management Strategies</td>
<td>429</td>
<td>9</td>
<td>0.63</td>
</tr>
<tr>
<td>Comprehension Monitoring</td>
<td>429</td>
<td>7</td>
<td>0.66</td>
</tr>
<tr>
<td>Planning</td>
<td>429</td>
<td>7</td>
<td>0.63</td>
</tr>
</tbody>
</table>
The alpha coefficient for the items within the eight subcomponents in the construct of metacognition showed low internal consistency (\( \alpha < 0.70 \)). The reliability analysis was then performed using items that define the two components of knowledge of cognition and regulation of cognition. In both cases – knowledge of cognition and regulation of cognition – the alpha coefficient showed the items within each grouping had a relatively high degree of internal consistency (\( \alpha > 0.70 \) for both knowledge of cognition and regulation of cognition) as shown in Table 3.6.

Table 3.6: Coefficient of reliability on the components of the Metacognitive Awareness Inventory.

<table>
<thead>
<tr>
<th>Component Scale</th>
<th>Number of Respondents</th>
<th>Number of Items</th>
<th>Cronbach’s Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of Cognition</td>
<td>429</td>
<td>17</td>
<td>0.79</td>
</tr>
<tr>
<td>Regulation of Cognition</td>
<td>429</td>
<td>34</td>
<td>0.88</td>
</tr>
</tbody>
</table>

While the reliability coefficients were > 0.70, and within an acceptable range, the findings of the reliability scale could be influenced and explained by the larger number of variables.

The reliabilities were troubling so an exploratory factor analysis was conducted using the same 52 items to determine how the items would cluster based on the results of the medical students’ responses. A principal component analysis was conducted on the 52 items with orthogonal rotation (varimax). Bartlett’s test of sphericity \( X^2 \) (1326) = 6654.92, \( p < .000 \), indicated that correlations between items were sufficiently large for principal component analysis. Fourteen components had eigenvalues greater than 1, and in combination explained 57.99% of the variance. However, the factor structure did not yield components that represented clearly descriptive and defensible a priori categories.
Schraw and Dennison (1994) found that their unrestricted factor solutions did not correspond to their eight theoretical sub-components for metacognition.

**Conclusions.**

In this particular phase of the study, the metacognitive awareness instrument showed low reliability or validity justification. The explanation may lie in the cohort of students themselves. The mean scores for metacognitive awareness in this population of medical students did not follow a normal bell curve. Skewness on the MAI shows that the data piles on the left of the curve, meaning that the scores clustered on the scale that measured a high level of metacognitive awareness. This finding suggests the MAI may not be sensitive enough and unable to discriminate levels of metacognition when scores are all at upper level of metacognitive awareness.

One obvious possible explanation is in the medical school’s selection process. While medical students may come to medical school with a wide variety of life experiences and interests, the medical school selection process is heavily weighted on the medical students’ demonstration of intelligence and academic achievement. The selection process itself screens out and tightly controls variability in academic achievement within the student population by considering MCAT scores, undergraduate course and GPA scores, SAT scores, the undergraduate college or university, and the rigor of the student’s undergraduate degree program. The students who matriculate into medical school are highly intelligent, academically successful high achievers, and who are in control of both test performance as well as their self awareness. Medical students know how to be book smart, and master keen test-taking skills on medical school exams.
that are based much on factual information. Therefore, one can expect that the students’
amademic performance will be high overall without significant variability.

Because of the high stakes in medical education, the conclusion from this study is
a need to better understand metacognition in this unique cohort of students. Perhaps the
constructs we use to define metacognition in the general population do not apply.
Whereas the constructs used on the instruments that might be valid in the general
population, the constructs may not be sensitive enough to effectively discriminate for
measuring metacognition in this cohort.

The mean score of the one-hundred ten undergraduate participants in the 1994
Schraw-Dennison study was 67.27 on a 100 mm rating scale. When converted to a 1–6
Likert scale, the mean score was 4.08. This mean was larger than the 2.12 mean score
calculated from the medical student participants.

Phase two.

Phase Two of the investigation focused on answering Research Question #4:
What effect do metacognitive question prompts during the study of the autonomic control
of the heart rate have on first-year medical students’ representation of knowledge as
seen on concept mapping scores and multiple-choice-question scores?

Study population.

Nineteen first-year medical students wanted to continue, and consented to
participate in Phase II of the study. The students were randomly assigned to two groups:
the control group (Treatment Group A) and the treatment group (Treatment Group B).
Ten students were assigned to Treatment Group A, and nine students were assigned to
Treatment Group B. One student who was assigned to Treatment Group B withdrew due to time constraints.

**Procedure.**

The students were registered in the first-year, fall semester Cellular and Molecular Basis of Medical Practice course. The topic of interest was the autonomic regulation of the heart rate. During the instructional period when the students studied the autonomic control of the heart rate, the students in Treatment Group B were given a set of metacognitive prompts to use when they studied this concept. Samples of metacognitive prompts include the following:

1. Something interesting that I learned about the eyeball today is…
2. My approach to learning all about the eyeball is…
3. A question I still have unanswered about the eyeball is…
4. In reference to the eyeball:
   a. It seems important to note:
   b. I feel stuck on:
   c. I can’t decide if:
   d. I’m wondering why:

Treatment Group A, the control group, was given no metacognitive prompt questions.

The Monday after the students learned about the autonomic control of the heart rate, and after being instructed on concept mapping, the students were asked to draw a concept map of the autonomic control of the heart rate, and answer five multiple-choice questions written for the autonomic control of the heart rate. Samples of the students’ maps are seen in Figure 3.2. The maps were drawn by hand, then manually converted to a computer image using IHMC CMapTools v4.15.

**Data analysis and findings.**

A basic criterion of looking at pertinent terms on the map was used in scoring the concept maps (Novak & Musonda, 1991; Rice, Ryan, & Samson, 1998). The pertinent
propositions and terms were determined by the ‘expert’ concept map drawn by the faculty members teaching the autonomic control of the heart rate as shown in Figure 3.3. The experts were asked to draw a map showing what they felt a first-year student should master on this particular topic.

*Figure 3.2: Two student maps of the autonomic control of the heart rate.*
Figure 3.3: An expert’s map of the autonomic control of the heart rate.

If the student’s map had the correct propositions and the correct terms on the map that coincided with those on the expert’s map, the student received a +1 for each correct response, because everything that was important was there. An example is shown in Table 3.7.

Table 3.7: Example of the concept map scoring criteria.

<table>
<thead>
<tr>
<th>Score</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1</td>
<td>Student’s map shows the medullary center</td>
</tr>
<tr>
<td>+1</td>
<td>Student correctly links sympathetic and contractility</td>
</tr>
</tbody>
</table>

An analysis was done to compare the means in Treatment Group A (control group) and Treatment Group B (metacognitive study questions). Levene’s test of homogeneity of variance shows $p > .05$, not significant, meaning the variances appear to be the same across treatment groups; therefore the null hypothesis was retained. On average, students in Treatment Group A, the control group, had lower concept mapping scores ($M = 50.9, SE = 4.11$) than did the students in Treatment Group B ($M = 59.1, SE =$
However, the results displayed in Table 3.8 of the independent samples T test showed the difference in the mean GPAs was not significant $t(16) = -1.54, p > .05$.

One explanation for these findings of non-significance is the sample size. There were only 10 observations in the dataset for Treatment Group A, and 8 observations in the dataset for Treatment Group B. The numbers do not give enough power to detect significant differences. Despite the fact that there might be some cases where the difference in the means is interesting to explore (e.g., concept map score), the p-value was not significant at the 0.05 level. However, regardless of the non-significance in the mean scores, the student concept maps were important because they illustrated how the semantic properties – facts, concepts, rules, and principles – were arranged in each participant’s memory. To some degree, the maps gave a peek into the ‘mind's eye’ of these students as to how they understood, organized, and integrated the knowledge and concepts.

**Table 3.8**: Results of the independent samples t-test that was used to analyze the comparison of mean scores between the control group and the group that received metacognitive question prompts.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Treatment A (Control)</th>
<th>Treatment B (Metacognitive Question)</th>
<th>P-Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept map score, Mean (SE)</td>
<td>50.9 (4.11) N=10</td>
<td>59.1 (2.98) N=8</td>
<td>0.14</td>
</tr>
</tbody>
</table>

*Significant at $p = .05$

On visual inspection, the student maps, as illustrated in Figure 3.2, show a broader range of specific details than the expert map shown in Figure 3.3. This difference between the expert and student concept maps might be expected at early stages of learning, suggesting the students’ need to further consolidate and organize their knowledge. The noticeable differences between the two student maps need further
investigation to determine how and if these differences are related to metacognition, multiple intelligence, problem solving, and/or achievement.

In the process of collecting the concept maps, I was surprised by the medical students’ spontaneous enthusiasm for drawing concept maps. In particular, the students expressed how this exercise helped illuminate what they did not yet understand about the concept. Since the mapping procedures were completed after each student covered the material in lectures and before the course examination, the process of drawing the concept map helped the students identify areas that needed to be either reviewed or learned anew. The students were describing a thinking pattern that fit into what I knew about metacognition.

The students, in monitoring their thinking through the mapping process, were encountering metacognitive experiences; some of the metacognitive experience was affirmative (students felt confident that they comprehended the material), while other parts of the experience were negative (students felt confused and unsure of their comprehension of the material). This unintended finding was so unexpected and intriguing that it prompted the next investigation to explore the students’ perceptions of concept mapping.
Study #2

STUDY #2: The Medical Students’ Perception of Concept Mapping. A continuation study funded by a grant from the Penn State College of Medicine’s Woodward Endowment for Medical Sciences Education.

**Introduction to the Study.**

The purpose of this research project was to better understand the meaning of the concept mapping experience through the reflections of second-year medical students in the Penn State College of Medicine. The question guiding this research is: *How do second-year medical students, enrolled in the Penn State College of Medicine’s educational program leading to the M.D. degree, describe and interpret the meaning of concept mapping as it relates to learning?*

Working in a constructivist paradigm (Guba, 1990), the study was designed to get at the perspective and description of concept mapping through the students’ reflections. In moving forward with the study, the following assumptions were made:

1. Participants could still relate to their educational experience in a meaningful way.
2. Participants would be interested and able to accurately and explicitly give their perspective of concept mapping.
3. Patterns or common themes would emerge from the participants’ descriptions.
4. I could suspend any relationship and opinions I had with concept mapping.
5. In good faith, I would reconstruct the students’ story of concept mapping and reject, as much as possible, any value position I brought to the study.
**Research Design.**

There are a variety of theoretical and philosophical orientations for qualitative inquiries (ethnography, case study, phenomenology), all in difference to a positivistic method of inquiry (Bianco & Carr-Chellman, 2002). In choosing the design that would capture the meaning and essence of concept mapping as seen through the intentional awareness and description of the medical students, the characteristics of qualitative research and the theoretical foundation of phenomenology seemed to be the most likely to maximize the chance for success (Hammond, Howarth, & Keat, 1991; Patton, 2002). Thus, a qualitative research design, with a planned phenomenological approach, was chosen to assess the meaning of concept mapping. Consistent with a phenomenological perspective, it was designed to explore the essential descriptions and interpretations of concept mapping through the accounts of the participants. The intent of the applied research was to gather and interpret sufficient data that could eventually lead to decisions regarding instructional methods in the College of Medicine’s educational program.

**Study Population.**

A purposeful sampling strategy was used to target a particular group of medical students who would be homogeneous within the context of the study, and who have the experience with the concept being explored through concept mapping (Cresswell & Plano Clark, 2007). Eighteen second-year medical students in the Penn State College of Medicine’s educational program leading to the M.D. degree consented to participate in the study. My intent was not to generalize the findings to a broader population; therefore, I purposefully chose to select a sample of students from the College of Medicine.
Data Collection and Analysis.

Each student was instructed in the technique of concept mapping before starting the study. Once there was a level of comfort with concept mapping, the student was given the following brief description to describe the context of the topic, and provide the focused question that would be used for the concept mapping.

- **Description:** The hypothalamus/pituitary axis is often considered the master endocrine regulator in the human body. The hypothalamus and pituitary glands have major regulatory control over growth, metabolism, maturation, and sexual reproduction.

- **Focused Question:** What is the description and effect of ischemic damage to the pituitary gland?

The student was instructed to answer the focused question by drawing a concept map on a piece of flipchart paper. No time restriction was given for the concept mapping experience. The student was also given two open-ended questions to answer as soon as the concept mapping was completed: (1) What surprised you most as you were drawing the concept map? and (2) What was most beneficial to you in this exercise? When the student handed in the concept map and the answers to the questions, a one-on-one, post-concept-mapping interview was conducted. This one-on-one interview was guided by a basic set of open-ended questions in areas I wished to further explore to corroborate the student’s written answers, and areas I wanted to learn more about that enriched my understanding of how these students learned the topic. The following were basic questions that led the interview: (1) How would you explain your feelings about the concept mapping process? (2) How did you approach learning the autonomic control of
the heart rate? and (3) Where would you find the most useful application of concept
mapping in the curriculum, such as your study time, in lectures, or in problem-based
learning?

In phenomenology, the researcher assumes a principle role as the data-collection
instrument, and over time, understands the phenomenon through the accounts of the
participants’ perspective (Hammond et al., 1991; Marshall & Rossman, 1999; and Patton,
2002). And so was the case in this inquiry. I was the sole person conducting the
interviews, managing the data, and drawing conclusions; therefore, everything that I
subsequently report has been selected, filtered, and interpreted by me.

Findings.

The description and interpretation of concept mapping emerged as an
uncomplicated, individualized construct of meaning to the students. There was little
variability in the students’ descriptions. Two overarching themes emerged: integration of
knowledge, and organization of knowledge. The following are written statements taken
directly from the students’ written answers to the questions: (1) What surprised you most
as you were drawing the concept map? and (2) What was most beneficial to you in this
exercise?

“At first I had a difficult time creating the map because it seemed sloppy and chaotic –
but – as I continued, I forgot how chaotic it was, and actually had fun trying to piece
together all the connections. Actually thinking through the connections was really
beneficial. This allowed me to see both the individual role of each event/item, but also
the BIG PICTURE. In a way, this kept things organized and in perspective, despite how
chaotic my map looks :)”
“How many things fit into each other so much. I seemed to follow patterns when I divided terms into anatomy, hormones, pathology, etc. The most beneficial was “categorizing the different concepts.”

“The concepts fit pretty well into a logical mental map, but it was hard to transfer the map into a physical manifestation. The paper shows the connections I have, but not quite the way I picture it in my head. It’s the best I can express it, though. What was most beneficial was “Forcing myself to connect as much as I can made me realize there are more connections than I thought.”

“How quickly I was able to pull the concepts together.” What was most beneficial was ”drawing/seeing the connections between pathophysiology and how you treat and diagnose the problem.”

“How much I remembered!” What was most beneficial was ”I felt like I was studying in a way – connecting major concepts helped me see a bigger picture”.

“The connections between conditions that I had not realized until just now!” What was most beneficial was “Being able to organize seemingly unrelated diseases with the unifying concept of ischemia. We tend to learn each disease as a separate entity and forget to make important connections regarding disease etiologies.”
“How many connections there were! I could have made more, but it got messy. It showed me the connections are important, but so is the organization.” What surprised me most was “drawing together my knowledge and making connections.”

My intent in the one-on-one interviews was to focus on the function of concept mapping; however, in realizing the importance of process to the participants, I changed my direction of questioning and gave them the chance to talk about it. In allowing the students to talk about the process, I uncovered the most talked-about value of concept mapping that emerged in all interviews – the presumed integration of what they knew about the concept. It was by far the most frequently stated and valued benefit that directly applied to the concept mapping experience. What I learned from the interviews was that every student expressed some level of appreciation for what they experienced in the concept mapping exercise. A student named Britt said, “I went into this feeling apprehensive, but once I got into thinking about the pituitary gland, I was surprised with all I knew and for the first time was able to see how it fit with ischemia. We just had a test on this and I know more now than I did for that.” Another student named Cyrl said, “I know what I don’t know and I must study the pituitary again.”

Overall the basic sentiment among the students was that participating in this study to do concept mapping gave them a space of time where they could think through what they knew about the pituitary gland. All agreed that concept mapping would be useful in their lectures and problem-based learning, but less so in studying. The time commitment to work through a concept map was a factor in studying. This finding did not come as a surprise, considering the large amount of material these students must learn in a relatively short period of time.
When I asked the students how they would study for a topic such as the pituitary gland, their answers ranged over a host of study strategies. The most popular strategies that emerged were listening in class, breaking the topic down into parts, writing headings and lists, and drawing pictures. Four students said they actually took time to plan out a strategy. While this question did not relate to the topic of concept mapping, I found it interesting that drawing pictures was one of the most popular themes in how they study.

**Conclusion.**

What I learned was concept mapping gave the students a chance to make connections in the knowledge they had about the pituitary gland. The answers I gained in listening to the students led to more questions. What was the role of concept mapping in the students’ experience? Was it merely an act of retrieving knowledge from memory, or a function of having the time to really reflect on what they knew and make decisions on how to relate one aspect of the concept with another? The students’ written and verbal statements led me to believe the meaning behind the concept mapping laid beyond the process of retrieving information from memory. The feeling of knowing more about the pituitary gland than they thought, the feeling of accomplishment, the feeling that for the first time the students understood the connections, all began fitting into what Flavell defined as the metacognitive experience (Flavell, 1979; Flavell, Miller, & Miller, 1977), which are internal responses to the person’s metacognitive knowledge, goals, and strategies.

The mapping process was an experience that demonstrated metacognition and cognition operating simultaneously. Cognition was performing the mental function of processing the information that needed to be included in the map (retrieving facts,
classifying the information, making distinctions, etc.). Metacognition was monitoring what was and what was not known, examining thought process, thinking about the connections among the terms, and interpreting the different kinds of links that were needed during the mapping.

There was more to learn about the relationship between concept mapping and metacognition, which led me into the study proposed for my dissertation. The focus of the research is deemed important by the discipline of medical education, and by my own admittance for personal intellectual curiosity. The desired result is to contribute to what we know about concept mapping and metacognition, specifically relating it to a population of high achieving, intellectual students.

**DISSERTATION STUDY: MIXED-METHODS INVESTIGATION**

**Introduction**

The intent of my previous studies was to learn as much as I could to explain metacognition as it relates to the medical student population; specifically wondering if the definitions of metacognition that are applied to the general population apply to a population of students whose average I.Q. scores are at the 96th percentile relative to the general adult population (Kole & Matarazza, 1965). Initially, I used concept mapping as an assessment instrument, but from observations and student reactions, I learned that the students were responding to concept mapping in a manner that extended beyond what was intended. These unintended findings were so interesting that I redirected my studies to explore the function of concept mapping in the context of the metacognitive theories. Was concept mapping a means to engender metacognitive thinking whereby students had
time to think about what they were learning, and help them understand how their learning involved integrating information into a huge structure of knowledge?

My theory was concept mapping is an artifact that can be used to encourage metacognitive thinking in collaborative, medical school learning environments, and it does this by providing an opportunity of time, whereby students can pause to engage in the kinds of thinking – specifically self-assessment and reflection – that improve the capability to learn and remember. Thus, the investigation for this dissertation focused on concept mapping as an artifact that engenders metacognitive thinking. The context of the study was problem-based learning. The problem-based learning case focused on salicylate intoxication, during which groups of students worked together to draw a concept map of the topic. The students were enrolled in their required first-year Cellular and Molecular Basis of Medical Practice course. The investigation addressed two research questions:

**Question #1**: How does concept mapping, used as an artifact in a problem-based learning session during the Cellular and Molecular Basis of Medical Practice, influence the intragroup discussion compared to the problem-based learning group that does not use concept mapping.

**Question #2**: Do first-year medical students who draw group concept maps during their end-of-case discussion in a problem-based learning session in the Cellular and Molecular Basis of Medical Practice course achieve higher scores on test questions than the first-year medical students who did not draw a group concept map during the end-of-case discussion?
Null Hypothesis: $H_0$: $\mu_1 = \mu_2$  First-year medical students who drew group concept maps during their problem-based learning session in the Cellular and Molecular Basis of Medical Practice course will score the same on questions related to the problem-based learning topic as students who did not draw concept maps in their problem-based learning group.

The null hypothesis was tested against an alternative hypothesis, denoted as $H_1$:

Alternative hypothesis: $H_1$: $\mu_2 > \mu_1$  First-year medical students who drew group concept maps during their problem-based learning session in the Cellular and Molecular Basis of Medical Practice course will score higher on questions related to the problem-based learning topic as students who did not draw concept maps in their problem-based learning group.

The null hypothesis was assumed to be correct unless there was sufficient evidence from the sample as tested by the significance level to reject it.

**Research Design**

Following Creswell’s criteria for selecting the research method, I chose a two-phase, embedded, mixed-methods research design (Creswell, 2003; Creswell & Plano Clark, 2007). The decision for choosing the method was driven by the research questions (Johnson & Onwuegbuzie, 2004), and in this study qualitative and quantitative research approaches were necessary to best answer the questions. The qualitative investigation sought to describe and explain what was occurring during the concept mapping experience. The intent was to learn how concept mapping did or did not influence the discussion among the medical students in the problem-based learning group. Attention to the variations in the discussions and to what degree these variations serve in our
understanding of metacognition in this population of students was important. While I believe concept mapping provides an opportunity whereby students engage in discussion that is rich in metacognitive thinking, this has not been explored in the medical student population. The \textit{quantitative investigation} sought to measure if groups of medical students who drew concept maps during problem-based learning scored higher on case-related exam questions than groups of students who did not draw a concept map.

The reason for collecting both qualitative and quantitative data was to bring together the strengths of both forms of research to explain the phenomenon of concept mapping as an artifact to engender metacognitive thinking. As written by Patton (2002), “qualitative data can put flesh on the bones of quantitative results, bringing results to life through case elaboration.” (p. 193) Thus, using a combination of qualitative and quantitative approaches to this study will provide a better analysis and understanding of the questions (Creswell, 2003; Creswell & Plano Clark, 2007).

\textbf{Context of the Study}

The context of the study was problem-based learning during the Cellular and Molecular Basis of Medical Practice course, a required first-year course in the Penn State College of Medicine’s educational program leading to the M.D. degree. This study is considered single site since data are only being collected at the College of Medicine.

I chose problem-based learning for the context because it has remained an important instructional method in the medical school’s educational program since the College of Medicine introduced problem-based learning in academic year 1995-1996. Approximately thirty percent of a first-year medical student’s instructional contact hours is spent in problem-based learning during the spring semester, and this increases to
approximately fifty percent in the second year of medical school (both fall and spring semesters).

In the first year of medical school, students investigate a case over a three-day period (Monday, Wednesday, and Friday). They spend two hours of problem-based learning each day for total of six hours to work through the case and master the learning objectives. This study was conducted on Day Three (Friday, February 24th) when the students were wrapping up the case and discussing the learning objectives. The students had been working together with their facilitator in their problem-based learning groups since the course began in January 2012. Therefore, the students were familiar with each other, the facilitator, and had formed group dynamics. The students had completely worked through four other problem-based learning cases, between January 2nd and February 17th, before they started working through the case chosen for this study on Monday, February 20th. The case was titled ‘Janice is Down’, and presents with a 17-year-old depressed female who just broke up with her boyfriend. She was rushed to the hospital after reports of ingesting 250 tablets of a regular strength aspirin in a suicide attempt.

The salicylate intoxication (aspirin poisoning) case was chosen for the study because of the complicated biophysiologic interactions, requiring the students to integrate information regarding complex systems of action from physiology and biochemistry. The toxic levels of salicylate uncouples oxidative phosphorylation and inhibits some enzymes in the cell, creating a cascade of complex clinical syndromes involving the gastrointestinal, renal, respiratory, and neurological systems. The patient falls into a critical acid-base disorder, and can quickly die. The clinical case is not straightforward in
salicylate intoxication as are other cases the students get in problem-based learning; studying this case takes a high level of thinking to understand the mechanisms of action associated with the intoxication. In choosing the case, an assumption was made that the complexity of the case determined, to some degree, the level of thinking that was necessary for the student to learn.

**Location of the Study**

The study was conducted in the small-group, problem-based learning classrooms at the Penn State College of Medicine in Hershey, PA. Each small-group classroom is set up in the same configuration. Each room is equipped with a plasma screen, a large white board, various colored white-board markers, and a large conference-type table that comfortably seats ten individuals, and accommodates their laptop computers.

**Entering the Field of Study**

Permission to conduct the study was obtained from the medical school’s vice dean for educational affairs, associate dean for pre-clinical curriculum, and the course co-directors of the Cellular and Molecular Basis of Medical Practice course. Conditions for the study were set forth by the medical schools policies and included

- Students were randomly assigned to problem-based learning groups by the Office of Medical Education prior to the start of the Cellular and Molecular Basis of Medical Practice course.
- Group assignments could not be manipulated based on the students who volunteered to participate.
- Data collection had to occur during normally scheduled problem-based learning sessions.
Institutional Review Board Approval

Approval from the Penn State College of Medicine’s Institutional Review Board (IRB) was successfully obtained for this study. The IRB Protocol number assigned to the study is 38229EP. The consent form, included in Appendix A, was used to recruit participants. All participants were informed that participation in the study was on a volunteer-only stipulation and that all measures to assure confidentiality were in place and approved by the IRB. The medical students were required to give individual consent to participate. This criterion for participation meant that if one student in a problem-based learning group declined to participate, the group had to be eliminated from the study.

Population of Interest

The population from which I recruited participants was one-hundred forty-four first-year medical students enrolled in the Penn State College of Medicine’s educational program leading to the M.D. degree. A deliberate decision was made to select first-year medical students to participate, because these students went through the fall semester in their first year of medical school together, taking the same courses taught by the same faculty members. This sample of medical students best give us answers to the questions under study, and illuminate our understanding of how concept mapping engages the student in metacognitive thinking. These students also had the same number of problem-based learning experiences that began in the first year of medical school.

Rules and Procedures for Random Assignment

One-hundred forty-four first-year medical students were randomly assigned to twenty problem-based learning groups, with approximately equal numbers of students in
each group. Group size was seven or eight student per group. This random assignment to problem-based learning groups is a requirement by the College of Medicine and is made by the Office of Medical Education prior to the start of the course.

Randomization balances the characteristics of the students, so in the quantitative phase of the mixed-methods design, the difference in scores can be attributed to the concept mapping treatment, and minimize the effects of extraneous factors or variables (Kutner, Nachtsheim, Neter, & Li, 2005). To minimize the effect of the faculty facilitator in the groups the faculty facilitators were also randomly assigned to the groups.

**Sampling Method**

A purposeful, homogeneous sample of first-year medical students was recruited for this mixed-methods study. Purposeful sampling assumes that the selected sample is chosen based on what most can be learned in answering the research questions (Merriam, 1998). Sampling was based on specific criteria (Merriam, 1998), and listed below are the criteria I used to target the population-of-interest (as defined by the essential attributes I needed for the purpose of the study):

- Medical students
- Enrolled in the first year of medical school
- Academic good standing
- Successful completion of the first-year Fall semester Clinical Learning Competency course (problem-based learning course)
- Registered (not scheduled) in the spring semester Cellular and Molecular Basis of Medical Practice Course
Participants

Fifty students in seven problem-based learning groups consented to participate in the study. There were students who were interested and volunteered to participate; however, if one student in a group declined to participate, the group was eliminated from the group-participant list, and those students who were assigned to that particular group and volunteered could not take part in the study. Table 3.9 lists the groups and shows if they were assigned to concept mapping.

*Table 3.9: Group-participant list*

<table>
<thead>
<tr>
<th>Group Number</th>
<th>Group Size</th>
<th>Concept Mapping</th>
<th>Audio Recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The students had to consent to the concept mapping portion of the study and the audio recording portion of the study. If a group of students consented to participate in the concept mapping portion, but not the audio recording portion of the study, the group could not be included in the qualitative method of the study. Therefore for the purposes of this study, Group 2 and Group 4 were eliminated from the qualitative method. Group 3 was eventually removed because a student withdrew consent to be audio recorded, which eliminated the group.

**Qualitative Investigation: Case Study Perspective**

At the heart of the study I was intrinsically interested in determining the impact of concept mapping as an artifact that engenders metacognitive thinking behaviors in
collaborative groups of first-year medical students. I selected a particular instance in problem-based learning to study this phenomenon in depth. From the qualitative perspective of the mixed-methods investigation, a case study research design was determined to be the best approach. As shown in Table 3.10, Merriam’s (1988, 1998) criteria for choosing a case-study design are listed, and the decisive factors I used to make the determination for each criterion are provided.

In 1998, Merriam claimed the single most important criterion defining case-study research is the bounded system, and how the case is delimited is the “single most defining characteristic” of the case (p. 27). Thus, most important in my decision to proceed with a case study was the notion of the bounded system. The case is bounded within a finite time, place, topic, and group. Data were collected on a pre-determined day (Friday, February 24, 2012) and time (1:00-3:00 p.m.) based on the course’s sequence of problem-based learning sessions and the schedule of classes. All problem-based learning cases span three days to complete. Data were collected on the third day of the case when students were discussing the learning objectives disclosed for the case. The case was bounded in the topic of salicylate intoxication. All data were collected from small groups of first-year medical students at the Penn State College of Medicine.

This case study is further defined as a single-entity, embedded, comparative, and descriptive study. First, the case is a single entity (Merriam, 1998), and in this study, concept mapping in the larger context of problem-based learning was studied for the purpose of understanding something else – metacognition. The model of analysis in case study research, according to Merriam (1988), is largely inductive, building abstractions, constructing conceptual understandings, and offering hypotheses. The analysis in this
study is considered embedded rather than holistic because I am focusing on a particular aspect of the case rather than aspects of the entire case (Yin, 2003). This case study is further defined by its comparative analysis; an analysis that will be presented in two stages – the within-case analysis and the cross-case analysis (Merriam, 1998). Lastly, the study is considered a descriptive case study, because the end result of the case study will be a thick, detailed description that will give a complete and literal explanation of the real-life phenomenon in the context of which it occurred (Merriam 1998). The design strategy for this case study includes the unit of analysis; development of the instrument; methodology; and analysis and outcome measures, which will be discussed in turn.

**Unit of Analysis and Sample Size**

The unit of analysis, which is the primary focus of data collection, was five problem-based learning groups of medical students. In the recruitment process I was able to get full-student participation in two groups that were assigned to discussion only, and three groups that were assigned to concept mapping and discussion. While Stake (1995) does not give parameters for sample size in case study research, Creswell (2007) does state that four or five case studies in a single study are sufficient to identify themes and conduct cross-case thematic analysis. In this study five groups are considered a minimum sample size “based on expected reasonable coverage of the phenomenon given the purpose of the study” (Patton, 2002, p. 246). This sample size accounts for 25% of the total groups in problem-based learning.
**Table 3.10: Criteria used to choose the case-study design.**

<table>
<thead>
<tr>
<th>Criteria of Importance in Choosing a Case Study (Merriam, 1988, 1998)</th>
<th>Decisive Factors in the Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research Question</strong>&lt;br&gt;<em>The question of ‘how’</em></td>
<td>The heart of the study was exploring ‘how’ concept mapping affects the students’ thinking through the salicylate intoxication problem-based learning case. The study is designed to document the issues of the concept mapping experience.</td>
</tr>
<tr>
<td><strong>Desired end product</strong>&lt;br&gt;<em>A comprehensive understanding of the topic of interest</em></td>
<td>The result of the investigation will be a detailed description and interpretation of concept mapping</td>
</tr>
<tr>
<td><strong>Nature of the system</strong>&lt;br&gt;<em>A bounded system</em></td>
<td>The study of how concept mapping affects students’ thinking is explored through several occurrences within the context of the problem-based learning case of salicylate intoxication. The overall strategy frames the study within the boundary of small groups of first-year medical students, and the group is the single unit of analysis.</td>
</tr>
<tr>
<td><strong>Number of participants involved</strong></td>
<td>Finite number of medical students are involved within this bounded system</td>
</tr>
<tr>
<td><strong>Data collection</strong></td>
<td>Finite amount of time for data collection; there is an end to the number of participants that can be interviewed and recorded to answer the research questions in this particular study.</td>
</tr>
</tbody>
</table>

**Choosing the Artifact**

Concept mapping during the salicylate intoxication case was the likely artifact to use in the study because according to Jonassen and Marra (1994) the mapping process actively engages the students in thinking and addresses the critical issue of how the students organize their knowledge structures within and between the domain of
knowledge. Therefore, to understand salicylate intoxication, one would agree that the students must engage in a sophisticated level of thinking to work through the mechanisms of the case. A concept map would show how they are linking the knowledge. To paraphrase Jonassen & Grabowski (1993, p. 433), a person’s structural knowledge can be depicted in a concept map, because the map is a way to visually describe the relationships between ideas in a knowledge domain. Additionally, there is a growing body of evidence indicating that concept mapping is assuming a larger role in the instructional decisions made in medical education, which makes it prudent to study concept mapping and learn what it brings to the learning environment.

**Development of the Instructions and the Instrument**

Two research protocols were developed for the qualitative phase of this mixed-methods investigation: concept mapping instructions and a focus-group interview guide. The concept mapping instructions were developed over a series of the previous investigations I conducted on concept mapping. Providing the students with a focus is very important in the concept mapping instructions and for this particular mapping exercise, the students were given the following information in the instructions to focus their thinking:

The major pathologic lesion created by salicylate intoxication is uncoupling of oxidative phosphorylation. This lesion affects major organ systems in the body. Using “uncoupling of oxidative phosphorylation” as your starting point or root concept, map out the effects on body systems once salicylate intoxication occurs. Focus on the respiratory system, renal system, and the brain. If you need to bring other systems into the map to explain how you ‘see’ the effects, that’s O.K.
If there are any relationships in the effects caused by salicylate intoxication, show them using cross links across systems.

A copy of the instructions is included as Appendix B. Before the instructions were given to the students and problem-based facilitators for this study, a pilot test was conducted with a small group of second-year medical students, and a small group of staff members in the Office of Medical Education.

A focus-group interview guide was developed for the investigation and can be read in Appendix C. The questions written for the interviews were driven by the research question aimed at discovering how the medical students described their experience during concept mapping in terms of thinking behaviors.

**Data Sources**

I was the primary instrument of data collection and analysis in this study. The data collection drew from audio recordings, field note observations, and interviews. This collection of data yielded a detailed description (Creswell, 2007), explaining aspects of the concept mapping experience during the problem-based learning case.

**Problem-based Learning End-of-Case Discussion.**

**Concept Mapping During the End-of-Case Discussion.** Concept mapping was explained to the students in the groups that were assigned to concept mapping prior to the day of data collection. Examples of concept maps were shown to the groups, and a small concept map was drawn for them. I found that in every group there was at least one student who stated familiarity with concept mapping. I personally met with each group facilitator several days before data collection to discuss the intent of the study, describe concept mapping, show examples of concept maps, and give them a copy of the
instructions. On the day of data collection, each student and facilitator was given the set of instructions written specifically for the salicylate intoxication case. Time was allowed for the students to read the instructions and ask any questions. The students were instructed to draw a concept map as they discussed the case. Audio recordings of the discussion in each of the three problem-based learning groups who consented to be audio recorded during the final discussion of the case were made. The discussions were audio recorded to characterize and compare the conversation among the group members. These recordings were word-for-word transcribed for the analysis. Two groups consented to draw concept maps, but did not consent to be audio recorded. Two problem-based learning groups consented to be audio recorded during the end-of-case discussion without doing any concept mapping.

_End-of-Case Discussion Only – No Concept Mapping._ Two groups were instructed to discuss the salicylate intoxication case just as they would normally do on the last day of the case. One group withdrew a day before data collection, the other group was audio recorded during the discussion.

_Focus-group Interview_

A focus-group interview was conducted following the problem-based learning sessions to corroborate the findings from the audio recorded data. As described by Merriam (2009), a constructivist perspective underlies focus-group data collection procedures because the focus-group interview involves a group of individuals (Merriam, 2009). Following Merriam’s (2009) continuum structure for interviews, a decision was made to conduct a semi-structured focus-group interview. The focus-group interview was guided by a mix of structured and unstructured questions that did not have to be followed
in any specific order during the interview itself. The focus-group interview was recorded to ensure that everything said would be preserved for the verbatim analysis.

*Qualitative Data Analysis: Outcome Measures*

The sole source of data came from the transcripts of the audio tapes, and the focus-group interview. The prime necessity was to manage the volume and complexity of the data collected. I chose not to create a provisional start list of codes before collecting data in the field. Rather after reading Creswell’s (2007) section on data analysis, I decided to inductively approach the coding process and allow the patterns to emerge within the context of the study. I also chose to code without the use of a computer program, because I wanted to become part of the students’ discussion, the patterns, and feel meaning in what I was doing.

The framework for analyzing the data was Stake’s (1995) four-phase case study analysis that includes the following phases: descriptive, categorical aggregation establishing patterns, and naturalistic generalizations. I will explain how I followed Stake’s model.

*Phase I: Descriptive.*

The verbatim audio tape transcriptions were read while listening to the audio recordings, and the first set of field notes were written. Simultaneously listening to the students’ conversations, hearing their voices was extremely helpful because I was drawn into the conversation. Notes, comments, observations and anything else that struck me as relevant and important to the study were written in the margins and comment section of the transcribed data. The purpose was to review the data to get a general description of concept mapping and the conversations associated with it.
Phase II: Categorical Aggregation.

This phase is similar in process to Corbin & Strauss’s (2007) ‘open coding’ in grounded theory (Creswell, 2007). The transcripts are read and reread line-by-line to identify and assign a descriptive code to each sentence and paragraph. Any segment of data that was felt to have meaning and usefulness in the identification of emerging themes, or gave insights into how the students were thinking was highlighted. I wrote comments on what I was ‘hearing’ in the students’ statements, and gave each statement a code. These codes, according to Miles and Huberman (1994), are the units of meaning assigned to the descriptive data – the words, sentences, and paragraphs.

In this phase, the descriptive data in the transcripts were being fragmented and deconstructed to the basic and elementary meanings of what the students were doing during concept mapping. An elaborate classification system was emerging during the coding process, and a sample list of first-cut coding examples that emerged in Phase II is provided in Table 3.11. An example of descriptive data and how I was proceeding through Phase II is in Appendix D.

I was doing my best not to make any interpretations and suspend any judgments in regard to what I was reading. The important step in the analysis was to develop a manageable coding scheme so that I could later construct categories or emerging themes by grouping the codes together (Merriam, 2009).

The analysis could be referred to as categorical because at this point in the analysis I was open to anything possible that emerged from the data (Merriam, 2009), and the points of conversation became conceptually similar in nature and meaning, and I could identify categories and patterns emerging. Categorical aggregation was a time
intensive process that provided the framework for further organizing the data that were collected during the problem-based learning discussion and the focus-group interview.

Coding is an inductive analysis because the researcher is looking for emergent themes from the data collected, and in notes made in the coding process (Patton, 2002). The coding allowed segments of the data to be consistently compared and contrasted for relevance and fit across segments of categories and themes.

Table 3.11: Sample Codes from the Transcriptions and Margin Notes in Phase II

<table>
<thead>
<tr>
<th>Code Label</th>
<th>Description of what the student is doing in the group discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>0I</td>
<td>Fitting together information</td>
</tr>
<tr>
<td>0R</td>
<td>Recalling information</td>
</tr>
<tr>
<td>0E</td>
<td>Explaining something to the group</td>
</tr>
<tr>
<td>0D</td>
<td>Detecting a gap in knowledge</td>
</tr>
<tr>
<td>0A</td>
<td>Assessing or reassessing information</td>
</tr>
<tr>
<td>0Q</td>
<td>Showing curiosity</td>
</tr>
<tr>
<td>0J</td>
<td>Judging what is or is not known</td>
</tr>
<tr>
<td>0EX</td>
<td>Elaborating or expanding on an idea</td>
</tr>
<tr>
<td>0U</td>
<td>Uncertain or confused</td>
</tr>
</tbody>
</table>

Phase III: Establishing Patterns.

The Phase II coding was further analyzed in Phase III to establish consistent patterns and themes across the data. Phase III groups the ideas in Phase II into emerging categorical concepts and patterns. A constant comparative method of analysis was used to analyze the data. According to Merriam (2009) this method compares one segment of data to another so that similarities and differences can be determined, and patterns can be identified, and categories established.
The codes from Phase II were read and reread to compare similarities and differences in how I categorized them. The data were recorded into common categories and the patterns in the students’ thinking processes were explicitly labeled. At this point, I was analyzing the codes for patterns, inferring more meaning from the discussion. Phase III coding reassembled the data from open coding, and through this reassembly process constructed emerging categories and themes. I moved back and forth between the transcribed data looking for recurring regularities and patterns in the data, and decipher what things fit together – the challenge of convergence (Patton, 2002). While open coding in Phase II described the data, establishing patterns in Phase III was more interpretive, because I was constructing categories or themes that capture recurring patterns in the data and finding relationships among them (Merriam, 2009); hence, the process led to ‘analyst-generated’ constructions. This type of analysis and interpretation, according to Stake (1995) is a direct interpretation, drawing issue-relevant meaning from data that is manipulated and worked in different ways to establish patterns and emergent categories. Table 3.12 is an illustration of the categories that emerged in Phase III. I judged the categories using Patton’s (2002) criteria for internal homogeneity and external heterogeneity. The extent of internal homogeneity was determined in how the categories dovetail with each other in a meaningful way. The extent of external heterogeneity was defined through the number of data items that could not be assigned to a category.

Guba and Lincoln’s (1981) description of convergent and divergent thinking in the development of categories apply in this phase of Stake’s model. Convergence determines what fits together on a single category. Divergence involves expanding and developing the meaning of those categories. This process of identifying and linking
codes and patterns is largely intuitive, occurs at a conceptual level, and eventually leads to the identification of major categorical concepts. These categories relate in such a manner that they are used to interpret the meaning of the data, and thus explain the phenomenon under study.

Table 3.12: Illustration of themes that emerged in Phase III based on the codes in Phase II

<table>
<thead>
<tr>
<th>Logic Analysis</th>
<th>Illumination</th>
</tr>
</thead>
<tbody>
<tr>
<td>L:E Explain and describe</td>
<td>CD:D Senses gaps in knowledge</td>
</tr>
<tr>
<td>L:R Reason through an idea</td>
<td>CD:F Feels confident</td>
</tr>
<tr>
<td>L:EX Expand on an idea</td>
<td>CD:Q Feels curious</td>
</tr>
<tr>
<td>L: I Fit together information</td>
<td>CD:U Feels uncertain/confused</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategizing</th>
<th>Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>S:A Organize approach to CM</td>
<td>M:A Assess/Reassess</td>
</tr>
<tr>
<td>S:G Organize group</td>
<td>M:G Observe and check group</td>
</tr>
<tr>
<td>S:S Organize self</td>
<td>M:S Observe and check self</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Judgment</th>
<th>Information Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV:E Evaluate a course of action</td>
<td>K:B Build on facts</td>
</tr>
<tr>
<td>EV:G Evaluate and judge group</td>
<td>K:F State facts and terms</td>
</tr>
<tr>
<td>EV:S Evaluate and judge self</td>
<td>K:R Recall information</td>
</tr>
</tbody>
</table>

Phase IV: Naturalistic Generalizations.

The thick, rich description of the findings was written, and recommendations were made. This phase was interpretive as I dove deeply into the meaning of the findings, interpreting them in light of using concept mapping in the context of problem-based learning.

Recognizing the links in qualitative data deals with commonality, and how to extract the common phrases and themes that capture the essence of what information you
need to answer the research question (Patton, 2002). Initially, all aspects of the data were
treated as having equal value, however as I proceeded through the process, irrelevant and
repetitive findings were eliminated. What emerged in this case-study analysis is a
description of the first-year medical students’ concept mapping experience, and a
conclusion on the effect concept mapping had on engendering metacognitive thinking.

**Ethical Considerations**

In qualitative research, the concerns for credibility – the validity and reliability – of the research may loom larger than in quantitative research where the account for validity and reliability occurs at the start of the design (Merriam, 1988). All types of research involve the disclosure of ethical issues such as motives and intentions, the protection of the participants, privacy and confidentiality, trustworthiness, establishment of ownership of the final analysis, sensitivity of time, and trust and consent (Guba, 1990; Guba & Lincoln, 1989; Merriam, 2009; Patton, 2002). Therefore, attention to the factors in the research design that influence the credibility of the study is important to disclose, and will be subsequently discussed.

**Motives and Intentions**

In research, the researcher assumes a principle role as the instrument for data collection, and over time understands the phenomenon through the accounts of the participants’ perspective (Patton, 2002). And so is the case in this inquiry. I was the sole person collecting the data through audio recordings and interviews, managing the data, and drawing conclusions; therefore, everything that I subsequently report was selected, filtered, and interpreted by me. I freely admit that my previous research in the area of metacognition may affect the analysis of data and the conclusions I may make, which in
itself is grounds for bias. I also admit that my perceptions and assumptions for the need to
develop integrated knowledge structures and teach students how to critically think and
reason through complex clinical problems comes from my position in the Office of
Medical Education. To address these concerns, I pledged to consciously remain sensitive
to my biases and stay focused on the participants’ data provided in the conversations
during problem-based learning. I frequently consulted a colleague who is highly trained
and experienced in qualitative research to corroborate my work, particularly in Phase II,
III, and IV of the analysis.

Protection of the Participants

The method for data collection in this study did not involve any chance of
stigmatization, ostracism by peers, legal liabilities, or political repercussions to the
participant. I carefully considered the risks associated with confidentiality or coercion,
and took all measures to protect the participant.

Privacy and Confidentiality

Digital audio recording affords researchers the ability to document all facets of
dynamic interactions and communication. However, the technology also brings with it
special ethical considerations, and the major issue is that of confidentiality (Schuck &
Kearney, 2006). Since the data collection contains recorded voice of the participant,
which is a sensitive matter, informed consent was necessary. Therefore, in this
investigation, the medical student participants had to give signed consent before
participating. Another consideration was the protection of the audio material from being
used beyond the intent of this investigation.
I am the sole person conducting the study and maintaining the records, and to prevent such incidence from occurring, the digital files were password protected, only accessible to me as the principal investigator. The data and any audio recording are housed in a confidential file, and will be maintained until the final report is written about the study and three years upon completion of the project, then it will be destroyed. An alias name was assigned to each participant. The alias will be used in the analysis section and any other subsequent reports.

*Trustworthiness*

Guba (1990) made a clear distinction in the criteria for trustworthiness between a conventional and constructivist inquiry:

In conventional inquiry, pure process leads to pure results. In constructivist inquiry, process is only one means of determining the utility, responsibility, and fidelity of the inquiry. Action and understanding were other components of the judgments regarding the goodness of any inquiry. (Guba, 1990, pp. 72)

Trustworthiness encompasses the following attributes ascribed by Lincoln and Guba in 1986: balance, fairness, and conscientiousness in taking account multiple perspectives, multiple interests, and multiple realities. Trustworthiness speaks directly to the validity and reliability of the study, which was established in techniques chosen for sample selection, data collection, and data analysis of this study.

*Triangulation*

A technique for methodological triangulation, and one that will shore up the internal validity in the study, is using multiple sources of data collection in the analysis (Merriam, 2009; Patton, 2002). Therefore, adding the focus-group interview in the study
to the audio recordings was done to help validate the strength of the evidence that supported the findings and conclusions made in light of the research question. I also relied on a colleague, Dr. Linda Kanzleiter, Professor and Vice Chair of Educational Outreach in the Department of Family and Community Medicine, to offer peer-reviewed comments on the analysis and findings as they emerged. She is highly trained and experienced in qualitative research. Dr. Kanzleiter co-taught qualitative research courses at University Park, and supervises the qualitative research projects conducted by medical students in the College of Medicine. Dr. Kanzleiter independently analyzed selected data sets so I could have a point of comparison between her findings and interpretations with mine.

**Transferability and Generalizability**

I provided detailed information on how the study was conducted so that another research may make a determination to how closely the research situations match. This roadmap should provide sufficient detail of the instrumentation of the study so that other interested researchers can replicate the study, while fully knowing the research itself may not yield the same results. I tried to be as transparent as possible and present the design, analysis and findings in such a manner that allows a critical review by others. For this study, I kept study protocols, transcribed data, and field notes in a retrievable format so the study could be reconstructed.

**Quantitative Investigation: Experimental Study**

The study was performed to investigate the effects of concept mapping (independent variable) used at the end of a problem-based learning case on the scores (dependent variable) achieved on questions related to the case. Particular reference was
given to the structure of the study, with specific reference to the following concepts that will be discussed in turn: sample size; rules and procedures of random assignment; factors and treatments; and the outcome measurements.

Sample Size

The calculated total sample size needed for the study is 59. The sample size for the quantitative investigation was estimated using an a priori power analysis (conducted before the investigation) using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007; Faul, Erdfelder, Buchner, & Lang, 2009). The following parameters were used in the calculation: power of .8, r = .35, and alpha of 0.05.

Development of the Test Questions

A decision was made to use test questions that were written by the faculty members who are the content experts in salicylate intoxication and acid-base balance, and are included in Appendix E. There is a strong emphasis in the medical school’s educational program to write test questions for the course examinations that are in the format of those exam questions written for the National Board of Medical Education’s United States Medical Licensing Examinations (NBME USMLE). These types of questions are used in the medical school examinations to prepare the medical students for these high-stake licensing examinations.

Factors and Treatments

The explanatory factor, also known as the treatment, in this study is a quantitative predictor X, which has two levels:

\[ X = 2 \text{ if the group created a concept map during the problem-based learning discussion; } \]
X = 1 if the group did not create a concept map during the problem-based learning discussion. Hence, there are two treatments in this investigation: (1) discussion with concept mapping, and (2) discussion only. Discussion only is the control treatment.

Problem-based learning groups in the experimental group (X=2) drew the concept map during the end-of-case discussion. Problem-based learning groups in the control group (X=1) discussed the case without any intervention of concept mapping.

The observed outcomes on exam question scores among the treatment groups were compared to assess treatment effects. Other relevant conditions and factors that could affect the exam-item scores, such as facilitator attributes were considered as observational factors in the design because these attributes were not under the control of the investigator (Kutner et al., 2005).

**Quantitative Data Analysis: Outcome Measures**

Using SPSS, a determination was made whether or not the factor-level means were the same by conducting an Independent t-test statistical analysis that compared mean scores between the control group (no concept mapping) and the treatment group (concept mapping). If the analysis showed a difference in factor-level means, the second step examined how they differed and considered the implications of the differences. This single-factor investigation was the single-factor analysis of variance (ANOVA), model 1, where the conclusions pertain only to those factor levels included in the study, and the associated F test for equality of factor level means (Kutner et al., 2005).

**Conclusion**

Chapter Three opened up with a summary report of findings that were made in previous research studies that lead up to and informed the study proposed for my
dissertation. This summary was followed by a detailed description and overview of the study conducted for my dissertation. The two-phase, embedded, mixed-methods research design was the most appropriate to use in this study. The method was especially useful for testing whether concept mapping influenced thinking behaviors in terms of the theoretical model of metacognition in a real-world setting of problem-based learning. Phase IV (Naturalistic Generalizations) of Stake’s (1995) four-phase case study analysis will be presented in Chapter Four.
Chapter Four

RESULTS

To understand how concept mapping engendered metacognitive thinking in the context of problem-based learning, a mixed-methods research design, using qualitative and quantitative research methods, was chosen to answer two research questions. The results of the study will be presented in order of the research question.

Phase IV: Naturalistic Generalization - Presentation of the Results

Research Question #1

How does concept mapping, used as an artifact in a problem-based learning session during the Cellular and Molecular Basis of Medical Practice, influence the intra-group discussion compared to the problem-based learning group that does not use concept mapping.

Introduction

A qualitative case study design was used to gain an in-depth understanding of the situation, and answer this research question. The unit of analysis was the problem-based learning group for which there were four groups participating, totaling twenty-eight students. Each group had a faculty member facilitator that held either a Ph.D. or M.D. degree. Students in three of the groups consented to draw a concept map and be audio recorded during the concept mapping. One group consented to be audio recorded during the discussion only portion of the problem-based learning session. This group did not draw the concept map. Table 4.1 gives the description of the groups.
Table 4.1: Problem-based Learning Group Descriptions

<table>
<thead>
<tr>
<th>Group Number</th>
<th>Group Size</th>
<th>Concept Mapping</th>
<th>Audio Recording</th>
<th>Gender Female/Male</th>
<th>Facilitator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
<td>4/3</td>
<td>Ph.D.</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>Yes</td>
<td>Yes</td>
<td>3/4</td>
<td>M.D.</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>Yes</td>
<td>Yes</td>
<td>2/4</td>
<td>Ph.D.</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>No</td>
<td>Yes</td>
<td>3/5</td>
<td>M.D.</td>
</tr>
</tbody>
</table>

I read the transcribed conversations of the students while listening to the audio recordings, and my general impression was that concept mapping is a process that prompts a number of discrete but inter-dependent levels of thinking. During the categorical aggregation phase (Phase II) of the analysis, this idea became clearer as I was coding the data, and during Phase III, six themes emerged that described what I was hearing from the data. The patterns were titled (1) logic analysis; (2) Information Recall; (3) illumination; (4) judgment; (5) monitoring; and (6) strategizing. These six emergent themes, and how they are defined for the purpose of this study, are shown on Figure 4.1.

Findings from the four groups will be discussed in light of the themes surrounding concept mapping that was done during the third and final problem-based learning discussion of the salicylate intoxication case. Statements were coded to distinguish between a student (Stdt) or a facilitator (FAC) statement. Appendix F shows examples of statements coded into each emergent theme. The concept-mapping groups got the same information and focused question in the concept-mapping instructions as follows:

The major pathologic lesion created by salicylate intoxication is uncoupling of oxidative phosphorylation. This lesion affects major organ systems in the body. Using ‘uncoupling of oxidative phosphorylation’ as your starting point or root concept, map out the effects on body systems once salicylate intoxication occurs.
Figure 4.1: Emergent themes after Phase II’s Categorical Aggregation

**Concept Mapping Groups**

**Group #1.**

Group 1 was very engaged in the concept mapping activity. The facilitator played a very small role in steering them through the concept mapping experience. The students’ conversations helped frame their understanding of salicylate intoxication case. Several students were participating in the conversation while they were working through a section of the map on respiratory alkalosis and metabolic acidosis. Their conversation had varying levels of thinking as they moved back and forth developing the concept, monitoring their progress, recalling facts, and validating their understanding and progress.
Oh that’s okay. [Monitoring] Okay yes, and then with respiratory alkalosis, where I would write bicarb excretion? And maybe make that like [inaudible] somewhere we can go from there. Yeah. [Strategizing]

Let’s, …should we include keto acids off of anaerobic respiration too so it’s found in the urine. [Strategizing]

Mm-mm. And I also have [inaudible] as well. [Monitoring]

Okay. So the hypoglycemia and keto acids. Or you could, or…..no you’re fine. You should put it off of hypoglycemia, keto acids. [Monitoring]

Metabolic acidosis off the keto acids. [Strategizing] Yeah! [Illumination]

Okay. Metabolic acidosis. We should write that, draw a line to more in HS form maybe. More salicylate in HS to cross blood brain barrier. [Strategizing]

We might not go very far but I think it’s important that we recognize that. [Strategizing]

Yeah salicylate crosses blood brain barrier. [Information Recall] So you want to say more about the cell? [Monitoring]

Yeah. And then I think we should also go into from the toxic dose of aspirin, go into how the metabolism changes, and how the half life is really prolonged in this case which is why we go back into acidosis then, when the respiratory alkalosis can’t compensate anymore. [Strategizing] [Logic Analysis]

Okay. Run that by me again? [Monitoring]

So thinking from toxic dose of aspirin, there’s a change in pharmacokinetics like the change in there’s too much [inaudible]. [Logic Analysis]

In this period of conversation, the students were primarily regulating the mapping through monitoring and strategizing. The students moved on to connect another idea to the map, which was involving the kidneys. Acid-base homeostasis in the body is extremely important to maintain, and the kidneys play a crucial role in the acid/base mechanisms. The students were discussing the alpha and beta intercalated cells that play important roles in the kidney's response to acidosis and alkalosis. The alpha-intercalated
cells secrete acid and absorb base; the beta intercalated cells secrete base and absorb acid. These cells are instrumental in maintaining acid/base homeostasis in the body. In metabolic acidosis, beta-intercalated cells are converted to alpha-intercalated cells, giving the kidney a greater ability to secrete protons and return pH to the normal. These biochemical pathways are extremely important for the medical students to master, but their complexity makes it difficult for students to learn and apply them to clinical problems. Once again, the students’ discussion had varying levels of thinking as they built this section of the knowledge structure on the map. The students were monitoring their understanding, pinpointing confusion, organizing ideas, linking information, and correcting gaps in knowledge.

_Stdt_ And the other one has a K [Information Recall]. Just a K exporter? [Monitoring]

_Stdt_ Is this like on the other side…… [Monitoring]

_Stdt_ That would be okay, so then betas aren’t taking that potassium, right? [Monitoring] They don’t want anymore. But the alphas are preferentially excreting it because it’s high in those cells. [Logic Analysis]

_Stdt_ I got lost. [Illumination]

_Stdt_ I don’t know where you’re talking about. [Illumination]

_Stdt_ The question is how are you getting too much if we’re not taking it up at the beginning? Like if that’s not working, K is going to go out so where are we getting this accumulation of K+, if we’re not reabsorbing it. [Logic Analysis]

_Stdt_ Because, isn’t it because there’s too much acid. You’re exchanging them. Right if there’s too much…. [Monitoring]

_Stdt_ Well if there’s acid in the urine, you just want to get rid of it? [Monitoring]

_Stdt_ No, not in the urine, the blood. [Information Recall] All cells take up more potassium, right? Isn’t that what you were saying that was in these notes? [Monitoring]

_Stdt_ Yeah, there’s an H/K exchanger on the virtual cell. [Information Recall]
Student: This is like on the peripheral, like the H/K exchange… [Information Recall]

Student: That’s what I’m saying. I’m not saying you’re wrong. I’m saying it just doesn’t belong under renal. Well we put renal comes in up there [inaudible]. [Judgment]

Student: This does happen in the kidney… [Information Recall]

Student: It happens to the intercalated cells in the kidney. [Information Recall]

Student: So the thing that you drew that, where’s that located? [Illumination]

Student: This is in the kidney. [Information Recall]

Student: Okay.

Student: So those are the beta, so there’s two like you know the ducts and then we have the two types of intercalated cells, alpha and beta. And there’s principal cells right? [Logic Analysis]

Student: I don’t remember…… [Illumination]

Student: Okay so beta, okay. See I’m not 100% sure [Illumination] because I know the principal cells when they get high potassium in them, they get rid of their extra potassium and that’s what happens in metabolic, or in alkalois, when you have an alkaline state and you want to make your ECF, not your urine, you want to make your ECF more acidic so you secrete an H+. [Logic Analysis]

**Group #2.**

Group 2 demonstrated very similar patterns as Group 1 during the concept mapping exercise. During the mapping process, the facilitator only spoke from time-to-time without steering the mapping process. The students were conversational, in what seemed like a willingness to help each other understand a very complex topic. Similarly to Group 1, the group was working through a section of the map, and this was atop of layers of monitoring and building knowledge. In this segment of the conversation, members of Group 2 were mapping the alkalinity of urine and how this affects the body’s
buffering system. The students are recalling facts, explaining the mechanism, monitoring their understanding, and making statements that affirm knowing.

\textit{Stdt} Wouldn’t using a Hydrogen ion show up to the right of everything else? So if H$_3$PO$_4$, you are going to use up your H+’s and are more likely going to want to make more, right? \textit{[Monitoring]}

\textit{Stdt} Yeah! \textit{[Illumination]}

\textit{Stdt} Just like the bicarb. \textit{[Monitoring]}

\textit{Stdt} Oh, so you’re saying if this thing gets reacting [inaudible]… \textit{[Monitoring]}

\textit{Stdt} Right.

\textit{Stdt} And it’s gonna shift down. \textit{[Information Recall]}

\textit{Stdt} So it shifted down O.K. \textit{[Monitoring]}

\textit{Stdt} By alalinizing the urine, you are also causing a reabsorption of bicarbonate. So to help build a buffering system, it will take a lot of bicarbonate. It’s a 600,000 or more ratio of bicarbonate to nitrogen ions in the blood, so that’s why you don’t have this as part of the huge change when you give more bicarbonate compared to prior changes. \textit{[Logic analysis]}

\textit{Stdt} Are you sure? \textit{[Monitoring]}

\textit{Stdt} Something like that, yeah. \textit{[Judgment]}

\textit{Stdt} You are saying bicarb ions to protons? \textit{[Monitoring]}

\textit{Stdt} Something like that, or just the – it had such a large concentration that it changed – you know for normal concentration, that was acceptable. \textit{[Judgment]}

The students moved on to map the hydrogen-potassium exchange, and the effect on the acid base status, which later moves into conjugation.

\textit{Stdt} So say you don’t fix the rate of breathing, how does that translate to respiratory alkalosis? \textit{[Monitoring]}

\textit{Stdt} You could just let the C02 coming off the …. Yeah. \textit{[Logic Analysis]}

\textit{Stdt} They will send us a photo of this if we request it. That’s what the one page said. \textit{Stdt} Respiratory alkalosis [inaudible].
**Std** I have a question about the heat exchange. Should it be $H + N = \text{[inaudible]}$ polyemia. I forgot which occurs in the kidney, but… [Illumination]

**Std** If you have a low H, plus you want more of that out, so then you’ll – and they go in opposite directions, K would come in. It’s going into …. [Logic Analysis]

**Std** Okay, so are we saying… There’s two things going on. There is what is going on in the kidney and there is what is going on in the blood. So we are talking about the Hydrogen Potassium exchange in the kidney, or are we talking about the Hydrogen Potassium exchange in the blood? [Monitoring]

**Std** The kidney? [Monitoring]

**Std** Potassium is going into the lumen, right? Or into the cell? [Illumination]

**Std** If you want to think of that with respect to the blood, it would be Hydrogen going into the blood and Potassium going out of the blood. Which makes sense if it was in the [inaudible] alkaized. H would go out to compensate. [Logic Analysis]

**Std** The unconjugated is what makes your blood [inaudible] too, right? [Monitoring]

**Std** The conjugated is going to go down to the kidneys. [Monitoring]

**Std** That looks…. It would be the unconjugated one that continues to circulate around. The point of conjugating is to make more water soluble so it can be excreted. [Logic Analysis]

**Std** I was thinking it would use up a lot of oxygen, so at some point you are not going to have enough oxygen so you have to rely on anaerobic metabolism. [Logic Analysis]

**Std** But you are taking in a lot, aren’t you? [Monitoring]

**FAC** So as it is conjugating, what happens to hydrgated salicylate?

**Std** Once it is conjugated, it goes to the kidney and gets excreted. [Logic Analysis]

**Std** Okay.

**Std** I got this from an article about aspirin overdose, and it says uncoupling leads to interruption of a series of enzyme mediated mitochondria functions and anaerobic metabolism and cellular immersion of prior mate to lactate and subsequent development of lactic acidosis. [Information Recall]

**Std** You are going through the whole chain up into the electron[inaudible] it is going to build up usually. [Logic Analysis]
**Stdt** So through anaerobic metabolism, you can either go into the Kreb’s cycle or you can go off to lactic acid. If you go into Kreb’s cycle, that’s when you eventually get the ETC and the uncoupling. [*Logic Analysis*]

**Stdt** Mmhmm.

**Stdt** So this is saying that the uncoupling is going to back up then, inhibiting and knocking if off the lactic acid, so they don’t really seem like they can occur concurrently. [*Monitoring*]

**Stdt** So is the decoupling because hydrogen or [inaudible] pass back up or is because of mild dysfunction because that would make the difference. Because if it is the hydrogen ions are messing up, then half-life will still continue and it will just never made ETP, whereas if it is the actual proton – or like enzyme that is messed up, then that will back up and then so I don’t know which one it is. Is it decoupling….* [Monitoring] [Illumination]*

**Stdt** The excess oxygen is just – the proton gradient is dissipating without ATP motion. [*Logic Analysis*]

**Stdt** So the hydrogens are – so there is no gradient? [*Monitoring*]

**Stdt** Right. [*Judgment*]

**Group #3.**

Group 3 was also engaged in back-and-forth conversation during the mapping process. All the students were working together to construct the map. This segment of the map was focused on metabolic acidosis and compensatory respiratory alkalosis.

**Stdt** Ketones cause acidosis. [*Logic Analysis*]

**Stdt** Acidosis affects everything else. [*Logic Analysis*]

**Stdt** And she has an increased need for oxygen, so she has been breathing faster. [*Logic Analysis*]

**Stdt** Yea… and the heat production, that is metabolic acidosis. [*Logic Analysis*]

**Stdt** Whoa whoa. [*Illumination*] Using more glucose. Like there were [inaudible] GP you will use more oxygen. [*Logic Analysis*]

**Stdt** Is that what were you saying? [*Monitoring*]

**Stdt** Yeah…because she uncouples it. [*Logic Analysis*]
And now she needs more oxygen.  [Logic Analysis]

More oxygen to make more – to go through more [inaudible].  [Logic Analysis]

That’s just the metabolic acidosis.  [Information Recall]

No… I wasn’t talking about that.  KP just wants to throw in those key words.  [Monitoring]

What happens is metabolic acidosis … [Logic Analysis]

Compensatory respiratory alkylosis – that’s what she's breathing.  That’s in addition to…  [Logic Analysis]

I thought the respiratory alkylosis comes first.  [Monitoring]

Hmm?  What did you just say?  You said the respiratory alkylosis comes…[pause]  [Monitoring]

No, no, no.  [Illumination]  She has acidosis….because of the ketone…  [Logic Analysis]

… because of the ketones.  [Logic Analysis]

The first thing the aspirin goes to whatever respiratory center.  [Logic Analysis]

Yeah!  [Illumination]

This increases respiration. Then this uncoupling also causes increased need for oxygen.  [Logic Analysis]

The students then moved on to expand the structural knowledge, this time connecting to the brain.  Once again, they were organized, putting things together, reasoning through the idea, and affirm feelings of knowing they were on the right track.

So why are you connecting respirations to the brain?  [Monitoring]

Because that’s the respiratory center?  [Information Recall]

Okay, so it would be alkylosis …  [Information Recall]

Even renal and then you would need like….  [Logic Analysis]

Acidosis and the increased oxygen whatchamacallit – demand.  [Logic Analysis]
And Salicylic. [Information Recall] Here we go! [Illumination]

That would go to, that would go to, ummm… the brain or respiratory. [Monitoring]

Right! [Illumination] Respiratory. Acidosis would go to respiratory center. [Logic Analysis] WOW. [Illumination]

Nice. And the increased respiration leads to respiratory alkalosis. [Logic Analysis]

Discussion-Only Group: No Concept Mapping

Group #4.

Group 4 was audio recorded but did not draw a concept map during the end-of-case discussion of the salicylate intoxication case. There were two notable differences in the comparison of the concept mapping groups and this group: (1) the tone of the conversation and (2) the involvement of the facilitator. There were extremely long pauses that would last upwards to 90 seconds between the statements, and this pattern went on during the entire session. The facilitator played a large role in this discussion compared to the other groups.

So if you had a patient who is may be in respiratory acidosis for some other reason in addition to salicylate toxicity, if there is some other co-existing disease going on, giving bicarb may not be your treatment of choice because she is already retaining CO2 and giving more bicarb will retain more CO2.

So we talked about when to give it, when not to give it, how to give it, what are some of the complications of the treatment itself, and how to treat some of those complications.

Do you want to talk about the anion gap and non-gap acidosis? [Strategizing]

Mmhmm.

It seemed to me the most common one is acidosis that would present with anion gap, especially not in all metabolic acidosis. We aren’t really talking about metabolic acidosis, but if there is no anion gap it’s due to chloride it should be pumped out to compensate the bicarb loss, which will show you a normal anion gap, but you are still depleted in bicarb. [Logic Analysis]
Stud Why don’t you be a little more specific about the anion gap acidosis and some major causes of anaphylactic acidosis which we saw. Ketoacidosis, and you can also have a sp[inaudible] renal failure and things that you ingest that could contain anions so that’s why you have ketones and [inaudible] aspirin? [Strategizing]

FAC Did anyone come up with a fifth mnemonic or come across something?

FAC Did anyone in the group come across that?

FAC Okay. So moving onto a non-GAP acidosis –

Stud There is a few things, like if you have diarrhea or [inaudible] like renal dysfunction, for certain like conditions. [Logic Analysis]

FAC Is alcohol part of a gap or a nongap acidosis? Does anyone know?

Stud A non-gap? [Illumination]

Stud It’s a gap. [Information Recall]

Stud Isn’t a non gap almost – most of the time just diarrheal? [Illumination]

FAC There’s a couple more things that can cause it, too. Diarrhea is the most common cause.

FAC But there’s some other causes. I’d give you bicarbonate wasting, thus making you acidic. So the two ways to think about it is gaining of an organic acid making you acidotic, or losing bicarbonate making you acidotic.

FAC Did anyone find a mnemonic or a non-gap acidosis?

FAC Marty, do you want to explain that one to the group?

Stdt I don’t know, I saw it. It’s HARDUP. [Information Recall]

Stdt What is it? [Illumination]

Stdt Does it stand for something? [Illumination]

Stdt Yeah. [Illumination] Hyperalimentation Acetazolamide, Renal tubular acidosis, Diarrhea, Uteroenteric fistula and Pancreatic and duodenal fistula. [Information Recall]

Much later in the conversation, the group began discussing uncoupling phosphorylation – a major learning objective for the case, and the focus of the concept mapping.
Resembling the discussion on acidosis, this section also had a similar pattern of facilitator involvement and long pauses between statements.

_Std_ … With metabolic acidosis with the uncoupling phosphorylation, you get lactic acid accumulation which leads to the acidosis. [Logic Analysis]

_FAC_ Is that the only mechanism that it uncouples, the oxidative bicarb [inaudible]?

_Std_ Are you asking about how they uncouple? [Monitoring]

_FAC_ At what level—you mentioned bicarb because one mechanism into slowing down that – is there any other way to uncouple the oxidative transport change?

_Std_ Is taking a flow count and combining it with oxygen and bringing it back in? [Information Recall]

_Std_ Yeah – a hydrogen reading. [Information Recall]

_Std_ Yeah, take it in … a bunch of pathways… [Information Recall]

_Std_ So we have to know specifically which places? [Monitoring]

_Std_ Yes, you do.

_Std_ A general uncoupler [inaudible] [Information Recall]

_FAC_ You want to – your uncoupling the oxidative transport chain. So you are ATP is heat. That is why she is sweating. So it needs – the salicylic acids themselves are coming in, crossing the cell membranes, going into the mitochondria and poisoning the electron transport chain.

The distributions of the emergent themes in each group’s discussion are shown in Table 4.2. In looking across the groups that did concept mapping, logic analysis and monitoring were the highest in number. Strategizing and judgment were the lowest.

Table 4.3 shows the rank order of the emergent themes for the concept mapping groups combined and the discussion-only group. In the concept mapping groups, logic analysis and monitoring were the most prevalent patterns, whereas in the discussion only group, Information Recall was the most common type of statement.
Table 4.2: The distribution of the students’ application of the emergent themes.

<table>
<thead>
<tr>
<th>Group</th>
<th>Logic Analysis</th>
<th>Information Recall</th>
<th>Illumination</th>
<th>Judgment</th>
<th>Monitoring</th>
<th>Strategizing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8 (22%)</td>
<td>5 (14%)</td>
<td>5 (14%)</td>
<td>1 (3%)</td>
<td>11 (30%)</td>
<td>6 (17%)</td>
</tr>
<tr>
<td>N=36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>12 (34%)</td>
<td>2 (6%)</td>
<td>4 (11%)</td>
<td>3 (9%)</td>
<td>14 (40%)</td>
<td>0</td>
</tr>
<tr>
<td>N=35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>18 (55%)</td>
<td>4 (12%)</td>
<td>5 (15%)</td>
<td>0</td>
<td>6 (18%)</td>
<td>0</td>
</tr>
<tr>
<td>N=33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3 (15%)</td>
<td>8 (40%)</td>
<td>5 (25%)</td>
<td>0</td>
<td>2 (10%)</td>
<td>2 (10%)</td>
</tr>
<tr>
<td>N=20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Group 1, 2, and 3 were the concept mapping groups; Group 4 was discussion only

Table 4.3: The rank order of the average scores of emergent themes by the concept mapping groups and the discussion only group.

<table>
<thead>
<tr>
<th>Concept Mapping</th>
<th>Discussion Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logic Analysis</td>
<td>38 (37%)</td>
</tr>
<tr>
<td>Monitoring</td>
<td>31 (30%)</td>
</tr>
<tr>
<td>Illumination</td>
<td>14 (13%)</td>
</tr>
<tr>
<td>Information Recall</td>
<td>11 (11%)</td>
</tr>
<tr>
<td>Strategizing</td>
<td>6 (6%)</td>
</tr>
<tr>
<td>Judgment</td>
<td>3 (3%)</td>
</tr>
</tbody>
</table>

Focus-group Interviews

A focus-group interview was held after the problem-based learning session to further my understanding of the students’ opinions of concept mapping and what concept mapping contributed to the learning experience in the problem-based learning session. I was particularly interested to learn about the students’ thinking patterns. When asked how they approached the discussion of a case, the students said that they brought with them discrete bits of information. Generally they discuss the case through the list of learning objectives, and Shilo said, “the learning objectives are good for the concrete points, but they don’t pull it all together.” Breano explained in a different way by saying, “we can come to conclusions, but we don’t know how they connect.”
The students seemed eager to talk more about the concept mapping, so we spent most of the time discussing it in detail. There was a unanimous agreement that the most notable benefit of the concept mapping process was to help them see how everything fit together. Eloise also explained how, in the group situation, the concept map helped the group work through a disagreement.

Concept maps are in general helpful. We get all these discrete bits of information, but HOW does this work together? We had a big argument in our PBL about just like one little concept. It was a good way because it was on the board and everyone could see it. You kinda knew what people were talking about, and you knew where the disagreement was. You could work through the information so everybody could say, Yea we’re fine!, rather than all eight of us thinking of different things. It’s a good space to think… because everybody could see it on the board and you know everybody must come to the same agreement at the end of the day.

Bob said that “just the physical act of drawing the arrow from one term to another helps cement it in your mind…” and the students all agreed that they felt confident with the material they learned and would perform well on the test questions.

While explaining their exact thought processes that occurred during the concept mapping was difficult, Gwen said, “It made me question myself if I really understood… or if I made the correct arrow and if it fit. During the mapping they all nodded when Gwen said “I was thinking through the next step, and planning what would go with what.” In the context of problem-based learning, Ken said, “PBL itself is a good space to allow us to think through things, but concept mapping is a good outlet to do that within a group.”

**Research Question #2**

*Do first-year medical students who draw group concept maps during their end-of-case discussion in a problem-based learning session in the Cellular and Molecular Basis of*
**Medical Practice course achieve higher scores on test questions than the first-year medical students who did not draw a group concept map during the end-of-case discussion?**

An independent samples t-test was used to analyze the comparison of mean scores between the groups that did the concept mapping with the group that did not do concept mapping during the end-of-case discussion. The t-test was chosen as the best statistical method to answer the question because there were two experimental conditions with different participants used in each condition. Levene’s test of homogeneity of variance shows p > .05, not significant, meaning the variances appear to be the same across treatment groups; therefore the null hypothesis was retained.

Table 4.4 shows the results of the independent t-test. On average, participants who were in the concept mapping groups scored lower on the test questions (M = 71.57, SE = 2.28) than the participants who were in the group that did not draw a concept map (M = 72.92, SE = 4.38). This difference was not significant t(40) = -0.26, p > .05, and represented no effect size.

**Table 4.4:** Results of the independent samples t-test that was used to analyze the comparison of mean scores between the control group and the group that received metacognitive question prompts.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Concept-mapping Group</th>
<th>Discussion-only Group</th>
<th>P-Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test-question score, Mean (SE)</td>
<td>71.57 (2.28) N=34</td>
<td>72.92 (4.38) N=8</td>
<td>0.80</td>
</tr>
</tbody>
</table>

*Significant an p = < .05

Even though there was no significant difference between the means in the independent t-test, a follow-up ANOVA was conducted to determine if differences
existed between the groups. The results showed no significant differences across the group means, $F(5,36) = 1.44, p > .05$.

**Summary**

The goal of the study was to determine if concept mapping engendered metacognitive thinking in problem-based learning discussions, and if concept mapping had any effect on students’ exam-question scores. In the analysis, there are several key findings that will be elaborated on in Chapter Five:

1. The concept mapping groups and the discussion-only group moved back-and-forth between different patterns of thinking to discuss the salicylate intoxication case during the session. What I found distinctively different was the concept mapping groups, compared to the discussion-only group showed higher patterns of logic analysis (37% versus 15%) and monitoring (30% versus 10%), and a lower pattern of information recall (11% versus 30%).

2. There was no significant difference in exam-question scores between the groups that drew concept maps and the group that discussed the case without a concept map.

3. Student opinion was that benefits of concept mapping related to learning how many concepts fit together for a complete conceptual understanding, and how concept mapping was a chance for them to question how many discrete bits of information fit together.
Chapter Five

DISCUSSION

There is opinion, backed by scholarly work, that the strategic application of metacognitive thinking is essential to achieve cognitive goals (Meijer, Veenman, & van Hout-Wolters, 2006). Therefore, the goal of the study was to learn if concept mapping is an artifact that engenders metacognitive thinking in problem-based learning discussions. I was seeking to bring a perspective to thought processes that medical students’ engage in as they draw a concept map. In addition, the mean scores on specific test questions were compared to determine if students who concept mapped in their problem-based learning group scored higher than those students who were in the discussion-only group. Chapter Five provides the discussion of the findings, focusing on the emergent themes and patterns of thinking that evolved in the analysis of medical student discussions during the concept mapping experience in problem-based learning.

Qualitative Findings

The literature has shown that cognition and metacognition are not the same processes, however they interact and rely upon each other, facilitating the achievement of learning, problem solving, and decision-making goals. An influential description of the cognition-metacognition relationship is by Nelson and Narens (1990, 1994) who describe cognition and metacognition on two levels: the object level is knowledge-based memory and mental representations, and the meta level monitors and controls how information is processed at the object level. Bearing this in mind, the themes that emerged in the qualitative method of the study provide us insights in how concept mapping engendered metacognitive thinking, and how metacognition and cognition interrelate when students
are manipulating knowledge to draw the map. While the strength and associations among these six patterns of thinking were not always clear, nor predictable, the interaction among the students’ comments was interdependent, meaning that in most cases, one mutually supported another.

Based on the six emergent themes and subsequent findings, a model is proposed to show the types of thinking engendered by concept mapping in the context of problem-based learning. The themes were collapsed further because they possess either an association or interaction with two broader categories – metacognition and cognition. The model, as shown in Figure 5.1, provides the framework for discussing the emergent themes, and what they mean based on current theoretical underpinnings related to cognition and metacognition.

Figure 5.1: The six emergent themes associated with the thinking patterns of medical students during the concept mapping experience collapsed down to cognition and metacognition.
There were clear examples of metacognitive thinking throughout the concept mapping process, but this level of thought could not be independently separated from cognition; therefore, I cannot discuss metacognition in isolation of cognition. The two themes titled logic analysis and information recall were most closely associated with patterns of cognitive thinking. Any discussion during the concept mapping activity related to recalling facts, using acronyms, fitting together ideas, explaining principals, or reasoning through a mechanism-of-action by way of facts and figures was referred to as cognitive. Metacognition was explained through the four themes titled, illumination, judgment, monitoring, and strategizing. Illumination was related to the statements that were affective in nature; statements that were interpreted as feeling confident in knowledge, or sensing gaps in knowledge, or feeling unsure of one’s comprehension. Illumination was placed under the label metacognition because these statements fit Flavell’s (1979) description of the metacognitive experiences. The theme titled judgment was associated with evaluation through statements that were opinions of how the group or self was progressing. Any statement that indicated the student(s) was assessing or reassessing the information coming forth for the map and group progress was lumped under the theme of monitoring. Statements that changed the course of the mapping experience or how the student(s) was thinking through the case were placed under the theme of strategizing. These three themes were labeled metacognitive because the patterns of thinking align with the theoretical framework of metacognition, especially the control, monitoring and regulation components as described by Flavell, Brown, and Kluwe.
**Concept Mapping Groups.**

A specific example of how these themes interact in concept mapping is in the discussion among students in Group #1 when they were discussing the alpha and beta intercalated cells that play important roles in the kidney's response to acidosis and alkalosis. In cognitive processing, the students were expanding on the knowledge, fitting together information in,

“That would be okay, so then betas aren’t taking that potassium, right? They don’t want anymore. But the alphas are preferentially excreting it because it’s high in those cells.” The conversation continues, “The question is how are you getting too much if we’re not taking it up at the beginning? Like, if that’s not working, $K^+$ is going to go out so where are we getting this accumulation of $K^+$, if we’re reabsorbing it.”

The metacognitive function, working side-by-side the cognitive function, in this segment of the mapping experience is evident in how the students monitored the work the students were doing, pinpointing confusion and correcting inconsistency. Statements, such as,

“I don’t know what you’re talking about”, “…isn’t it because there’s too much acid?”, No, not in the urine, the blood. All cells take up more potassium, right? Isn’t that what you’re saying…?”

Analyzing the interplay between the students’ need for cognitive information and metacognitive monitoring during concept mapping was fascinating, and based on the theoretical understanding of metacognition, I was able to make the connections to the role of metacognition.

Tables 5.1 and 5.2 show the comparisons between the concept-mapping groups (n=3) and the discussion-only group (n=1). In comparing the two groups, the concept-mapping group showed a higher degree of metacognitive thinking (52%) than the discussion-only group (45%). Notable was the high percent of monitoring (57%) that was occurring during the concept-mapping experience. While there was a higher degree
of the cognitive activity calculated for the discussion-only group (55%), one must consider the types of cognitive activity that each group was engaged in. The concept-mapping groups were engaging a higher level of cognitive processing in logic analysis (78%) than the discussion-only group that was primarily processing at the information recall level (73%).

*Table 5.1:* Shows the percent of prevalence in metacognitive thinking between the concept-mapping groups and the discussion-only group.

**Metacognitive-only Themes**

<table>
<thead>
<tr>
<th>Group</th>
<th>Metacognitive Total %</th>
<th>Illumination %</th>
<th>Judgment %</th>
<th>Monitoring %</th>
<th>Strategizing %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Mapping</td>
<td>52</td>
<td>26</td>
<td>6</td>
<td>57</td>
<td>11</td>
</tr>
<tr>
<td>N=3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion Only</td>
<td>45</td>
<td>56</td>
<td>0</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>N=1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 5.2:* Shows the percent of prevalence in cognitive thinking between the concept-mapping groups and the discussion-only group.

**Cognitive-only Themes**

<table>
<thead>
<tr>
<th>Group</th>
<th>Cognitive Total %</th>
<th>Logic Analysis %</th>
<th>Information Recall %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept Mapping</td>
<td>48</td>
<td>78</td>
<td>22</td>
</tr>
<tr>
<td>N=3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion Only</td>
<td>55</td>
<td>27</td>
<td>73</td>
</tr>
<tr>
<td>N=1</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Metacognition was in the driver’s seat of thinking during the mapping experience, and in much the same way that Bruning, Schraw, and Ronning (1999) described, metacognition seemed to be controlling the students’ thinking by way of monitoring, thus
enabling them to judge how they were progressing, making corrections, and bringing together an extensive knowledge base to draw the map. For example, in this concept mapping exercise, recalling the facts of the anion gap was not metacognitive. In contrast, monitoring the progress to find the facts’ relationships and links to acidosis was metacognitive. Likewise, feeling unsure of that knowledge structure and how those relationships were being mapped out, and thus making the decision to step back and clarify the correctness of how that was linked to the map was metacognitive. Particularly evident was the monitoring activity of metacognition. The active monitoring and subsequent regulation are important to achieve cognitive goals (Flavell, 1976). Therefore, this monitoring component of metacognition was important in the concept-mapping activity to activate the high level of cognitive thinking required to break down the principles and mechanisms, and make the important cross links among and between important concepts.

**Discussion-Only Group: No Concept Mapping**

There was a remarkable difference between the conversation in the concept mapping groups and the discussion-only group. Unfortunately little can be made, beyond speculation, of the significance in the differences between the groups since there was only one group to analyze in the discussion-only. However, the patterns associated with the conversation in this discussion-only (no concept map) group are worth mentioning in light of the research question.

Forty-five percent of the statements were defined as metacognitive. The most prevalent pattern was illumination, making up twenty-five percent of all six patterns, and fifty-six percent of the statements that fell under metacognitive thinking. Forty percent of
the statements were coded as cognitive thinking patterns, the most prevalent was
information recall that accounted for forty percent of all six patterns and seventy-three
percent of cognitive-only thinking patterns. This group showed little sign of
metacognitive monitoring, and while there was some logic analysis, the level of thinking
was not at the sophisticated level of the concept-mapping groups. The facilitator played a
significant role in this group’s conversation, asking questions and going into long
descriptions of information. Thus, there was no need for the students to think at a high
degree of logic analysis to successfully get through the case. The group had no artifact to
encourage them to think how ideas fit together, and discussed the case in lock-step
fashion following the list of learning objectives. For example, the group would discuss
one objective, and then move to the next, based on how well they discussed the main
points of the objective.

Another characteristic I noticed with this group in contrast to the concept-
mapping groups was the flow of information and the exchange of ideas in this group were
strained. There was little collaboration; most of the conversation was among three group
members, and as stated previously, the facilitator played a significant role in the
discussion taking up significant chunks of time to explain concepts. There were long
pauses between the students’ statements and responses, some clocked at over sixty
seconds of silence. This group was in stark contrast to the concept-mapping group that
moved through the case with a mutual exchange of ideas among the group members, with
little or no facilitator involvement. Their discussion was more conversational,
collaborative, and the group moved back and forth, crossing learning objectives as they
drew the concept map.
The focus-group interviews provided greater insight into what was occurring in the minds of the students during the concept-mapping discussion. The concept-mapping groups had to move away from the lock-step discussion of the learning objectives in order to create a knowledge structure that integrated the concepts in the case. The most important outcome of the concept mapping, and one that all the students agreed on, was they knew how the important concepts of salicylate intoxication connected at the end of the session. Concept mapping engaged all the students in the group, and it helped them come to group consensus for understanding certain concepts on the map. They found concept mapping a place to think about the many bits of information they learned, and understand how they fit into an integrated structure of knowledge.

The analysis of the findings, brings me to Schön’s (1983, 1987) theory of reflection-in-action. I believe McAleese’s (1998) conceptual framework for concept mapping as the arena for reflection-in-action is plausible, and this study may begin to operationalize this framework. The theory and the practice are brought together to explain how concept mapping was effective in engendering metacognitive thinking through reflection-in-action and reflection-on-action. Linking this finding back to metacognitive theory (Flavell, 1971, 1976, 1979, 1987; Brown, 1980, 1987; Kluwe, 1987), and the taxonomy of metacognition put forth by Tarricone (2011), reflection-in-action was metacognitive in the core components of metacognitive monitoring, control, and the regulation and executive control of the cognitive structure. The monitoring component was especially strong across all the groups that drew concept maps.

Schön (1995) suggests that reflection-in-action occurs in a framework of stability, and from that framework comes the element of surprise or conjecture as the reflective
responses build on whatever problem the person(s) is solving. Best put, in a dynamic
process of actions, the experience leads to some conjecture, which brings about
reflection, which leads to another level of the experience. In this study, concept mapping
the salicylate intoxication case provided a stable framework for the medical students to
apply their knowledge.

To paraphrase Schön (1983, p. 176), students draw on theoretical knowledge and
skills to confront puzzling situations and problems that do not necessarily fit their
structure of understanding, and they come to results through the ‘reflective conversation’
with the situation. The concept-mapping artifact made the students piece together their
discrete bits of knowledge to understand of a larger, integrated structure of knowledge,
and come to a collective agreement. Group #1 provides a good example of the ‘reflective
conversation’ in a section of dialogue among several students.

Stdt #1 comes in with

“OK, yes, and then with respiratory alkalosis, where I would write
bicarb excretion. And maybe make that like [inaudible] somewhere
we can go from there. Yea.”

Stdt #2 jumps in looking at the concept a little differently, and adds

“Let’s, … should we include keto acids off of anaerobic respiration
too, so it’s found in the urine?

Stdt #3 listening to what’s going on, starts to add to what Student #1 said with

“OK. So the hypoglycemia and keto acids. Or you could, or… no
you’re fine. You should put it off of hypoglycemia, keto acids.”

Student #2 picks up the thought and adds

“Metabolic acidosis off the keto acids. Yeah!

Student #1 jumps in with
“Okay. Metabolic acidosis. We should write that, draw a line to more in HS form maybe. More salicylate in HS to cross the blood brain barrier.”

In this example, the students expanded an idea of acid-base, and worked through pieces of information until the full idea had been transformed into a section on the map. From here the students moved on to map another idea involving metabolic changes with toxic doses of aspirin.

The concept-mapping experience is similar to a puzzle. In this study, the problem to be solved was initially set by the focused question. A well-developed, focused question was extremely important because it posed a logical and conceptual challenge to the medical students. The focused question put the students in a conundrum, challenging them to resolve the matter in the form of a concept map.

The countless discrete bits of knowledge that the medical students had in their memory were the pieces to the puzzle, and in the mapping process were piecing all these parts together to show the integrated picture of salicylate intoxication. In the previous example given of Group #1, the students were recognizing patterns and creating some logical order to their thinking as they mapped out the concept. Sometimes the students’ frame of understanding fell apart in that ‘reflective conversation’ with themselves or the group, and the students fell into a disagreement that had to be worked through to a resolution. The concept map provided the vehicle to work through this disagreement, as best described by one student in the focus group,

“We had a big argument in our PBL about just like one little concept. It was a good way because it was on the board and everyone could see it. You kinda knew what people were talking about, and you knew where the disagreement was. You could work through the information so everybody could say, ‘Yea we’re
fine!’, rather than all eight of us thinking of different things. It’s a good space to think… because everybody could see it on the board and you know everybody must come to the same agreement at the end of the day.”

Metacognitive experiences are also considerations in this analysis because they are affective and prompt internal responses to metacognitive knowledge, goals, monitoring, and strategies (Flavell, 1979; Flavell, Miller, & Miller, 1977). These experiences occurred most prominently in reflection-in-action when students were expressing feelings about the progress and achievement of success in piecing together the concept. As the students were moving back and forth, adding pieces of information, reflecting on the results, adding more information, or changing direction, they voiced expressions such as, “whoa whoa” when the group should change course, and “yeah!” when the group was successful and should keep going.

An important component of reflection-in-action is reflection-on-action, which is reflecting on the reflection-in-action (Schön, 1983). Reflection-on-action is coming to some understanding of the thought processes, decision making, and the outcomes of the experience. The baseball pitcher reflects-on-action when he goes back and watches the films in the privacy of the locker room, or the physician reflects-on-action when she goes back and reads through a patient’s chart in the privacy of her office, thinking about the progression of thinking and the decisions that led to the patient’s death. In both cases, the pitcher and the physician are going back and reflecting on the thinking, strategies, decisions, and actions that were taken during the event.

Most of what can be deduced about reflection-on-action from this study is based principally on what was learned from the focus-group interviews. The analysis points to
metacognitive knowledge having the most to gain in reflection-on-action. For example, one student was talking about the information and concept mapping and said,

“The physical act of drawing the arrow gives a connection in your mind to think about it later on…. Making the concrete connection helps cement it.”

The student was expressing something she learned about herself. She now knows that the physical act of drawing the arrow and making that connection helped cement the concept in her mind for later recall. Another example, is when a student was thinking about her strategy in mapping, and said,

“It made me question myself if I really understood or if I made the correct arrow, and we looked at it as a group I had to be able to defend myself if I drew the arrow, and it if fit.”

This student was thinking through her strategy and was gathering knowledge about herself and how she applied her domain knowledge to the concept map. In this next example, the student was talking about concept mapping, and was sharing her knowledge and beliefs of learning, and the effects it has down the road,

“More time you’re engaging the material, the better you’ll be at critical thinking in the long run. PBL, case studies, and concept maps are important to synthesize information so you can remember it later.”

In general, the students’ comments were describing the transformative stage of Moon’s (1999) map of learning, whereby a reflective process brings about change in self knowledge, and the deeper meaning of learning integrates knowledge into the existing knowledge structure.

One must be cautious to infer from this study that reflection-on-action occurred unprompted as a cause-and-effect response from reflection-in-action, because the focus-group interview may have prompted the students to reflection-on-action. Assuming that
the students reflected on the concept-mapping experience independent from the focus group is hard to say.

**Quantitative Findings**

No significant difference in the mean scores on the test questions indicates that concept mapping in problem-based learning discussions does not have any effect on student performance compared to the students who go through the case without concept mapping. However, any interpretation of these findings is highly suspect, because the number of participants in the concept-mapping group was 34 versus the 8 participants in the discussion-only group. Assuming any value in these results, there are a few plausible explanations. First is the nature of knowledge in concept mapping and how that compares to the knowledge being tested. Concept mapping is all about structural knowledge, and the integration and amalgamation of information stored in memory (Jonassen, Beissner, & Yacci, 1993; Jonassen and Grabowski, 1993; Jonassen, Reeves, Hong Harvey, and Peters 1997). The maps represent one’s understanding and knowledge of whatever the concept-of-interest is for the map. In comparison, test questions are often written to assess the mastery of fragments of knowledge rather than conceptual frameworks. This is contrary to how students were thinking in the concept mapping exercise. In this study, a decision was made to write questions in a format that a student would find on the United State’s Licensing Examination (USLME) for medical students. This is a high-stakes exam that medical schools must prepare students to pass. In doing so, course exams are written to include USMLE-style questions, and the choice was made in this study because of the need to see if concept mapping made a difference in how the students would perform on these types of questions.
Another plausible explanation deals with retention of knowledge. While the students may have learned the information for the short term, measuring their retention later, perhaps when they are in the organ-based courses in their second year of medical school, may prove if concept mapping affects retention. Long-term retention of basic science knowledge is a long-standing concern in medical education (Custers, 2010). In Custers (2010) review of the literature on long-term retention of basic science knowledge, he suggested that approximately two-third to three-fourth of basic science knowledge is retained after one year, decreasing to below fifty percent in the second year. However, the findings in the investigations cited in Custers review ranged from remembering little of anything to greater than ninety percent after twelve to fifteen months. The results also were different depending on the basic science domain, and biochemistry is a particularly vulnerable domain (Custers, 2010).

Limitations

I believe the strength of this study is that it provides me with a valuable source of more insights into concept mapping, metacognition, and problem-based learning that I can continue to explore and expand. However, there are limitations in the design and methods of the study that may have in various ways, influenced the findings, and they will be subsequently discussed. First, while I designed the study to protect the validity through triangulation and using an independent review for the qualitative analysis, the differential loss of participants and the testing instrument posed great threats to the internal validity of the study. There was a discussion-only group of students that withdrew from the investigation hours before it was to start because a few students did not want to be audio recorded. This decreased the number of discussion-only groups to
one, which was a major concern and all interpretations must be made in this light. The decision to use the USMLE-formatted test questions as the dependent variable may have influenced the finding of non-significance on the exam questions’ mean scores in a study in which the participants were working with structural knowledge. The decision was made to use these types of questions because mastering these types of questions is high stakes for the students, and any interference to how they were tested went against school and course policy. The study was conducted within tight parameters of school and course policy, so much of the study’s design had to factor in those conditions.

Second, the external validity factors were controlled as much as possible within the parameters and policies of the medical school’s curriculum and the course. All the facilitators are trained in the same manner before they can lead a problem-based learning group, and they are randomly assigned to the groups. While each facilitator was personally contacted by me so I could explain the study and their role in the study, I could not control what occurred in the room during the session.

Lastly, the focused question may have influenced the findings by redirecting or repurposing the goal for the last day’s discussion of the salicylate intoxication case. Considering this study through the lens of the goal would perhaps give the findings a different interpretation for a couple reasons. First, in concept mapping, the context is defined by the focused question (Cañas, & Novak, 2006). This focused question is significant in the outcome of the map. If written well, the question clearly defines the problem and directs the mapper’s attention to a specific goal. In this study, the role of this question given to the concept mapping group could be significant when comparing it to the role of the learning objectives that the discussion-only group was following.
because it changed the goal. Second, and related to the change in goal, is the way the focused question focused the mapper’s thinking from the outset. The focused question was written pull in the major areas of the salicylate intoxication case’s learning objectives, so from the start, the students in the concept-mapping groups were directed to think in a more comprehensive manner than those students who were looking at the learning objectives in a lockstep (1, 2, 3) manner. The findings may have been very different had I given the discussion-only group the same focused question to discuss, rather than the group’s list of learning objectives. They, too, may have demonstrated similar metacognitive thinking patterns as the concept-mapping groups.

**Future Research**

Medical students are a unique population of students because they are highly skilled at achieving academic goals and highly intelligent with an average I.Q. of 126.18 (Kole & Matarazzo, 1965). Once in medical school, a sense of information overload is frequently expressed. Medical students do not, in the ordinary way of a medical school curriculum, have very many chances to think about what, or how, they are learning in the larger context of what learning goals they need to achieve. This study leads me into more questions about this population, and areas that have little empirical evidence:

- What is the association between structural knowledge and metacognitive operations? How and what specific metacognitive operations are most influential in the construction of a medical student’s structural knowledge is still unclear. Physicians must synthesize large amounts of information to evaluate and make accurate judgments about the care of a patient. Therefore, we need to help medical students master highly complex, integrated knowledge structures, and
teach them how to use these structures to care for patients. This thinking requires a high degree of cognitive processing, and the role of the various metacognitive components is important to understand.

- What are the effects on the students’ metacognitive thinking patterns using focused questions in problem-based learning versus lists of learning objectives?
- What is the most beneficial application of concept mapping in the medical school curriculum? More specifically, where are the most appropriate places in the curriculum to use concept mapping, particularly in what types of problem-based learning cases would the students most benefit? The students in this study’s focus-group interview said concept mapping would be valuable in the highly complex cases.
- What is the relationship between reflection and metacognition? Medical educators need to fully understand this relationship in order to construct a model to prepare students to be what Schön (1983, 1987) has described as “reflective practitioners.” In the final analysis of my findings, I applied Schön’s theory to show the intersection of theory and practice. While I might by one step closer on my ideas, much progress needs to be made in the construction of a model that can be applied and assessed in medical education.
- How do the components of metacognition relate to critical thinking? While scholars in medical education, such as Cooke et al. (2010) and Croskerry (2003, 2011) urge medical schools to teach metacognition and critical thinking skills in the educational program, little empirical evidence exists to help educators make curriculum and policy decisions in this area. In this study, the emergent theme of
logic analysis is most probably associated with critical thinking, yet the relationship remains a mystery.

- What are the best methods of assessing metacognitive operations in the medical student population? First, the question if metacognition in this highly intelligent population is somehow different compared to the normal population has yet to be answered, because if it is different, the standard ways in which metacognition has been assessed will be different. Second, medical students enter medical school with a high degree of metacognitive awareness; however, Graber et al. (2005) concluded that internists cognitive errors overwhelmingly reflect inappropriate cognitive processing, and/or poor skills in monitoring one’s own cognitive processes (metacognition). What happens to metacognitive thinking between matriculation into medical school and medical practice? Medical educators need a model to assess metacognition across years in medical education. Perhaps the application of metacognitive thinking changes over the years from pre-clinical medical education to clinical medical education.

**Conclusion**

The key issue for choosing a mixed-methods design was the compatibility with my goals and research questions. The research itself, even with its limitations, led me to achieve my intellectual goal, which I set out to gain a greater understanding of what is going on in concept mapping and metacognition in the context of problem-based learning.

In closing, there are several key lessons learned in this study. First medical students are hesitant to participate in research that in any way might interfere with their habits of
studying, in-class participation, and testing. They are so focused on learning material for the exams, that anything they perceive as a threat to that end, is unpopular. However, I do not see that as a barrier that cannot be overcome for future studies, because the continuation in this line of research is an opportunity to make important instructional decisions and programmatic changes as additional information is gained. I believe in light of these findings, there are important factors to pay particular attention to, and those are in the words of the students. Concept mapping is an artifact that influences the students’ ability to integrate complex mechanisms. The play between metacognition and cognition in how the students think through a concept map to learn and remember that integration is still open for more research.


Croskerry, P. (2003). The importance of cognitive errors in diagnosis and the strategies to minimize them. *Academic Medicine, 78*(8), 775-780.


CONSENT FOR RESEARCH

Penn State College of Medicine

The Milton S. Hershey Medical Center

Title of Project: The Effects of Using Concept Mapping as a Metacognitive Prompt in Medical Students’ Problem-based Learning Discussions: A Mixed Methods Investigation

Principal Investigator: Glenda H. Shoop, M.Ed., R.R.T.

Other Investigators: Susan M. Land, Ph.D.

Telephone Numbers: (717) 531-6917 Weekdays: 8:00 a.m. to 5:00 p.m.

Participant’s Printed Name: ________________________________

I am asking you to be in a research study. You may opt out for including your information in any report written in regards to the study. If you agree to participate in the study, you may opt out at any time.

This form gives you information about this research study. Please ask questions about anything that is unclear to you.

Please take your time to make your choice.

1. Why is this research study being done?

We are asking you to be in this research because you are currently taking part in the Penn State College of Medicine’s curriculum leading to the M.D. degree.

This research is being done to find instructional methods that prompt reflective thinking (a skill associated with well developed critical thinking) and learn if these prompts influence learning and achievement. This research will take place during one of your Problem-based Learning (PBL) group meetings and will be guided by the course director and teaching faculty.
Approximately 143 medical students will take part in this research study at the Penn State Hershey College of Medicine.

2. **What will happen in this research study?**

   If you agree to participate in this research, you will first sign this consent form. You will be given a copy of the signed consent form for your records.

   The study will be conducted during one of your PBL sessions. As with previous courses, you will be randomly assigned to one of the twenty PBL groups. All twenty groups will receive the same case material in the same manner, and at the same time. Ten of these groups will be assigned to ‘discussion only’ and will move through a PBL case just as was done in all previous courses. The other ten groups will be assigned to ‘concept mapping’ and asked to move through the case in the same manner, except during the final discussion, these groups will draw concept maps of the case topic.

   Four of the twenty PBL groups will be selected for audio recording: two ‘discussion only’ groups, and two ‘concept mapping’ groups. You may participate in the main research study and opt-out of the audio recording part of the research (see Section 12). The audio records of the discussion in each of the four PBL groups will be collected to characterize and compare the conversation that occurs during concept mapping. These recordings will be transcribed verbatim for analysis. The instructions for concept mapping will be sent to you, and placed on the University’s course management system, ANGEL, so you can access it before the session. You may also be asked to participate in a focus group at the conclusion of the case discussion if you participate in one of the audio recorded sessions.

   Five questions related to the PBL case will be placed on ANGEL as a ‘practice quiz’ to determine if there is a difference between ‘concept mapping’ and ‘discussion only’ scores. These questions are optional and will not count toward your course grade, nor will your course grade be used for this research.

3. **What are the risks and possible discomforts from being in this research study?**

   Loss of time to participate is the most risk the participant will incur because concept mapping during the end-of-case discussion might lengthen the time of the discussion. For those PBL groups that are audio recorded, a loss of confidentiality is the main risk to be considered in the study. There is a risk of loss of confidentiality if your information or your identity are obtained by someone other than the investigators, but precautions will be taken to prevent this from happening. To minimize the chance of this risk factor, the principal investigator is the only person who will have access to the audio files.
What are the possible benefits from being in this research study?

4a. What are the possible benefits to me?

The results of this study may provide information about the effects of reflection and metacognition on learning so the course co-directors may incorporate components into other PBL sessions.

4b. What are the possible benefits to others?

The results of this research may help medical educators incorporate components of reflection and metacognition in medical education to promote information retention in long-term memory.

5. What other options are available instead of being in this research study?

You may choose not to be in this research study.

6. How long will I take part in this research study?

You will be in the research study for the length of a PBL session, and the additional time for the post-concept mapping focus group.

7. How will you protect my privacy and confidentiality if I decide to take part in this research study?

7a. What are the measures taken to protect my privacy and confidentiality?

In our research files at The Milton S. Hershey Medical Center (HMC) and Penn State College of Medicine (PSU), we will include these identifiers: your name and a code number. Your name will also be substituted with a “name alias” to enhance your confidentiality.

- A list that matches your name with your code number will be kept in a locked file in Ms. Shoop’s office.
- Your research records and audio recordings will be labeled with your code number and/or your name alias.

In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

We will do our best to keep your participation in this research study confidential to the extent permitted by law. However, it is possible that other people may find out about your participation in this research study. For example, the following people/groups may check and copy records about this research.

- The Office for Human Research Protections in the U. S. Department of Health and Human Services
The HMC/PSU Institutional Review Board (a committee that reviews and approves research studies) and
The HMC/PSU Human Subjects Protection Office
The HMC/PSU Research Quality Assurance Office

Some of these records could contain information that personally identifies you. Reasonable efforts will be made to keep the personal information in your research record private. However, absolute protection cannot be guaranteed.

8. What are the costs of taking part in this research study?

8a. What will I have to pay for if I take part in this research study?

There are no monetary costs associated with your participation in this research.

9. Will I be paid to take part in this research study?

You will not receive any payment or compensation for being in this research study.

10. Who is paying for this research study?

The institution and investigator are not receiving any funds to support this research study.

11. What are my rights if I take part in this research study?

Taking part in this research study is voluntary.

- You do not have to be in this research.
- If you choose to be in this research, you have the right to stop at any time.
- If you decide not to be in this research or if you decide to stop at a later date, there will be no penalty or loss of benefits to which you are entitled.

During the course of the research you will be provided with any new information that may affect your decision to continue participating in this research.

12. If I have questions or concerns about this research study, whom should I call?

Please call the head of the research study (principal investigator), Glenda H. Shoop at 717-531-6917 if you:

- Have questions, complaints or concerns about the research.
- Believe you may have been harmed by being in the research study.

You may also contact the research protection advocate in the HMC Human Subjects Protection Office (HSPO) at 717-531-5687 if you:

- Have questions regarding your rights as a person in a research study.
- Have concerns or general questions about the research.
- You may also call this number if you cannot reach the research team or wish to talk to someone else about any concerns related to the research.
You may visit the HSPO’s web site at http://pennstatehershey.org/irb under participant information for:
- Information about your rights when you are in a research study;
- Information about the Institutional Review Board (IRB), a group of people who review the research to protect your rights; and
- Links to the federal regulations and information about the protection of people who are in research studies. If you do not have access to the internet, copies of these federal regulations are available by calling the HSPO at (717) 531-5687.

**Signature and Consent/Permission to be in the Research**
Before making the decision about being in this research you should have:
- Discussed this research study with an investigator,
- Read the information in this form, and
- Had the opportunity to ask any questions you may have.

Your signature below means that you have received this information, have asked the questions you currently have about the research and those questions have been answered. You will receive a copy of the signed and dated form to keep for future reference.

**Participant:** By signing this consent form, you indicate that you voluntarily choose to be in this research.

Signature of Participant  Date  Time  Printed Name

**Person Explaining the Research:** Your signature below means that you have explained the research to the participant and have answered any questions he/she has about the research.

Signature of person who explained this research  Date  Time

Printed Name

(Only approved investigators for this research may explain the research and obtain informed consent.)
Optional Research

You may be in the main part of the research without agreeing to participate in this optional part of the research. This optional part of the research involves the use of audio recordings of two “discussion only” groups and two “concept mapping” groups during their PBL group sessions. If your PBL group is not selected for the optional research, no recordings of you will be made even if you agree to participate in this part of the research.

Audio Recording Addendum to the Consent Form

The recordings will include your voice and will be used for metacognitive thinking behavior research analysis purposes only. The recordings will not be used for evaluation/grading purposes, nor will the recordings be used for commercial purposes.

The following measures will be taken to protect your privacy and confidentiality.

- Each recording will be labeled with a unique study ID code.
- The recordings will be stored in a locked file drawer and/or on a password protected Hershey Medical Center computer.
- Only the PSU/HMC research team will have access to the recordings.
- The recordings will be stored for three years after the completion of the research and then destroyed.
- You will be free to change your mind at any time.
- You should contact Glenda H. Shoop at 717-531-6917 and let her know if you wish to withdraw your permission for audiorecording in your PBL group.

You should initial below to indicate if you want to participate in a PBL session that will be audio recorded.

I consent to participate in the audio recording of my PBL group session (please initial yes or no):______ Yes  ____ No

Participant: By signing below, you indicate that you have read the information written above and have indicated your choices for the optional part of the research study.

______________________________  __________  __________  ________________
Signature of Participant  Date  Time  Printed Name

Person Explaining the Research: Your signature below means that you have explained the optional part of the research to the participant and have answered any questions he/she has about the research.

______________________________  __________
Signature of person who explained this research  Date  Time

______________________________
Printed Name
Appendix B

Concept Mapping Instructions
CONCEPT MAPPING INSTRUCTIONS

Concept maps are two-dimensional drawings made of propositions linked together in ways that show how your mind “sees” a particular topic. Important terms or concepts are written in nodes, and then arrows are drawn between the nodes to show how or in what way the concepts are related. For example

Concept Map Instructions:

1. Read the “focus of the map” at the bottom of the page.
2. Develop a list of terms that you feel are most important to that focus or root concept. Write these terms on the post-it notes. If you choose not to use the post-it notes, write the list on the white board.

   For example, if I instructed you to map the autonomic control of the heart rate, the list might include terms such as heart rate, sympathetic, parasympathetic, medullary centers, baroreceptors, blood pressure, etc.

3. Organize the terms on the whiteboard according to logical relationships between and among the terms based on what you know about the topic.
4. As you organize the terms, draw lines that logically connect two individual terms or phrases. Label these lines with linking words and short linking phrases to specify the relationship. You may use different colored lines to show distinct “concept routes” within the whole map if you wish.

   For example, caffeine \(\rightarrow\) inhibits \(\rightarrow\) sleep. The linking verb is “inhibits”.
5. Draw any cross-links – these are links between different segments of the map that help to show how certain areas are related (choose most prominent and most useful links that you have in your memory of this concept)
6. Once you have completed your map, please do not erase it from the whiteboard. I will send you a copy of the concept map for your records if you wish.

FOCUS OF THE MAP

The major pathologic lesion created by salicylate intoxication is uncoupling of oxidative phosphorylation. This lesion affects major organ systems in the body.

Using “uncoupling of oxidative phosphorylation” as your starting point or root concept, map out the effects on body systems once salicylate intoxication occurs.

\- Focus on the respiratory system, renal system, and the brain. If you need to bring other systems into the map to explain how you “see” the effects, that’s O.K. It’s your map!
\- If there are any relationships in the effects caused by salicylate intoxication, show them using cross links across systems.
Here is an example of what your map might look like if we used the autonomic control of the heart rate as your focus:
Appendix C

Focus-Group Interview Guide
FOCUS-GROUP INTERVIEW GUIDE

Research Title:
The Effects of Using Concept Mapping as a Metacognitive Prompt in Second-year Medical Students’ Problem-based Learning Discussions: A Mixed Methods Investigation

Research Question:
How does concept mapping, used as a metacognitive prompt in a problem-based learning, influence the intragroup discussion and interaction compared to the problem-based learning group that does not use concept mapping.

This guide is created to direct the discussion of the focus groups.

PART I: INTRODUCTION

A. Thanks and appreciation for taking time to attend
   a. Introduce yourself

B. Objective of the focus group
   a. What we are trying to do (find out if concept mapping can be used to impact and stimulate metacognitive thinking)
   b. Why are we doing this (need for strategies to promote metacognitive thinking)

C. Explanations
   a. Length of the focus group interview – promise to end on time
   b. Audiotaped interview
   c. Confidentiality of participants
   d. Free to leave at any time
   e. There are no “wrong” answers or opinions. Everyone’s input is welcomed, encouraged, and will be incorporated into the final analysis.
   f. What the focus group is NOT, e.g., not an opportunity to talk about changes in PBL, operating procedures, or facilitators. Your impressions and opinions are what is most important.
   g. Any questions? Comments?
PART II: KEY QUESTIONS

QUESTION 1: Tell me how you approached the discussion of the case?

- What were your beginning thoughts?
- What was most important in your thinking?
- How did you learn the material to prepare for the discussion?
- What are strategies you use to store this information in your memory?

(Objective is to warm up the group, focus the attention on the discussion)

QUESTION 2: How were you making decisions as you talked through the case?

- How were you formulating the important questions?
- How were you assessing the information?

(Objective is to explore metacognitive knowledge and regulation capabilities)

QUESTION 3: What do you feel about your knowledge and understanding of the case at this point in time?

- Explain the depth of your knowledge (how well you understand the concept)
- How successful do you feel you would be at answering test questions on the topic?
- What approach would you use to teach others about the case?
- How did you adjust your thinking when you came to a point where you felt uneasy about your knowledge of the content?

(Objective is to get at that ‘feeling of knowing’ (the metacognitive experience)

PART III: CONCLUSION

Thanks to the participants; facilitator’s contact information if anything comes up later for the participants.
Appendix D

Phase II Descriptive Data Sample
<table>
<thead>
<tr>
<th>Line Number</th>
<th>Transcribed Conversation</th>
<th>Phase II</th>
<th>Phase III</th>
<th>Comments</th>
<th>F/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>551</td>
<td>I know but I don’t think [pause], I’m just saying in this area under renal compensation, I don’t think it goes there. Because this isn’t what happens in the kidney. This happens….</td>
<td>Detects inconsistency;</td>
<td></td>
<td>Student was defining the problem differently at this point based on her understanding</td>
<td>S</td>
</tr>
<tr>
<td>553</td>
<td>It actually does happen in the kidney. At the, you know how there’s two intercalated cells?</td>
<td>Monitors the action;</td>
<td>Redirects with a justification</td>
<td>Student reaffirmed the correct thinking of the the prior statement</td>
<td>S</td>
</tr>
<tr>
<td>554</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>555</td>
<td>Yeah!</td>
<td>Affirms</td>
<td></td>
<td>Enthusiastic like she got it</td>
<td>S</td>
</tr>
<tr>
<td>556</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>557</td>
<td>And the other one has a K, just a K exporter?</td>
<td>Uncertainty;</td>
<td></td>
<td>Student was asking the others for the answer to something he wasn't sure about</td>
<td>S</td>
</tr>
<tr>
<td>558</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>559</td>
<td>Is this like on the other side…</td>
<td>Monitoring</td>
<td></td>
<td>Student was trying to contribute to the mapping, but not sure where to put the concept</td>
<td>S</td>
</tr>
<tr>
<td>560</td>
<td>That would be okay, so then betas aren’t taking that potassium, right? They don’t want anymore. But the alphas are preferentially excreting it because it’s high in those cells.</td>
<td>Seeking affirmation;</td>
<td></td>
<td>Students were fitting together information</td>
<td>S</td>
</tr>
<tr>
<td>561</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>562</td>
<td>I got lost.</td>
<td>Monitoring</td>
<td></td>
<td>Student experienced a feeling of not knowing the material… being lost in the material</td>
<td>S</td>
</tr>
<tr>
<td>563</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>564</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>565</td>
<td>I don’t know where you’re talking about.</td>
<td>Monitoring</td>
<td></td>
<td>Student experienced a feeling of not knowing… being lost in the material; sounds frustrated</td>
<td>S</td>
</tr>
<tr>
<td>566</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>567</td>
<td>Okay.</td>
<td></td>
<td></td>
<td></td>
<td>S</td>
</tr>
<tr>
<td>568</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>569</td>
<td>The question is how are you getting too much if we’re not taking it up at the beginning? Like if that’s not working, K is going to go out so where are we getting this accumulation of K+, if we’re not reabsorbing it.</td>
<td>Restate and reason through the problem; repeating important information; describing</td>
<td></td>
<td>Student was explaining by reasoning through the problem</td>
<td>S</td>
</tr>
</tbody>
</table>
Appendix E

Salicylate Intoxication Test Questions
1. Which statement regarding the pharmacokinetics and metabolism of salicylates is **TRUE**? (If all of the statements are true, select "E.")

   A. Aspirin is readily deacylated in the blood by esterases present in RBCs and various tissues.
   B. At therapeutic concentrations, the majority of the salicylate is bound to plasma proteins, most preferably albumin.
   C. Salicylate absorption occurs primarily by passive diffusion across the gastrointestinal cell membrane.
   D. The biotransformation of salicylate occurs in many tissues, but particularly in the hepatic endoplasmic reticulum and mitochondria.
   E. All of the above statements are true.

2. The rate of titratable acid excretion is equivalent to the rate of new bicarbonate formation by the kidneys because:

   A. Excretion of phosphate as a titratable acid uses protons generated from the conversion of CO$_2$ to bicarbonate.
   B. In the process of new bicarbonate formation, carbonic anhydrase catalyzes the conversion of bicarbonate to CO$_2$ inside cells of the proximal tubule.
   C. The process leads to excretion of protons in the form of H$_2$PO$_4^-$.
   D. The process uses protons pumped by the proton ATPase and not protons secreted by the sodium/proton exchange carrier.
   E. This process occurs primarily in the late part of the nephron (distal tubule and collecting duct) and this is the main location of the proton ATPase activity.

3. Which statement regarding the metabolic effects of salicylate poisoning is **FALSE**?

   A. Salicylates increase hepatic and muscle glycogen content.
   B. Salicylates increase production of ketone bodies.
   C. Salicylates stimulate lactate production.
   D. Salicylates uncouple oxidative phosphorylation in a manner similar to that of 2,4-dinitrophenol.
   E. The effects of toxic concentrations of salicylates on metabolism lead to a metabolic acidosis.
4. Aspirin overdose leads to an increase in body temperature due to its effect on oxidative phosphorylation. It does this by:

   A. Absorbing electrons as they are transported out of the mitochondria.
   B. Creating holes in the mitochondrial membrane.
   C. Dissipating the proton gradient across the mitochondrial membrane.
   D. Increasing ATP production.
   E. Reacting directly with NADH.

5. Susan T. reports to the ER with a decreased pCO2, Kussmaul breathing, elevated pH, and low serum HCO3 levels. It is determined that she overdosed on aspirin. What is the physiological mechanism behind Susan's initial hyperventilation?

   A. Build-up of ketones and lactic acid in her blood.
   B. Directly lowered blood pH due to the presence of salicylic acid.
   C. Increased CO2 due to bicarbonate elimination by the kidney.
   D. Salicylate broken down to CO2 and needs to be removed from the body.
   E. Stimulation of the respiratory center due to uncoupling of oxidative phosphorylation.

6. The activity of the enzyme carbonic anhydrase is not found in which of these fluid compartments?

   A. Within cells forming the collecting duct.
   B. Within cells forming the proximal tubule.
   C. Circulating plasma.
   D. Within red blood cells.
   E. Within skeletal muscle cells.
Appendix F

Six Emergent Themes: Examples of Coded Statements
Emergent themes after Phase II’s Categorical Aggregation

The following are examples of students’ statements coded to each emergent theme. These examples show what I was looking for in the utterance as I was coding for the analysis.

1. **Logic analysis**

   *Defined by any statement that was interpreted to be reasoning through principles or explaining mechanisms of action were coded as logic analysis.*
   - So those are the beta, so there’s two like you know the ducts and then we have the two types of intercalated cells, alpha and beta. And there’s principal cells right?
   - The question is how are you getting too much if we’re not taking it up at the beginning? Like if that’s not working, K is going to go out so where are we getting this accumulation of K+, if we’re not reabsorbing it.
   - If you want to think of that with respect to the blood, it would be Hydrogen going into the blood and Potassium going out of the blood. Which makes sense if it was in the [inaudible] alkalized. H would go out to compensate.

2. **Information recall**

   *Defined by any statement that was merely regurgitating information was coded as information recall.*
• It happens to the intercalated cells in the kidney
• I got this from an article about aspirin overdose, and it says uncoupling leads to interruption of a series of enzyme mediated mitochondria functions and anaerobic metabolism and cellular immersion of prior mate to lactate and subsequent development of lactic acidosis.
• Hyperalimentation Acetazolamide, Renal tubular acidosis, Diarrhea, Uteroenteric fistula and Pancreatic and duodenal fistula.

3. Illumination

*Defined by any statement that was stating a feeling of uncertainty, confidence, unknowing was coded as illumination.*

• I forgot which occurs in the kidney, but…
• I don’t remember……
• Metabolic acidosis off the keto acids. Yeah!

4. Judgment

*Defined by any statement that was passing on an opinion or evaluating how the group was progressing was coded judgment.*

• That’s what I’m saying. I’m not saying you’re wrong. I’m saying it just doesn’t belong under renal.
• Something like that, or just the – it had such a large concentration that it changed – you know for normal concentration, that was acceptable.

5. Monitoring

*Defined by any statement that was indicating that the person or group was keeping track of progress, or verifying if the group was on track was coded monitoring.*

• That would be okay, so then betas aren’t taking that potassium, right?
• All cells take up more potassium, right? Isn’t that what you were saying that was in these notes?
• So why are you connecting respirations to the brain?

6. Strategizing

*Defined by any statement that redirected the course of the mapping experience or changed the direction of the student or group’s thinking was coded as strategizing.*

• Let’s, …should we include keto acids off of anaerobic respiration too so it’s found in the urine.
• We should write that, draw a line to more in HS form maybe. More salicylate in HS to cross blood brain barrier.

    Do you want to talk about the anion gap and non-gap acidosis?
VITA

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- B.S. General Studies – Lebanon Valley College, 1990
- M.Ed. Training and Development – Penn State Harrisburg, 1993
- Ph.D. Instructional Systems – The Pennsylvania State University, August 2012

Current Areas of Research Interest: Metacognition, critical thinking, and program evaluation specifically related to systems thinking and accreditation

Recent Publications & Academic Papers


Recent Presentations
